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Archives

The Economics of Photovoltaic (PV) Drip Irrigation Systems

A Case Study for India

by

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a report submitted under the supervision of

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in partial fulfilment of the requirements for the degree of

Master of Engineering

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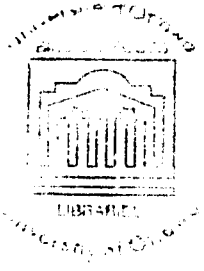
August 30, 1996



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Dedication

This study is dedicated to Sion Jennings who dragged me here in the first place, Mark Paddison who made it worthwhile, Michael Jones who suffered through the final stages of writing, Paul Guy for the loan of his computer and work space, and my parents who supported me through the whole thing.

ACKNOWLEDGMENTS

Many thanks are extended to all who contributed information and guidance which made this work possible. First, to my supervisor, Dr. E. Schiller. Second, to all those in India who helped me obtain data and gave me an understanding of work going on in the fields of photovoltaics and irrigation. Special mention should be given to Mr. D. Brahmachari and Mr. N. Bhise, who arranged my stay in India and introduced me to a number of people working in the solar industry, and Mr. I.J. Raju, who allowed me use of his office and reference material. Finally, to the coordinators of the "CIDA Overseas Development Associates Program" which helped me obtain a work placement in India. The information, experience, and ideas obtained during this placement formed the basis for much of the work presented in this study.

ABSTRACT

Agriculture accounts for 50% of India's gross national product and irrigated agriculture for two thirds of the nation's crop output. The energization of agricultural pumpsets is one of the main goals of India's rural electrification program but the economics of these long power line extensions for small power loads are often unfavourable. Other options for satisfying India's need for remote irrigation water supply systems include the use of photovoltaic (PV) pumps. In this study an attempt was made to determine suitable applications for PV pumping systems in the irrigation sector. Drip irrigation was considered the most appropriate method of irrigation for use with a PV pump. Grapes were considered a suitable crop due high water savings under drip irrigation, the perennial nature of the crop, and high economic returns.

Insolation, evapotranspiration, and effective precipitation were determined for a number of stations across India. This information was used to calculate irrigation water requirements for grapes and size a suitable PV pumpset. The cost of irrigating with a PV pump was compared to costs for other remote water pumping options and the net present worth of all costs and benefits for grape cultivation were calculated from both an economic and financial perspective. PV pumping systems did not prove to be the least cost option for irrigation due to the exceptionally low cost of diesel pumpsets in India. In spite of this, the net present worth of grape cultivation with a PV drip irrigation system was found to be positive as was the incremental benefit of PV drip irrigation over surface irrigation with a diesel pump.

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GLOSSARY

Albedo: The fraction of incident radiation reflected by a surface.

Array: An interconnecting system of photovoltaic modules that function as a single electricity producing unit. The modules are assembled as a discrete structure, with common support or mounting.

Array Efficiency: The electrical power output from an array at any given instant divided by the total solar power incident on the entire frontal area of the array.

Balance of Systems (BOS) Components: Miscellaneous photovoltaic (PV) pumping system components not including the array, pump/motor, inverter or tracker. Generally includes the array support structure, wiring, junction box, and ground rod, and other small inexpensive components.

Concentrator: A photovoltaic array which includes an optical component such as a lens or focusing mirror to direct incident sunlight onto a solar cell of smaller area.

Critical (Design) Month: For the purpose of sizing a solar photovoltaic system, the month with the highest ratio of total load to available insolation.

Declination: The angular distance of the sun north or south of the celestial equator, where the celestial equator is a great circle of the sky in a plane parallel to the earth's axis.

Diffuse Radiation: Solar radiation scattered by the atmosphere.

Direct Radiation: Solar radiation transmitted directly through the atmosphere.

Extra Terrestrial Irradiation: The solar energy received outside the earth's atmosphere.

Global Radiation: The sum of diffuse and direct solar radiation incident on a horizontal surface.

Insolation: See solar insolation.

Inverter: A device that converts direct current (DC) to alternating current (AC).

I/V Curve: A graphical presentation of current verses voltage from a photovoltaic cell as the load in increased from the short circuit (no load) condition to the open circuit (maximum voltage) condition. The shape of the curve characterises the cell or module performance.

Maximum Power Point Tracker: Impedance matching electronics used to hold the output of the photovoltaic array at its maximum value.

Module: A number of photovoltaic cells electrically interconnected and mounted together, usually in a common sealed unit or panel of convenient size for shipping, handling and assembling into arrays.

Photovoltaic (PV): Pertaining to direct conversion of light into electricity.

Photovoltaic (PV) Cell: A semi-conductor device that converts light directly into electricity. A solar photovoltaic cell is designed for use in sunlight. All photovoltaic cells produce direct current.

Photovoltaic (PV) System: A set of components designed for a particular application and powered by a photovoltaic array. This includes the photovoltaic array, major application specific components (such as a water pump or distribution system), and balance of system components (such as pipes, wires and electronic devices).

Polycrystalline Silicon: Silicon which has solidified as such a rate that many small crystals have formed. The atoms which a single crystal are symmetrically arrays, whereas in polysilicon they are in a state of disarray.

Power Conditioning Equipment: The electrical equipment used to convert power from a photovoltaic array into a form suitable for subsequent use. A collective term for the inverter, transformer, voltage regulator, metre, switches and controls.

Pulses: The edible seeds of leguminous plants. Examples include beans, peas and lentils.

Solar Irradiance: The radiant solar power received per unit area at any given instant, generally expressed as a W/m^2.

Solar Insolation (Irradiation): The time integral of solar irradiance, or energy per unit area from the sun over a specified time period, generally expressed as a kWh/m^2.

Solar Radiation: Radiation emitted by the sun in the form of electromagnetic waves or particles.

Stand Alone: An isolated photovoltaic system not connected to a power grid. Most stand alone system require a battery or some other form of storage such as a water tank.

Tilt factor: The ratio of solar irradiation incident on a tilted photovoltaic array to global irradiation.

CONVERSION FACTORS

Money:	1 Rs (Rupee)	=	31.374 US$ (1994 average)
	1 Rs	=	22.968 Can $ (1994 average)
	1 US$	=	1.366 Can $ (1994 average)
General:	1 lakh	=	100,000
	1 crore	=	10,000,000
Length:	1 ft	=	0.3048 m
Area:	1 ha	=	1,000 m^2
	1 acre	=	4,046.86 m^2
Volume:	1 ha mm	=	10 m^3
	1 acre ft	=	1,233.48 m^3
Flowrate:	1 ft^3/s	=	0.0283168 m^3/s
	1 US gpm	=	0.227124 m^3/min
	1 US gpd	=	0.00378541 m^3/day
Weight:	1 quintal	=	100 kg
	1 tonne	=	1,000 kg
	1 British ton	=	1.016 tonnes
	1 US ton	=	0.9072 tonnes
Pressure:	1 ft of water (39.2°F)	=	2988.98 N/m^3
	1 psi	=	6894.76 N/m^3
	1 pascal	=	1 N/m^3
Power:	1 hp	=	550 ft.lb/s
		=	745.7 W
Energy:	1 J	=	1 W s
		=	3600 W.hr
	1 kW.hr	=	3.6 MJ
		=	860 kcal
		=	3414.4 B.th.U.
Irradiance:	1 W/m^2	=	0.317 BTU/ft^2
		=	0.00143 cal/cm^2
		=	0.086 Langleys/hr

Insolation: 1 peak sun hour = 1 kWh/m^2
= 3.6 MJ/m^2
= 86.0 Langleys
= 86.0 cal/cm^2
= 317 BTU/ft^3

Temperature: T (°C) = (5/9)(T_F-32), when T_F is measured in °F

LIST OF SYMBOLS

a	Regression parameter used in the calculation of global solar radiation
A	Annual payment (Rs or US$)
A_f	Annual fuel costs (Rs or US$)
A_m	Annual maintenance costs (Rs or US$)
A_p	Annual operating costs (Rs or US$)
A_t	Total annual costs (Rs or US$)
b	Regression parameter used in the calculation of global solar radiation
c	Adjustment factor for the Penman equation
C_f	Unit cost of fuel (Rs/*l* or US$/*l*)
CAP_1	Unit capital cost of a diesel, hand, or animal powered pump (Rs/kW, US$/kW, Rs/pump, or US$/pump)
CAP_p	Capital cost of diesel pump or all required hand or animal powered pumps (Rs or US$)
CF	Correction factor for height of the aneometer (used to wind data convert wind data measured at height, h, to wind data at 2 m height)
CPI_t	Consumer price index for year t
d	Average depth of water applied to a field (mm)
d_i	Depth of water applied to a subsection of the field (mm)
D	Cloud cover
DP	Deep percolation (mm)
ea	Saturation vapour pressure at the mean air temperature (mbars)
ed	Actual mean vapour pressure of the air (mbars)
E	Overall irrigation efficiency

EA	Field application efficiency for an irrigation system
EA_{drip}	Field application efficiency for a drip irrigation system
$EA_{surface}$	Field application efficiency for a surface irrigation system
EU_{drip}	Emission uniformity
ET_o	Reference crop evapotranspiration (mm/day)
ET_{crop}	Crop evapotranspiration (mm/day) for a specific crop
ET_{grape}	Irrigation water requirement (due to evapotranspiration) for grapes
F	Single future payment (Rs or US$)
F_c	Fuel consumption (*l*/kWhr or *l*/hr)
f(T)	Temperature function used in the Penman equation
f(ed)	Vapour pressure function used in the Penman equation
f(n/N)	Function of the ratio of actual to maximum possible sunshine hours used in the Penman equation
$f_g(x)$	Gamma probability density function (method 4)
$f_n(x)$	Normal probability density function (method 3)
F (u)	Wind function used in the Penman equation
$F_g(X)$	Gamma probability distribution function (method 4)
$F_n(X)$	Normal probability distribution function (method 3)
G	Global solar radiation on a horizontal surface (kWh/m^2)
G'	Modified global solar radiation on a horizontal surface (kWh/m^2)
G_I	Direct radiation on a horizontal surface, a component of G (kWh/m^2)
G_D	Diffuse radiation on a horizontal surface, a component of G (kWh/m^2)
G_R	Reflected radiation on a horizontal surface, a component of G (kWh/m^2)

G_S	Global solar radiation on a tilted surface (kWh/m^2)
G_{IS}	Direct radiation on a horizontal surface, a component of G_S (kWh/m^2)
G_{DS}	Diffuse radiation on a horizontal surface, a component of G_S (kWh/m^2)
G_{RS}	Reflected radiation on a horizontal surface, a component of G_S (kWh/m^2)
h	Anemometer height for wind measurement (m)
H	Total pumping head (m)
i	Annual interest rate (%)
I	Current (Amps)
I_{mp}	Current output at the maximum power point for a PV cell or module(Amps)
I_{sc}	Short circuit current for a PV cell (Amps)
k	Twentieth percentile in a rainfall data series (method 1)
kc	Crop coefficient
m	Rank number for data points in a rainfall data series (method 2)
M	Plotting position for data points in a rainfall data series (method 2)
M_p	Plotting position for data points in a rainfall data series, adjusted to account for periods with little or no rainfall (method 2)
n	Actual hours of bright sunshine in a day, averaged over a one month period (hrs)
N	Maximum possible hours of bright sunshine in a day, averaged over a one month period (hrs)
N'	Modified maximum possible hours of bright sunshine in a day (hrs)
N_m	Number of data points in a rainfall data series
p	Number of years with no rainfall in a monthly rainfall data series
P_d	Diesel engine power rating (kW or hp)

P_h	Hydraulic power required (kW or hp)
P_{hp}	Hydraulic power output of one pump (kW)
P_{max}	Maximum power output from a PV cell (W_p)
P_r	Engine power required to run pump (kW or hp)
PW	Present worth of a single future payment or an annual payment series (Rs or US$)
q	Annual inflation rate (%)
Q	Pump flow rate required (m/s)
Q_{crit}	Daily water requirement in the critical month (m^3/day)
Q_d	Actual maximum flow rate from a diesel pump (m^3/s)
Q_p	Actual maximum flow rate from all required hand and animal pumps (m^3/s)
Q_y	Total volume of water required for one year (m^3/yr)
r	Annual discount rate (%)
R_n	Total net radiation in equivalent evapotranspiration (mm/day)
R_a	Extra-terrestrial radiation in equivalent evapotranspiration (mm/day)
R_{ET}	Extra-terrestrial radiation on a horizontal surface (kWh/m^2)
R_{sw}	Total shortwave radiation in equivalent evapotranspiration (mm/day)
R_{ns}	Net shortwave radiation in equivalent evapotranspiration (mm/day)
R_{nl}	Net longwave radiation in equivalent evapotranspiration (mm/day)
RH	Relative humidity (%)
RH_{max}	Maximum relative humidity (%)
RO	Runoff (mm)
s	Number of sub-sections a field is divided into for calculation of EU

t	Time (years)
T_{max}	Maximum temperature for the month (°C)
T_{min}	Minimum temperature for the month (°C)
T_{med}	Median temperature for the month (°C)
u	Average daily wind run corrected to a 2 m elevation (km/day or m/s)
u_{day}	Average day-time wind speed (for the period 8:30 to 17:30) corrected to a 2 m height (m/s)
u_{night}	Average night-time wind speed (for the period 17:30 to 8:30) corrected to a 2 m height (m/s)
V	Voltage (Volts)
V_{mp}	Voltage output at the maximum power point for a PV cell or module (Volts)
V_{oc}	Open circuit voltage for a PV cell (Volts)
w	Daily wage for an agricultural labourer or daily costs for upkeep of one animal (Rs/day or US$/day)
W	Temperature related weighting factor for the Penman equation
WA	Water available to the plant in the soil root zone (mm)
WF	Water received at the field inlet (mm)
WP	Water supplied by the pump (mm)
W_p	A unit of power (watt peak). Quantifies the power output from a solar module under standard test conditions of 1000 kW/m^2 insolation and 25°C temperature.
x	Magnitude of a random rainfall event
X	Magnitude of the rainfall event with a given return period
Y_{AS}	Yield of Anab-e-Shahi grapes (t/ha)
Y_{TS}	Yield of Thompson seedless grapes (t/ha)

z	Number of workers or animals required to work one hand or animal powered pump
Z	Number of hand or animal powered pumps required
α	Parameter used in gamma distribution function
β	Parameter used in gamma distribution function
γ	Specific weight of water (9.789 kN/m^3 at 20°C)
δ	Monthly mean declination of the sun
ϵ_p	Pump efficiency
λ	Albedo (or reflectiveness) of the ground surface
λ_{crop}	Albedo of the crop
μ	Mean of a rainfall data series
σ	Standard deviation of a rainfall data series
σ_d	Standard deviation of d_i (depth of water applied to individual subsections of a field)
τ_d	Maximum daily run time for a pump (hrs/day)
τ_y	Annual run time for a pump (hrs/yr for a diesel pump; days/yr for a hand or animal powered pump)
ϕ	Station latitude (°)

ACRONYMS USED IN THE TEXT

AC	Alternating current
BHEL	Bharat Heavy Electricals Limited
BOS	Balance of system components
CEL	Central Electronics Limited
DANIDA	Danish International Development Agency
DC	Direct current
DNES	Department of Non-conventional Energy Sources
EGS	Employment Guarantee Scheme
GET	Global Environment Trust Fund
IDA	International Development Agency
IREDA	Indian Renewable Energy Development Agency
LCB	Linear current booster
MNES	Ministry of Non-conventional Energy Sources
NABARD	National Bank of Agriculture and Development
NDWM	Rajiv Ghandi National Drinking Water Mission
PV	Photovoltaic
REIL	Rajastan Electronics and Instruments Limited
SDC	Swiss Development Corporation

CHAPTER 1

INTRODUCTION

Agriculture accounts for approximately 50% of India's gross national product and agriculture in India relies heavily on irrigation. Approximately one third of the nations's total cropped area is irrigated but this area produces two thirds of the crop output. Energy consumption for irrigation and dewatering accounts for 21% of India's total energy budget. The energization of irrigation pumpsets under the rural electrification program is one of India's main statistical indicators but the economics of these long power line extensions for relatively small individual pumping loads is not always favourable. Fortunately, other options exist in addition to extending the main electrical grid for water pumping in remote areas, including diesel pumps, animal powered pumps, hand pumps, and photovoltaic (PV) water pumps.

PV pumps are currently being actively promoted for irrigation water supply by government loan and subsidy programs in India. These programs are designed to aid in the development of a self-sustaining commercial market sector for the PV industry in general. It is hoped that increased production of PV equipment will help reduce system costs. As costs drop the number of economically viable applications for PV systems are expected to increase. If these applications prove successful the industry will develop a positive reputation and more people will be willing to invest in it. For these programs to be effective, specific markets must be targeted where photovoltaics have the greatest chance of success.

Similarly, if the use of PV pumps for irrigation is to succeed specific crops and suitable methods of irrigation must be targeted. Most of the studies conducted in the past to determine the economic viability of PV pumps for irrigation have looked at irrigation in very general terms, considering one or two methods of irrigation and assuming average values for economic returns on crops. This type of study does not adequately represent the full spectrum of possibilities in the irrigation sector. There are a wide variety of crops grown in India. Different crops have different water requirements, yield responses to irrigation vary, economic returns from different crops vary, and some crops are better suited to one method of irrigation or another. In addition, different methods of irrigation have different levels of compatibility with the special characteristics of PV pumps. The purpose of this report is to determine what, if any, niche exists for stand alone PV water pumps in the irrigation sector in India.

Chapter 2 provides background information on PV water pumping systems and other remote pumping options, methods of irrigation and Indian initiatives in the PV and irrigation sectors. Section 2.1 discusses the solar energy resource and how this varying power supply affects the pumping system. Section 2.2 looks at the components of a PV water pumping system in detail. Section 2.3 examines the relative advantages and disadvantages of PV water pumping systems compared to other remote pumping options. Section 2.4 discusses different methods of irrigation and their compatibility with PV pumping systems. Section 2.5 gives background information specific to India, looking at the development of the PV industry and government initiatives designed to promote it, the importance of energy in the rural irrigation sector, problems with current methods of irrigation and government initiatives designed to help promote drip irrigation.

Chapter 3 is the main body of the report. This chapter begins with an evaluation of previous studies on the use of PV pumping systems for irrigation. These studies are used to guide and direct the current work.

In Sections 3.2 to 3.7 the necessary climatic and geographic variables are determined for a number of stations across India. The amount of solar energy available to power a PV system is assessed for various stations across India in Section 3.2. Average monthly reference crop evapotranspiration and effective precipitation levels are calculated from climatic data for the same stations in Sections 3.3 and 3.4 respectively. Sections 3.5, 3.6 and 3.7 look briefly at Indian soils, depth to water table and typical farm sizes.

Sections 3.8 to 3.10 look at solar pump sizing and relative costs compared to other remote pumping options. Section 3.8 explains how to size a remote pumping system. Section 3.9 compares the life cycle costs of different remote pumping options using typical North American prices. Section 3.10 compares typical North American costs to those in India.

Section 3.11 looks at various crops grown in India under drip irrigation with a view to determining which crops are better suited to irrigation with a PV drip system. In Section 3.12 the most promising crop is singled out for further study. Irrigation water requirements are determined for a typical farm in India. Different types of remote pumps are sized to satisfy those irrigation requirements. Life cycle costs are estimated and compared for the different systems. The overall economics of the irrigation system are calculated taking into account the full cost of cultivation and expected returns from increased crop yields. Increased benefits from available subsidies are considered in the financial study.

CHAPTER 2

BACKGROUND

Every photovoltaic (PV) system application depends on the sun for energy and solar energy at the earth's surface is a variable resource. This variability creates special demands on the system. Section 2.1 discusses the solar resource and how it affects system design. Section 2.2 looks at the components of a PV water pumping system in detail. Section 2.3 compares the relative advantages and disadvantages of PV water pumps to other remote pumping options. Section 2.4 examines conveyance and irrigation with special emphasis on the suitability of different methods for use with PV water pumps. The last section of this chapter discusses concerns specific to India looking at both the solar and the irrigation sectors and highlighting government initiatives in both areas.

2.1 THE SOLAR RESOURCE

Unlike most traditional forms of energy, solar energy is a variable resource. The amount of solar radiation at the earth's surface varies with the location, season, time of day, and meteorological conditions. In general, the farther the radiation must pass through the earth's atmosphere, the lower its intensity when it reaches the surface. When the sun is directly overhead, radiation passes directly through the atmosphere at right angles to the surface and the intensity is high. When the sun is low in the sky (in the morning, evening, or winter) radiation passes through the atmosphere at an angle and looses considerable

energy by the time it reaches the earth's surface.

Varying meteorological conditions, such as clouds and haze, have an even greater effect on the amount of radiation reaching the earth's surface. The effect of meteorological conditions contributes to uncertainties when attempting to quantify the solar resource.

The intensity of solar radiation on a surface plane at any given time, is called irradiance, generally measured in kilowatts per metre square (kW/m^2). The amount of energy received over a given period of time is called insolation, normally measured in kilowatt-hours per metre square (kWh/m^2). One kWh/m^2 is equivalent to one hour of sun shine at an irradiance of 1 kW/m^2. This is commonly referred to as a peak sun hour. One kWh/m^2 (or peak sun hour) is roughly equivalent to one hour of bright sunlight on a clear day near the equator. Irradiance levels at the earth's surface rarely exceed 1.2 kW/m^2. PV systems are sized based on the average daily solar insolation measured in peak sun hours per day. These daily insolation values are typically averaged over a one month period for sizing purposes.

The amount of energy produced by a solar panel varies with the amount of sunlight available. Ideally the energy demand varies with sunlight levels as well, increasing when irradiance is high and decreasing when it is low. This is the case only in rare instances, for example with a PV powered fan used for cooling or ventilation. The fan requires more energy on hot, sunny days when the PV power source is suppling the most energy, and less on cool, cloudy days when energy output is low. Energy supply and demand are similarly well matched for a PV powered irrigation pump. Irrigation water requirements are highest on hot, sunny days when the PV pump is suppling the most water. On cool, cloudy days when the pump is supplying less water, evapotranspiration levels are generally low, humidity levels are generally high and irrigation water requirements are often more than satisfied by precipitation.

irregularities in the match between energy supply and demand are dealt with by building some form of energy storage into the system. For water supply systems this can be either a water storage tank or a battery bank. The better the match between energy supply and demand the lower the storage requirements for the system. Reducing or eliminating storage reduces system complexity and cost.

2.2 COMPONENTS OF A PHOTOVOLTAIC (PV) WATER PUMPING SYSTEM

A solar powered water pumping system consists of a solar array to generate power, an array mount structure, a motor, and a pump. These components are necessary for even the most basic PV water pumping system. In addition, a more complex system may include a controller (to match the power output from the array to the requirements of the pump/motor unit), a storage system, a water tank or battery bank (to supply water when there is no sun to work the pump directly), and/or a float switch or water level sensors to turn the pump on and off. These additional components may increase system efficiency, but also increase the system complexity, thus increasing the chances of failure in a remote area where high level technical support is lacking.

2.2.1 The Solar Array

A solar cell is a device made of semi-conducting material that produces direct current (DC) power when illuminated. A typical solar cell consists of a thin wafer of semi-conducting material, normally single or poly crystalline silicon, about 100 mm by 100 mm wide and 0.5 mm thick as shown in Figure 2.1. A p-n junction is created between the front and back faces of the wafer by infusing one side with impurities. The p indicates conduction by "holes" (or positively charged vacancies) and the n indicates conduction by

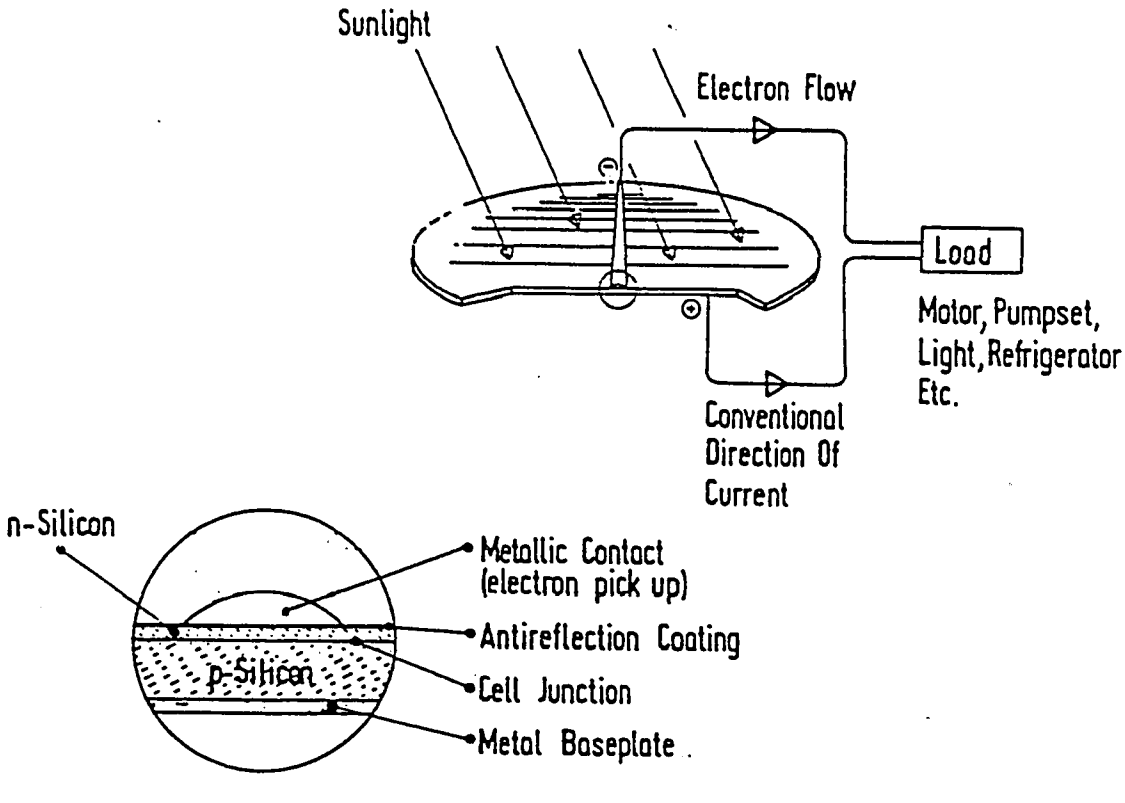


Figure 2.1 The Solar Cell (Derrick et al., 1989)

electrons. When light hits the wafer, the photons break the electron bonds in the junction region creating free charges, often referred to as electron-hole pairs. These charges migrate to the two sides of the junction, increasing the charge density and raising the voltage differential between the front and back faces of the cell. (EMR, 1991)

The wafer is printed with a metallic grid on the front face (which allows light to pass through) and a thin metal contact layer on the back. When the front and back faces of the cell are connected through an external circuit, the electrons which migrated to the front face of the cell (the n region) pass out through the grid and current flows freely around the circuit. No external current or voltage is required to create this flow of electrons.

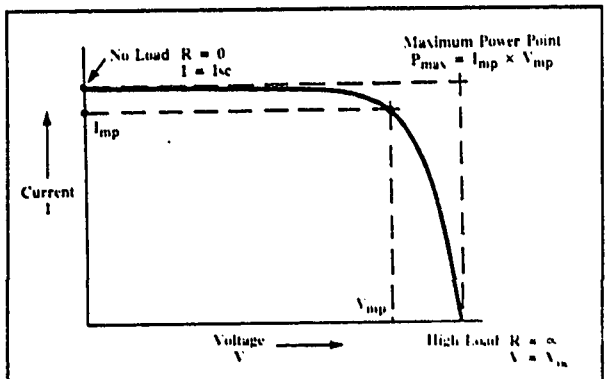


Figure 2.2 Solar Cell I/V Curve (EMR, 1991)

The current versus voltage (I/V) curve for a single cell is shown in Figure 2.2. The power output for the cell will always fall somewhere along this curve for given conditions of temperature and insolation. The point on the curve depends on the resistance encountered in the external circuit connecting the front and back faces of the cell. The curve crosses the y-axis at the short circuit current (I_{sc}). At this point resistance is zero, the current flows freely and the voltage differential drops to zero. The curve crosses the x-axis at the open circuit voltage (V_{oc}). At this point resistance is equal to infinity, and the flow of current stops. The maximum power output for the cell (P_{max}) occurs at the bend in the I/V curve. The voltage and current at this point are labelled V_{mp} and I_{mp} respectively. (EMR, 1991)

A typical solar module consists of a number of solar cells connected together in series and sealed between tempered glass and a tedlar backing. The tempered glass allows light to pass through and the tedlar protects the back of the cells. Individual modules are framed for strength and have an electrical junction box on the back for ease of installation.

Modules are normally rated in peak watts (W_p). The peak wattage for a module is the maximum power supplied (P_{max}) under standard test conditions of 1000 kW/m^2 insolation and 25°C

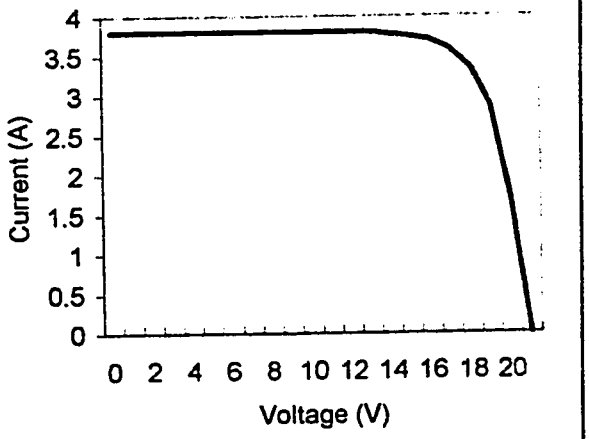
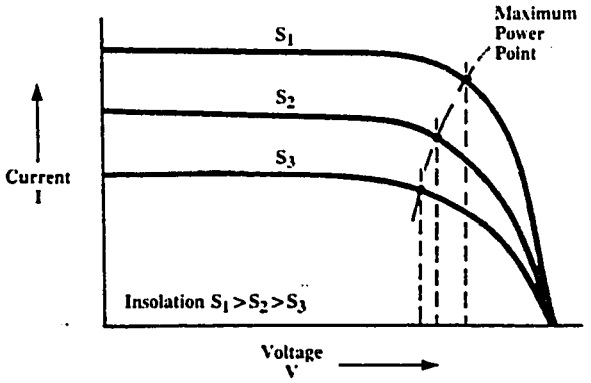


Figure 2.3 Module I/V Curve (Lenbrook, 1991)

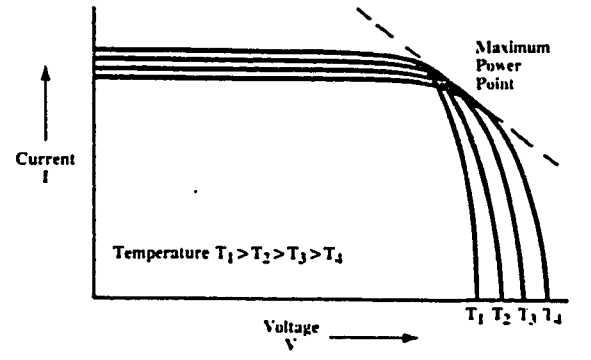
temperature. A typical I/V curve for a module under standard test conditions is shown in Figure 2.3. V_{mp} for most modules under standard test conditions is between 15 and 17 volts. Because the cells are connected in series the voltage output from a module is the sum of voltages from all cells and the module I/V curve is the horizontal addition of voltage from the cell I/V curves. The current output from a module is equal to that of the cell with the lowest current production. If even one cell in a module is shaded or covered with dirt, the current output for the entire module drops considerably. (EMR, 1991)

The actual power output in the field varies with insolation, temperature and system design. Field conditions (insolation and temperature) affect the I/V curve for the module. As insolation increases, the current output from the module increases, and the I/V curve shifts upwards, as shown in Figure 2.4a. If insolation levels remain constant and temperature increases, the voltage drops and the curve shifts to the left, as shown in Figure 2.4b. The system design affects the resistance encountered and thus the point on the I/V curve at which the module is operating.

A solar array consists of a number of modules wired together and mounted on a common structure. PV systems are generally discussed in terms of the peak



a) *I-V Curve Variation with Light Intensity*



b) *I-V Curve Variation with Temperature*

Figure 2.4 I/V Curve Variation with Insolation and Temperature
(EMR, 1991)

wattage of the array. A 500 W_p system, for example, is one with an array that would supply 500 W of power when operating at its maximum power point under standard test conditions of 1000 kW/m^2 insolation and 25°C temperature. This is not necessarily representative of actual power output in the field. Actual power output depends strongly on insolation, temperature and system design. Insolation and temperature determine the module I/V curves and system design determines whether the modules are operating at their maximum power point.

The power requirements of the pump, inverter, or battery bank determine the number of modules required and the series/parallel configuration of the array. The modules can be arranged either as a number of series strings wired in parallel (Figure 2.5a) or a number of parallel groups wired in series (Figure 2.5b).

As with individual cells in a module, individual modules in an array, if shaded, will lower the power output from the entire array. In large arrays diodes are used to control the flow of electricity and minimize the effects of shading. Bypass diodes allow electricity to bypass modules that are temporarily shaded. Blocking diodes are used to prevent reverse flow, and hence dissipation of energy through the array when the output voltage at one point is less than that produced at another point.

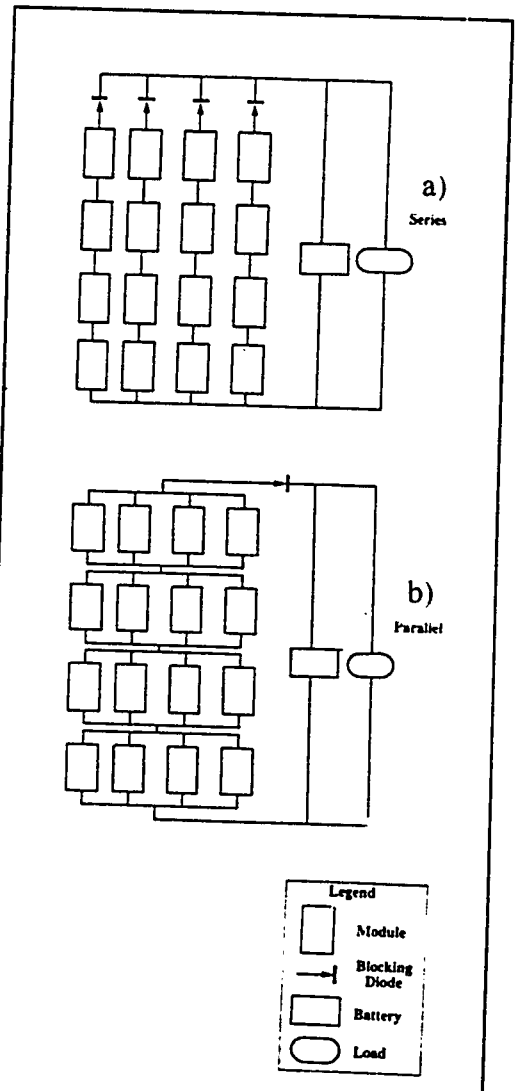


Figure 2.5 Series and Parallel Array Configurations (EMR, 1991)

Consider an array wired as a number of parallel strings (Figure 2.5a). If one module in a string is shaded, the bypass diode removes that module from the string, lowering the output voltage for the string, but not the string current. With the string voltage reduced, the blocking diode kicks in to prevent reverse dissipation of energy through that string. This effectively removes that string from the array. The overall effect is a reduction in array current but not voltage. This is the most common array configuration since most loads require a minimum voltage either for battery charging or to run electronics.

For an array wired as a number of parallel groups (Figure 2.5b) the bypass diode removes the entire group from the array if one modules is shaded. This causes a reduction in array voltage but not current. This array configuration is preferable for loads which require a constant torque such as positive displacement pumps. With this configuration a blocking diode is used between the array and battery (if there is one) to prevent dissipation of energy from the battery through the array at night.

In some systems the series/parallel configuration of the array is adjusted throughout the day to match the power requirements of the load. In the early morning when the energy output from the array is low all the modules can be arranged in parallel to provide a high starting current for a positive displacement pump. As more energy becomes available the array configuration will change, increasing the voltage output, and hence the pump speed. In newer systems this adjustment of current and voltage is normally done by an automatic controller (either a converter or linear current booster) rather than a reconfiguration of the array.

The electrical requirements of positive displacement and alternating current pumps are generally not well suited to direct connection with a solar array. An inverter is required between the array and pump for alternating current (AC) pumps, and a controller or battery bank for positive displacement pumps. When an inverter or controller is used, the

electrical characteristics of the array side of the device will be different from those on the pump side. Small centrifugal pumps (for heads up to 10 m) are often connected directly to an array with no controller.

2.2.2 The Module Mount Structure and Tracker

The module mount structure holds the array in position to best catch the available sunlight. The array can be mounted on the ground, on a post, or on a roof. Post mounted arrays may be either fixed, adjustable, or tracking. The intensity of sunlight falling on the array is greatest when the panels are directly facing the sun at an angle of 90°. In the summer when the sun is high in the sky the array should be tilted at a relatively shallow angle to catch the most sunlight, approximately latitude minus 15°. In the winter, when the sun is lower in the sky, the array will be tilted at a much larger angle, latitude plus 15°. Figure 2.6 shows the array output over the course of a year at tilts of latitude plus 15° and latitude minus 15° for a site at 45° latitude. A year round system with a fixed array is usually set at the winter tilt angle. This tends to level out the amount of energy received throughout the year. Many irrigation systems are used exclusively in the summer, with a fixed array tilted at the summer angle. This maximizes energy output when it is needed the most.

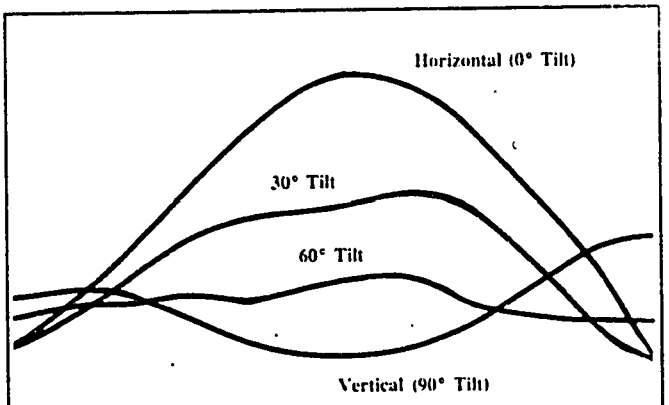


Figure 2.6 Energy Output at Various Tilt Angles (EMR, 1991)

Using a solar tracker increases energy production, and hence water output by approximately 30% in the summer. A solar tracker follows the sun throughout the day, adjusting the array so that it is constantly in the best position to maximize energy output. Trackers may be either active or passive. Active trackers use optical sensors and motor driven actuators to position the array so that it is always facing the sun. They can be either single or dual axis, with single axis trackers requiring seasonal adjustment. This type of tracker consumes some of the energy produced by the array to operate the tracking motor.

Passive trackers have a sealed, liquid filled frame. As the sun moves across the sky it heats both sides of the frame differentially. Liquid moves towards the warmer side forcing the frame to readjust so it is constantly facing towards the sun. Shock absorbers are used hold the frame against sudden impacts or wind changes. Passive trackers do not consume any of the energy generated by the array, but they only work within a certain temperature range, and are not recommended for areas prone to high winds.

Solar trackers represent a substantial portion of the total cost for a water pumping system and increase the system complexity. The added benefit should be weighed against the cost of additional panels and/or a higher capacity pump. Increasing the array size and eliminating the tracker reduces system complexity often for the same price with no loss in capacity. In areas such as India where capital is scarce and labour costs are low arrays are available with adjustable mounts that can be repositioned by one person four or five times a day. The increased energy benefits are similar to those obtained by tracking systems but with fewer potential technical difficulties and at less cost. Unfortunately this type of system requires diligent attention. If the array is left unadjusted or the adjustment is timed improperly the power output could be impaired.

The most common mount structure for smaller water pumping arrays in less developed countries is a fixed array with 3 manual adjustments for different seasons

(latitude, latitude plus 15° and latitude minus 15°). This type of structure is very simple, requires little care, and can be manufactured locally.

2.2.3 The Pump

Solar water pumps can be roughly broken down into two categories: submersible pumps and surface (non-submersible) pumps. Figures 2.7 and 2.8 show the setup for both types. Surface pumps are used to pump water from a lake, stream, or cistern. These pumps are capable of pushing water a considerable distance, but have a limited suction head (5-6 m maximum), and should be placed as close to the water source as possible. When a surface water source is used this type of pump can be placed on a raft where it floats just above the water surface.

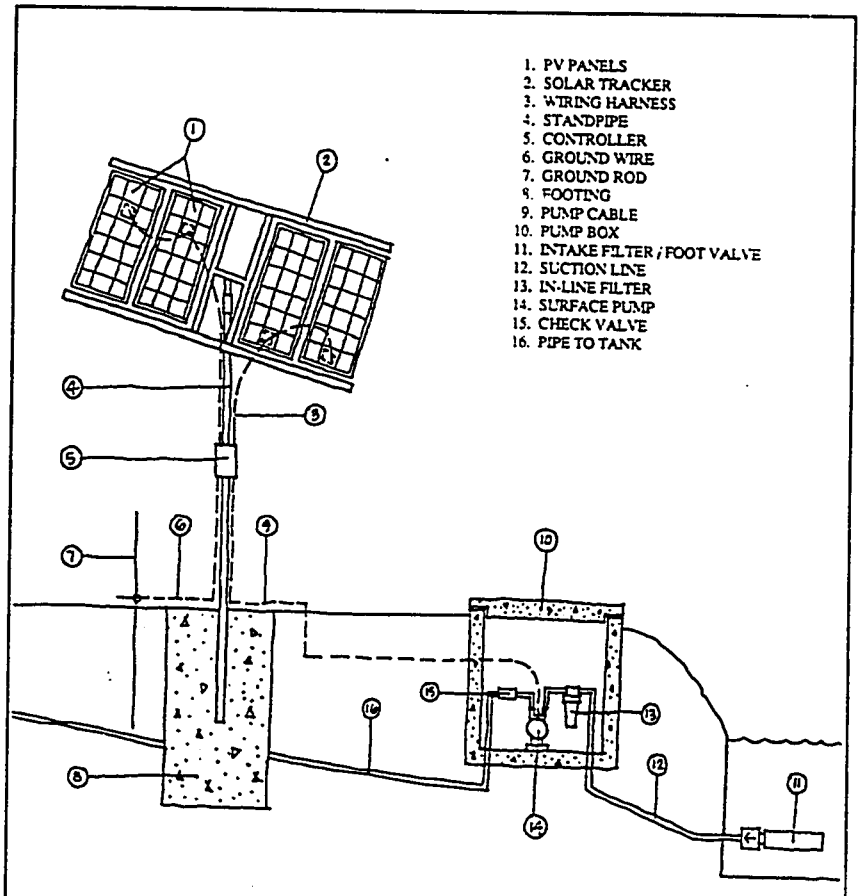


Figure 2.7 Surface Pumping System (Flowlight, 1992)

Submersible pumps are generally used for pumping from a deep well, but can also be used with shallow wells and surface water sources. These pumps

are placed below the water surface. Normally the motor is sealed with the pump and the entire system suspended in the well on a cable. A wire transfers power from the array to the pump-motor system and a pipe transfers water from the source to the well head.

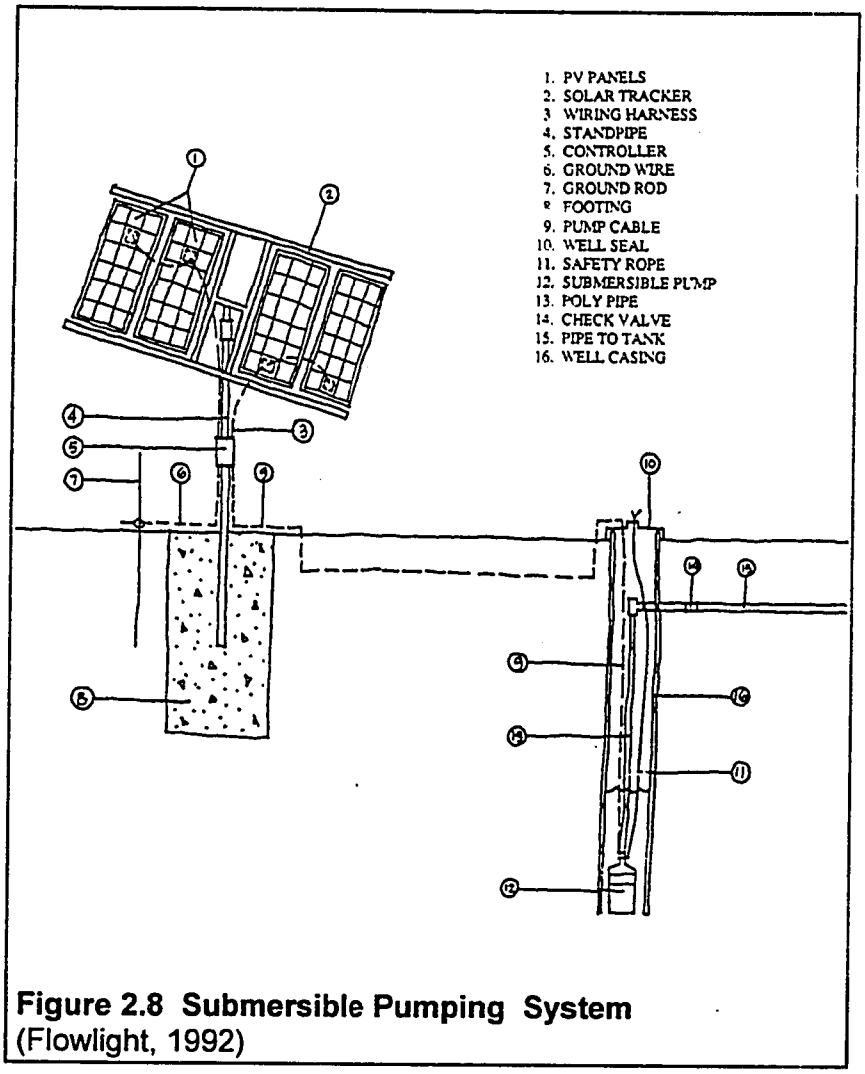


Figure 2.8 Submersible Pumping System
(Flowlight, 1992)

Pumps can also be divided along the lines of centrifugal or positive displacement pumps. Centrifugal (or rotodynamic) pumps move water with an impeller or rotating blade. Water enters at the centre of the blade and is thrown outwards by centrifugal force towards an outlet port on the perimeter casing. The flow rate and head against which the pump will work are dependant on the speed and torque of the impeller and motor, which are in turn dependant on the voltage and current of the power supply.

Most small DC powered centrifugal pumps are connected directly to the array because the power requirements can be matched to the energy supply. The centrifugal pump has a low starting torque and begins to rotate slowly even at low insolation levels

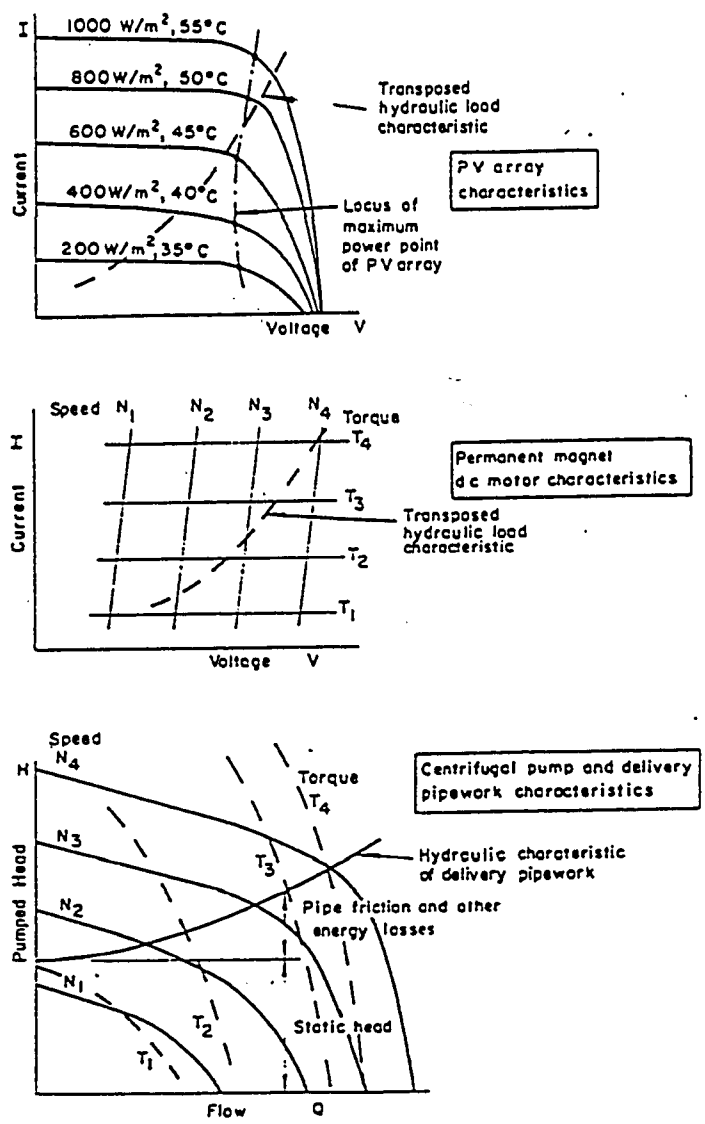


Figure 2.9 Performance Characteristics of a Direct Connected Centrifugal Pump
(Sir William Halcrow and Partners, 1983)

(Chaurey et al., 1992). As the insolation levels increase, the current supplied by the array increases and the pump speed increases. This increases the head against which the pump will work. Water is delivered when the speed increases to the threshold level for the required head. Further increases in speed will increase the volume of water delivered. Figure 2.9 shows how the electrical characteristics of the pump/motor subsystem and array influence each other. "Impedance matching" is used to ensure that the pump/motor system operates close to the locus of maximum power points for the array.

Positive displacement (or volumetric) pumps work by mechanically pushing a sealed quantity of water through a given head. The input voltage and motor speed affect the flow rate of the pump, but not the head against which it works. At low power levels the pump

moves water at a slower rate, but always against the same head. Because the pump must overcome the full pressure head to start, it requires a high starting torque, and hence a high starting current. This is incompatible with the array output which supplies a low current in the mornings. For this reason a controller called a linear current booster (LCB), is used to increase the current output and start the pump in the early morning when the sun is low.

Figure 2.10 shows the optimal pump type for various head and flow conditions. In general, positive displacement pumps are used to move small quantities of water against medium to high heads. Centrifugal pumps are best for lifting large volumes of water through low to medium heads. Single impeller pumps can move water about 20 vertical feet, but the impellers can be

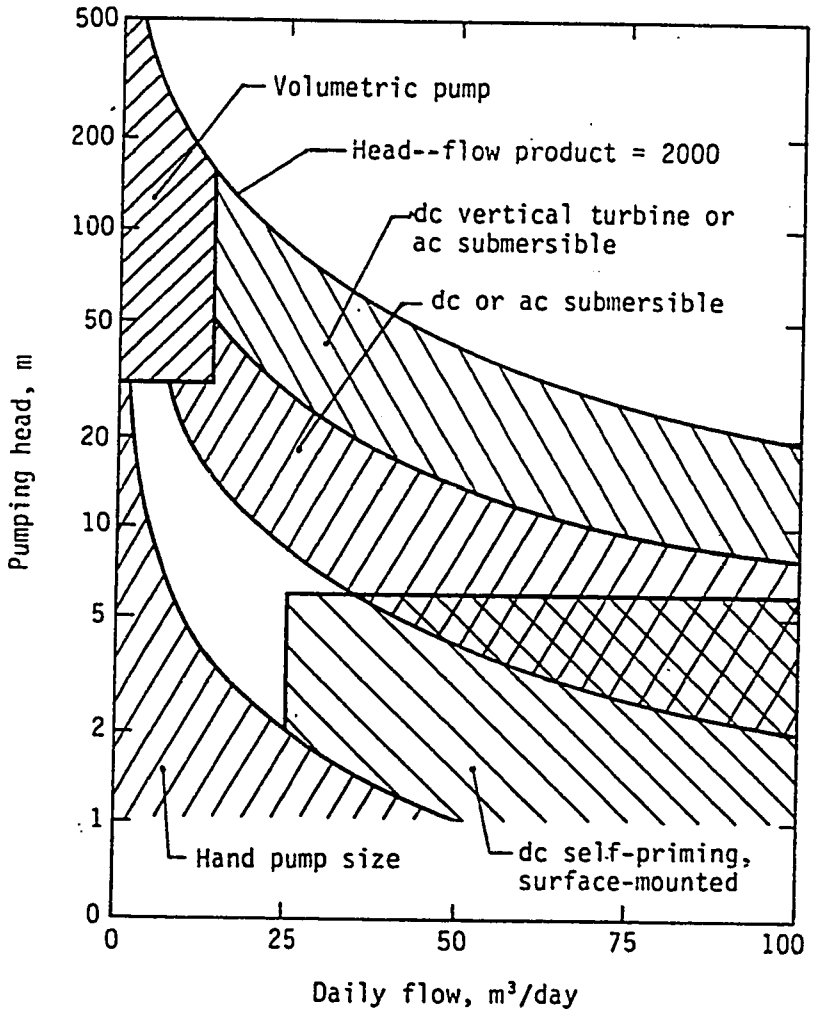


Figure 2.10 Optimal Pump Type for Different Pumping Regimes (Thomas, 1988)

stacked to lift water up to 440 feet. Correct sizing of the pump with regard to the number and size of impellers is essential since efficiency decreases at heads and flows different from the design.

Positive displacement pumps require regular maintenance, notably the replacement of worn seals. Silty or sandy water reduces the seal life and increases the maintenance requirements. Filters are therefore recommended for use with volumetric pumps. These require regular cleaning and must be replaced when clogged.

Large stacked impeller pumps using AC or brushless DC motors are currently the lowest maintenance pumps on the market. The impellers are the only moving parts in the system and there are no seals or sliding parts to wear out. Most of the large submersible pumps use some type of controller to maximize efficiency. Centrifugal pumps are generally capable of handling unfiltered, sandy water. This reduces pump maintenance and pretreatment requirements for the water supply, particularly if the irrigation system does not require clean, filtered water.

2.2.4 The Motor

The motors used for PV water pumping systems are selected for efficiency, reliability, availability, and price. They can be either direct current (DC) or alternating current (AC). DC motors can be either brushed or brushless. Brushed motors require periodic rebuilding and brush replacement. Most PV pumping systems contain a single pump/motor unit built into the same housing.

Most surface pumps designed to run off solar power use brushed DC motors. Surface mounted motors are readily accessible and do not require any special seal around

the motor. This makes brush replacement a simple matter. DC motors are preferred because the array produces DC power, eliminating the need for an inverter. DC motors also tend to be more efficient than AC motors. (Thomas, 1988)

Most of the "mini-submersibles" (DC volumetric pumps) have brushed motors. Since DC motors are oil lubricated, submersible units must have a sealed motor. The motor is generally factory sealed to ensure that water does not enter the housing and oil from the motor does not contaminate the pumped water. Some pumps are not rebuildable and the entire unit is discarded once the brushes wear out. Many pumps have a specially designed seal which allows the owners to change brushes in the field, others can be sent back to the factory for rebuilding. Continuing improvements in brush material and design mean brushes now last between 5,000 and 10,000 hours. Larger DC submersible pumps have brushless motors, eliminating the need for brush replacement.

AC motors are preferred for large submersible pumps because the motors tend to last longer than the brushless DC motors. AC motors are dependable, inexpensive, and readily available, with a long history of good service. Some AC motors used for submersible pumps have a wet rotor design. This means they are lubricated with the pumped water, eliminating the need to develop a seal on the motor. An inverter is required with all AC motors, to convert the power from the array to power suitable for the motor.

Some pumps designed for use with solar energy have a surface mounted motor connected by a drive shaft to a submersible pump. This allows easy access to the motor for maintenance and repair. Proper alignment of the pump and motor are critical. Failure to properly align the pump and motor will result in a significant reduction in efficiency and life span. This type of pump requires professional installation which significantly increases the system cost. This pump/motor configuration is rare in developed countries and cannot be justified for remote areas of less developed countries.

2.2.5 The Controller

Many types of pumps require, or run more efficiently, with some type of power conditioning equipment, or controller. The controller matches the varying power output from the array to the input requirements of the motor. It also simplifies system wiring, providing a convenient control box to wire in water level sensors and other options. Controllers are not required with battery storage, as the batteries themselves stabilize the system voltage, allowing the pump to draw as much current as required. Controllers can be either AC/DC inverters or DC/DC converters. The most commonly used DC/DC converter is the linear current booster (LCB).

All AC pumps require an inverter to convert the DC power from the solar array to three phase AC power for the pump. Although a number of efficient DC pumps have been designed for use with solar power, the large AC pumps still have a longer lifespan than their DC counterparts. Inverters used for direct connection to an array must be able to respond to a constantly varying current and voltage, and are more sophisticated than inverters drawing power from a constant supply. Most are equipped with maximum power point trackers, which use impedance matching to draw the maximum power available from the array at any given irradiation level. The output from the inverter is three-phase AC, with either a true or modified sine wave. Low harmonic distortion is required to reduce heating in the motor and increase the life of the pump.

Depending on the type of inverter, the AC output will vary in one of two ways. With some inverters the voltage current characteristics of the AC output remains constant while the frequency varies in direct proportion to the DC supply voltage. As the array voltage rises, the frequency of AC power increases. This increases the speed at which the motor rotates. With other inverters, both the frequency and output voltage vary with the irradiance level.

The conversion efficiencies of these inverters are very high, normally over 95%. The resulting power loss is small, but it must be accounted for in the array sizing or volume output from the pump will be lower than expected.

Controllers are not generally required for DC centrifugal pumps, since the power requirements of the centrifugal pump are well matched to the power output from the array. In contrast, a DC positive displacement pump requires a high starting torque, and hence a high starting current. At low irradiance levels such as that encountered early in the morning, the current output from the array is low, and not well matched to the power requirements of the pump. The performance of this type of pump can be improved by up to 40% with an LCB.

2.2.6 Battery Bank and Charger

Incorporating a battery bank into an PV irrigation system increases the system complexity and cost. It should only be considered when volume requirements for a tank are too large or portability is a factor. In developed economies where skilled labour is readily available the increase in system complexity is not a problem. A battery bank may even cost less than a water storage tank after land costs are accounted for. This is rarely the case in less developed countries.

Most PV systems use lead-acid batteries. These batteries require regular maintenance. The water level in the battery bank must be maintained, the specific gravity of the electrolyte monitored, and a periodic equalization charge given to ensure that all cells are all charging to the same level. Lead acid batteries for PV systems are similar to those used in recreational vehicles. They have thick plates which allow for deep discharge and numerous charge/discharge cycles. Most are designed for stationary use only.

Lead calcium (or gel cell) batteries can also be used for PV systems. These are a special type of lead acid battery with calcium added to the lead grid. This increases strength and reduces the gassing and water loss associated with battery recharging. These batteries are generally factory sealed with enough water to last the life of the battery. They are ideal for remote PV applications because of the low maintenance requirements and are much easier to ship overseas because they are sealed. Unfortunately gel cell batteries are also expensive and are not economically feasible for less developed countries.

A charge controller is required whenever a battery bank is used. The charge controller ensures that the battery bank is not overcharged or over-discharged. A number of different charge controllers are available. Single stage controllers have a simple on/off switch that cuts off power to the batteries when they are fully charged. Double stage controllers allow full current to the batteries until they are approximately 80% charged then switch to trickle charge mode to complete the cycle. This type of charge controller increases battery life considerably. Charge controllers can also be used to cut power to the load when the battery voltage, and hence the battery capacity, is low.

2.2.7 Water Storage

If storage is required for a PV water supply system, water storage is generally preferred over battery storage. Sizing a storage tank to meet irregularities in supply and demand for a PV irrigation system is a complex task. A statistical study would be required to determine if irrigation water requirements varied linearly with PV pump output. If not, the volume of storage required would depend on the type of irrigation system, the water holding capacity of the soil, the crop value and the risk of crop damage from lack of water. The crop root zone provides a large volume of water storage and plants will not suffer

permanent damage until the soil moisture content in the root zone drops below the permanent wilting point.

For systems with a constant energy demand, a general rule of thumb in the industry is to have three days of storage built in to cover periods of low sunlight. This would be impractical for the large volumes of water required by most irrigation systems, it would also be a significant overestimate of storage requirements since the irrigation water demand varies with the water supply. For solar irrigation systems some designers like to incorporate one days worth of storage. This is generally considered sufficient, but not entirely necessary. Daily storage may be justified so that water can be applied at night when evaporation losses are low. This allows the plant root zone to fill before water evaporates. Providing water storage increases the systems cost and should not be considered if it is not necessary.

Another reason to provide water storage, apart from irregularities in supply and demand, is to maintain a constant pressure head on the irrigation system. If a constant pressure head is required for the irrigation system, an elevated water tank is the simplest and most reliable option. In this case the volume of the tank is not as critical as the elevation. The tank fills during the day when the pump is working and drains at a rate determined by the irrigation system. The systems shuts down when the tank is empty.

2.2.8 Water Level Sensors, Float Switches, & Pressure Switches

Float switches, water level sensors, and pressure switches are designed to turn the pump on and off automatically as required. Float switches are used for open water storage tanks. They rely on a mechanical arm that floats on the water surface, turning the pump on when the water level is low and off when the tank is full.

Water level sensors can be used for the same purpose. Two sensors are required, one at the low water level to turn the pump on and one at the high water level to turn the pump off. Water level sensors can also be used in the well to turn the pump off when the water source is low and on again when it replenishes. Some pumps are equipped with dry run switches that automatically sense when the water level is low, or the motor is overheating and turn the pump off. Other pumps are not harmed by running dry. These pumps do not require external water level sensors at the intake end.

2.3 COMPARISON OF ALTERNATIVE REMOTE PUMPING OPTIONS

Table 2.1 outlines some of the relative advantages and disadvantages of the various alternatives to PV pumping systems commonly used in remote areas. Where extension of the electrical grid is not feasible a diesel generator is normally the first option considered. The technology is well tested, buyers generally know what to expect from it, and maintenance crews are familiar with it. Unfortunately, due to practical limitations in the minimum size of a diesel engine (2.5 to 3.7 kW), diesel pumps are often oversized for small water pumping needs and unit water costs over the life of the system can be high.

The cost of fuel and maintenance over the life of a diesel system are a significant portion of total systems costs. These costs rise dramatically with distance to the nearest urban centre. Transportation systems in remote areas of less developed countries are often inadequate and trips to town to collect heavy fuel barrels can be expensive, time consuming, difficult, and in some cases dangerous. The cost of bringing in a skilled technician for repairs is even more daunting. Thomas (1988) estimated costs for a remote diesel systems are typically twice that of the same systems located near a major urban centre. A study of remote pumping systems for water supply in Mali found that diesel systems became largely inoperable at remote sites with difficult access and unreliable fuel

	Advantages	Disadvantages
Handpumps	•low capital costs •possible local manufacture •easy maintenance, can be done locally •no fuel requirements	•inefficient for all but low yield or low demand boreholes •time spent collecting water could be used more productively in other tasks
Animal Powered pumps	•more powerful than human powered pumps •animals get lower wages •dung may be used as fuel or fertilizer	•animals require year round feeding and care •they are needed for other tasks during irrigation periods
Water (River Flow) Powered pumps	•low cost •long life span •high reliability •easy maintenance •no operator required	•low output •requires flowing water with sufficient power
Windpumps	•long life span •easy maintenance •possible local manufacture •no operator required •no fuel required	•difficult to install •requires an average wind speed of approximately 2.5 m/s •water storage required for low wind periods •requires a high degree of planning and system design
Diesel and Gas Pumps	•low capital costs relative to solar pumps •easy installation	•short life span •high maintenance costs •fuel can be expensive to transport •may be difficult to get fuel, parts, and maintenance personnel to remote areas •fumes and noise pollution
Solar PV Pumps	•easy installation •long life span •low maintenance •no operator required	•high capital cost •water storage required for overcast periods •requires proper planning and system design

Table 2.1 Advantages and Disadvantages of Different Remote Water Pumping Options (Derrick et al., 1989)

supplies (CORECT, 1990). In addition to these problems diesel systems are noisy and dirty. This problem is exaggerated by the lack of tuning for most diesel systems in developing countries. Finally, the high pumping rate of a diesel engine can be a problem in areas with low well yields and care must be taken to ensure the pumping rate does not exceed the recharge rate of the well.

Hand pumps are often considered an inexpensive option for low volume village water supply in remote areas where the water table is less than 20 m below the ground surface. There are, however, some important differences between village water supply and irrigation. The volume of water required for village water supply is typically quite low and one hand pump usually supplies enough water for many families. In addition, end users are gathering water for their own use and are not paid for this work. By comparison, irrigating even a small field requires a number of hand pumps and the farmer must pay labourers to work the pumps. Employee wages must therefore be factored into the economic equation. These wages constitute an annual operating cost which increases total costs over the life of the irrigation system, often to prohibitively high levels.

Another factor affecting the economics of any ground water supply system is the cost of well drilling, the resulting well yield and the discharge rate of the pumping system. Drilling wells can be expensive in less developed countries and wells should be utilized to full advantage wherever possible. The Mali water supply study found hand pumps inefficient for well yields over 5 m^3/hr (CORECT, 1990).

Animal powered pumps, or Persian wheels, can draw water from greater depth and at a faster rate than hand pumps. They therefore take better advantage of higher yield wells and are better suited to irrigation requirements. Sir William Halcrow and Partners (1983) showed animal powered pumps were competitive for irrigating small farms at lifts of less than 4 m. Saxena and Ilyas (1987) reported a 22% to 54% underutilisation of

draught animals on farms in India. These animals, used at the beginning and end of the cropping period for tilling, sowing and threshing, were normally free when irrigation was required. The economics of Persian wheel irrigation depends heavily on assumptions made regarding the availability of draught animals. If the farmer does not use these animals for other purposes, the full cost of purchasing, feeding, and caring for the animals must be factored into the cost of irrigation. With the increasing mechanization of all aspects of farming in India, the use of Persian wheels is expected to decline. Saxena and Ilyas (1987) reported the number of Persian wheels used in India decreased from 638,000 in 1972 to 566,000 in 1977. Farmers preferred the prestige of an electric or diesel pump in spite of the erratic supply of fuel and power.

Other options for water pumping in remote areas include "renewable energy" systems, such as wind, PV, or small hydro. The difficulty with these systems is to find a suitable location with adequate energy resources and a good match between energy availability and demand. Renewable energy systems require more time for resource assessment, equipment procurement, and user education than either diesel, hand or animal powered systems. The technology is not yet commonplace in India but the government (with the help of foreign aid agencies) is working actively to change this. All of the renewable energy options discussed in this section are pollutant free with zero emission levels.

Wind powered pumps are considered viable where the average wind speed is over 2.5 m/s (Sir William Halcrow and Partners, 1983) or 3 m/s (Thomas, 1988) during the least windy month. Compared to wind systems, PV pumping systems provide a more consistent supply of water and a better match between water supply and demand. Figure 2.11 compares the output from a wind and PV pump to irrigation water requirements for the Ganga Plain of India. This situation is typical of many areas in India: during critically dry periods when water is needed most, wind speeds are low and solar energy availability is

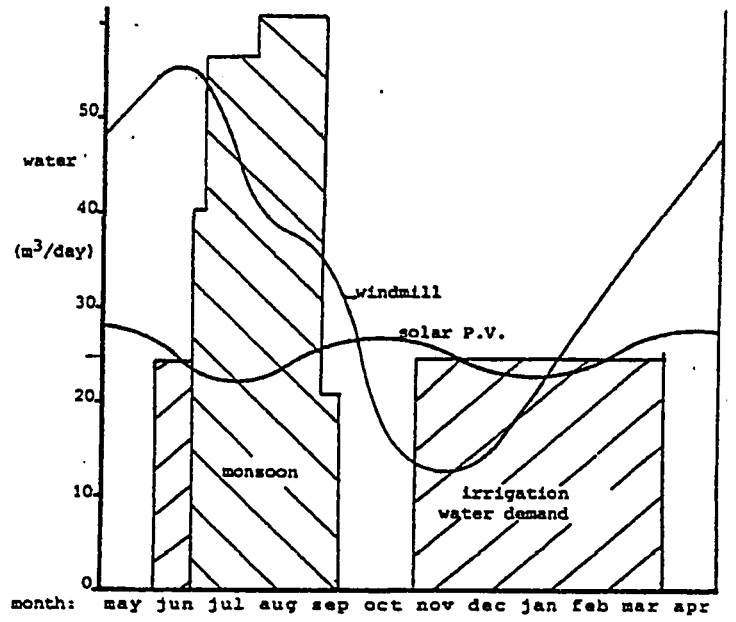


Figure 2.11 Irrigation Water Demand Compared to Supply from a Wind and PV Pump
(Kwant and van der Toorn, 1983)

high. Compared to wind systems, PV systems are easier and safer to install and maintain. Arrays are installed at easily accessible heights whereas wind generators are generally placed as high off the ground as possible.

Energy from flowing water can also be used for pumping water in remote areas. This type of system includes river current turbines, hydraulic rams or small hydroelectric plants powering an electric pump. The use of any of these options is restricted to areas where running water of sufficient energy is easily accessible.

A detailed review of PV systems for water supply in Mali found that they should be considered where the worst month insolation exceeds 3.0 kWh/m^2/day and well capacity is between 5 and 9 m^3/hr. At lower insolation levels and well yields hand pumps were sufficient for water supply (though not well suited to irrigation). At higher yields a larger diesel pump made more efficient use of the well capacity. For very remote sites, where access was exceedingly difficult and fuel supplies unreliable, the study found diesel systems became largely inoperable and larger solar systems were justified (CORECT, 1990).

PV powered pumping systems provide a better match between water supply and demand than wind systems. They are also easier to install and maintain. Compared to water powered pumps, suitable locations for PV power are more widely available. PV pumps are more economical than Persian wheels over a wider range of heads and flows and have much lower operating costs if the cost of feeding the animals is considered. PV pumps also have lower operating costs than hand pumps if the cost of labour is considered. Flow rates from a PV pump are also better suited to irrigation requirements than flow rates from hand pumps. Finally, compared to diesel engines, PV arrays provide a cleaner, more reliable supply of energy. They break down less often than diesel pumps. They also free the owner from dependance on irregular fuel supplies and time consuming trips to town to collect fuel. PV pumps can also be more precisely sized for individual water pumping requirements than diesel pumps.

The main advantages of PV water pumping systems for irrigation are listed below. These advantages extend beyond simple economic comparison studies, encompassing a number of intangible benefits.

- PV pumps are environmentally friendly. They do not contribute to noise pollution and no harmful pollutants are released during operation.
- Electricity is generated on site with a PV system, eliminating costly power distribution networks.
- PV generators are more reliable than either diesel or wind generators. Long term costs associated with mobile repair units and importing spare parts to remote locations are greatly reduced and user satisfaction increases.
- Maintenance is simple, inexpensive and easily handled by the owner.
- There are no fuel requirements. Time consuming and expensive trips into town to collect diesel or gas are eliminated.
- Reduced dependence on petroleum based fuels benefits the entire national economy for oil importing countries such as India.

- PV modules have a very long life span. Single and poly crystal silicon modules show little or no degradation in performance over a 30 year span. PV companies routinely guarantee modules for 10 years and some companies for up to 20 years.
- When foreign aid is used for equipment purchase funding is often available for capital expenditures but not recurring costs, a situation well suited to the use of photovoltaics since recurring costs are low.
- PV systems are modular and can be easily sized to meet individual water demands and budgets. Where funding is limited, pumps may be installed with a down-sized array to deliver a portion of the available water and modules added as funding permits until the pump is being used to full capacity. Similarly, PV systems can be sized to meet current pumping requirements with room allowed for future expansion.
- The owner of a PV system is free from worries over power blackouts, diesel shortages, poorly timed canal irrigation schedules or purchase of water from other farmers. The probability of power blackouts, fuel shortages, and water shortages increases as water demand increases and tends to happen most frequently during critical periods when crops are most vulnerable.
- There is an excellent correlation between water supply and demand for PV irrigation systems. PV pumps deliver more water on clear, sunny days when evapotranspiration levels are highest and less water on cloudy, rainy days when evapotranspiration levels are lower and crops are receiving all the water they need in the form of precipitation.

2.4 IRRIGATION METHODS AND COMPATIBILITY WITH PV PUMPS

There are many different ways to distribute irrigation water over a field. Irrigation can roughly be divided into surface, supersurface and subsurface methods. Surface irrigation allows water to flow directly over the field by flooding, furrow, border strip, border ditch, basin, or terracing methods. Supersurface methods spray water onto the plants from above via sprinklers. Subsurface methods distribute water underground through pipes, drip tape, or diffusive tubing. The method of irrigation chosen is dependant on the type of crop to be irrigated, the terrain, the soil type, the climatic conditions, and the cost of water.

The most expensive component of a PV water pumping system is generally the array. Minimizing the array cost, means minimizing the energy requirements for the system. The energy requirements are dependant on the head against which water must be pumped and the amount of water which must be pumped. The amount of water required depends on the crop, the climatic conditions and the irrigation efficiency. The irrigation efficiency and the total pumping head depend on the method of irrigation. These are the two most important factors to consider when choosing a method of irrigation for use with a PV pump. This section begins with a discussion of the measures of irrigation efficiency. These terms are used to compare the compatibility of different of irrigation methods with PV water supply systems.

2.4.1 Measures of Efficiency

The overall irrigation efficiency (E) is the product of conveyance efficiency (EC), application efficiency (EA) and emission uniformity (EU). EC is a measure of water losses between the pump head and field to be irrigated. It is defined by Equation 2.1 where WP is the water supplied by the pump and WF the water received at the field inlet.

$$EC = 100 * \frac{WP}{WF} \quad (2.1)$$

EA (given by Equation 2.2) is the ratio of the water directly available to the crop in the root zone, to the water received at the field inlet.

$$EA = 100 * \frac{WA}{WF} \quad (2.2)$$

WA is the water available to the plant in the root zone. WA is defined by Equation 2.3 where RO is runoff from the field and DP is deep percolation losses.

$$WA = WF - (RO + DP) \quad (2.3)$$

EU is a measure of the uniformity of water application across the field. To determine EU the field is divided up into s sub-sections and the depth of water (d_i) received by each sub-section is measured. EU is then given by Equation 2.4, where σ_d is the standard deviation of d_i (Equations 2.5) and d is the average value of d_i.

$$EU = 100\left(1 - \frac{\sigma_d}{d}\right) \quad (2.4)$$

$$\sigma_d = \frac{\Sigma |d_i - d|}{s} \quad (2.5)$$

Table 2.2 shows estimates of EA for different irrigation methods. For the hot, dry to moderate climates found over most of India, drip irrigation is the most efficient irrigation system available.

Method of Irrigation	USDA	US(SCS)	IDIC/ILRI
Surface Methods			
Light Soils	55		
Medium Soils	70		
Heavy Soils	60		
Graded Border		60-75	53
Basin and Level Ditch		60-80	58
Contour Ditch		50-55	
Furrow		55-70	57
Corrugation		50-70	
Sub-Surface Methods			
Drip		up to 80	
Super-Surface Methods			
Sprinkler (hot, dry climate)		60	
Sprinkler (moderate climate)		70	67
Sprinkler (humid and cool)		80	
Rice			32

Table 2.2 Water Application Efficiency (%)
(Doorenbos and Pruitt, 1977)

2.4.2 Conveyance

The conveyance network moves irrigation water from the source to the field. This is done by either a lined or unlined channel or a pipe. For an unlined channel EC depends on the channel length and wetted perimeter, the soil infiltration rate, and whether the flow is continuous or intermittent. Doorenbos and Pruitt (1977) estimate EC for unlined channels with continuous supply systems at about 90%. Relative losses per unit length of the conveyance channel will be higher with a PV pump because of the low flow rate. Lining the conveyance channel is an inexpensive way to improve system efficiency and minimize seepage losses. The cost of lining channels will more than be recovered in the down-sizing of the array and pump system. Switching to a piped conveyance system eliminates both seepage and evaporation losses. For piped conveyance EC is generally assumed to be 100%. If water is piped under pressure (as in a drip or sprinkler irrigation system), energy losses can be minimized by increasing the pipe diameter.

2.4.3 Surface Irrigation

Ninety-nine percent of all irrigation in developing countries is done via surface methods (Nir, 1995). It is the least expensive type of irrigation, requiring little or no capital investment for a small farm. Water is directed across the field by shaping the land surface into basins, terraces, furrows, corrugations, or bordered strips. Potential capital expenses include costs associated with distribution and control structures, lining of conveyance channels and land levelling. The different methods of surface irrigation are illustrated in Figure 2.12. The method chosen depends on the crop, topography, soil, water supply, and local customs.

Flood or basin irrigation requires a large flat field surrounded by check dams which

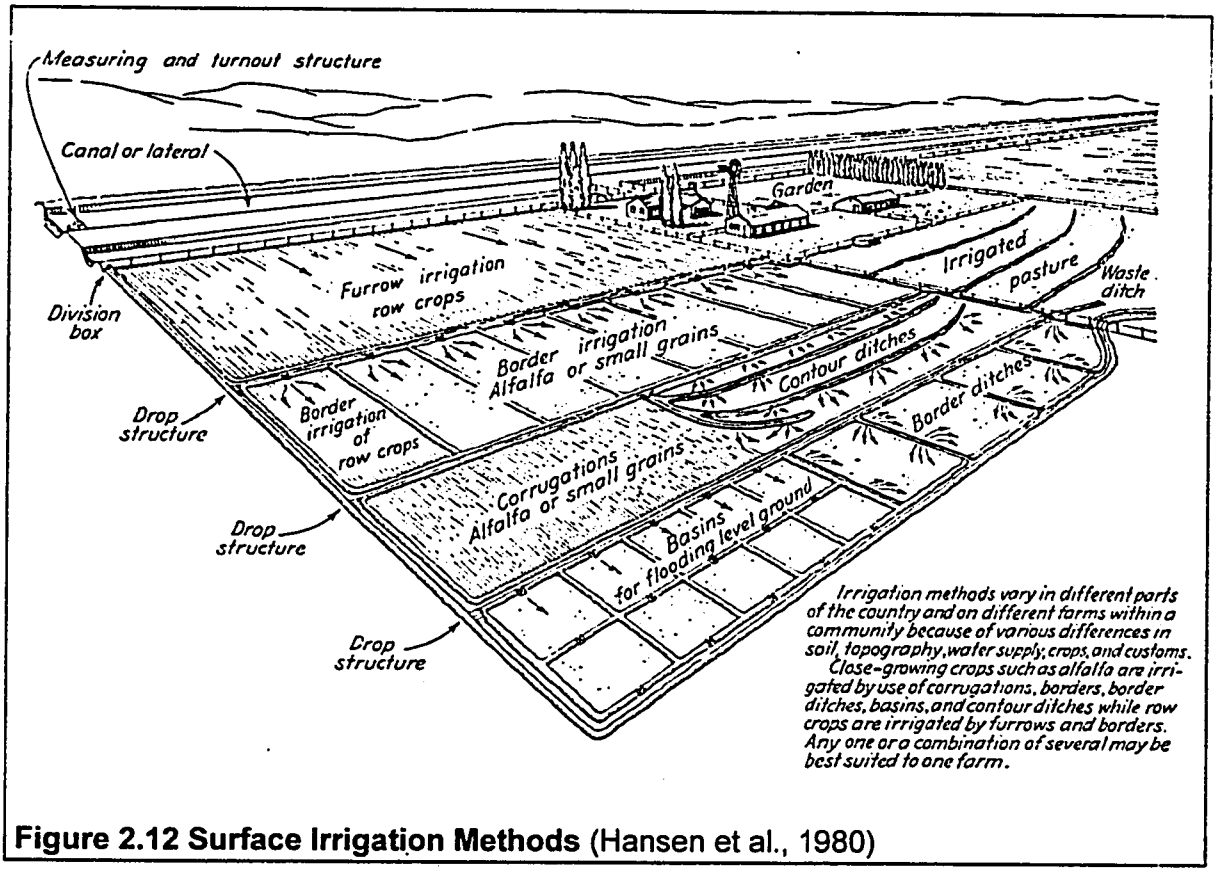


Figure 2.12 Surface Irrigation Methods (Hansen et al., 1980)

is completely flooded with water during irrigation. The Indian Practical Civil Engineers Handbook (Khanna, 1993) differentiates between flood and basin irrigation by the depth of water covering the field, with the latter requiring more water. Water volume requirements are extremely high for both methods. This type of irrigation is used mainly for rice and is not suitable for irrigation with a solar pump. Individual basins are often used for trees. Each tree is surrounded by a shallow basin with an area of about 1.5 m^2. Trees are placed approximately 6 m apart, depending on the type. This type of irrigation can be used on unevenly graded land. The water requirements are high but can be reduced by careful management and lining of channels leading to each basin.

Terracing is used for steep sloping land. The land is graded to form stairs with flat surfaces edged by a reinforced wall, as shown in Figure 2.13. Each level is flooded, usually by rainwater, or a mountain stream. Again, the water requirements are high because the entire cropped area needs to be covered in water.

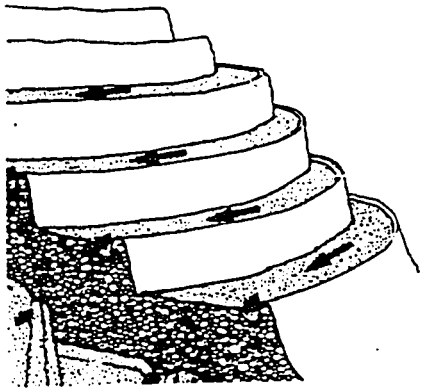


Figure 2.13 Terracing
(Stern, 1979)

Furrow irrigation is the most common method of surface irrigation. It is used with row crops, such as vegetables. It requires a relatively smooth gradually sloping ground surface. Water is directed along a channel which runs across the top of the field. The furrows run perpendicular to this channel, gradually sloping towards the bottom of the field as shown in Figure 2 14. Siphons are used to direct water over the edge of the channel into the furrow. Irrigation efficiency is higher for furrow irrigation than for flood, basin, or terraced irrigation because water is not applied to the entire surface.

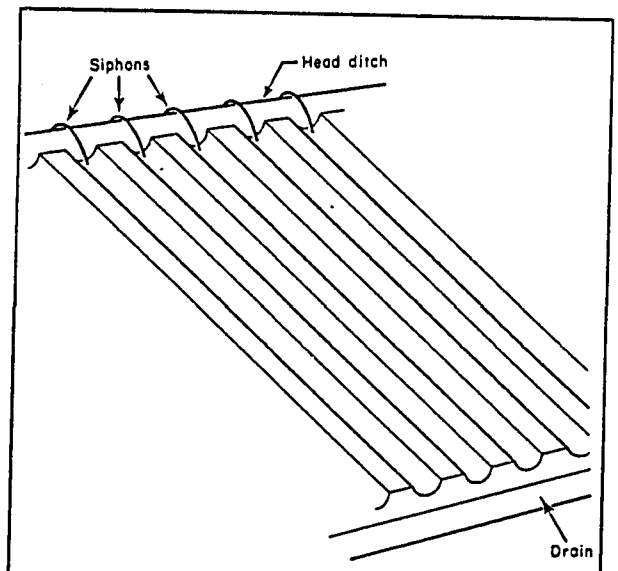


Figure 2.14 Furrow Irrigation
(Withers and Vipond, 1974)

Most PV irrigation systems used in less developed countries rely on furrow irrigation. It is the most common method of irrigation, pumping head requirements are low and the irrigation efficiency is higher than that of other surface methods. There are two problems associated with the use of PV water pumps for furrow irrigation. First, irrigation efficiencies, though higher than for other surface methods, tend to be low in practice. This is due largely to lack of training, poor land grading, high seepage and runoff losses, and imprecise, manual control of flow rates. A good deal of research has gone into developing ways of making furrow irrigation more efficient. Suitable steps include precision levelling, lining of canals which distribute water to the top of the field, recycling of runoff water and intermittent or surge application of water. Unfortunately these measures also increase costs. The cost of increased irrigation efficiency must be balanced against the cost of water and increasing the size of the array and pump.

Second, the flow rates associated with PV pumps are generally much lower than those required for furrow irrigation. Most irrigation pumps supply water at a high flow rate. PV pumps are sized to meet daily irrigation requirements, supplying water at a low flow rate over an entire day. If the farmer has to manually direct the flow of water over the field, it will take a few hours a week with a standard irrigation pump or an entire day, every day with a solar pump. This represents a significant increase in labour requirements. The problem can be overcome by building storage into the system or by automating the flow of water. Both solutions increase system complexity and cost.

Foroud, Elser and Ethier (1992) developed a PV powered automated controller for surge flow furrow irrigation. Using automated surge flow irrigation significantly increased the irrigation efficiency and decreased the labour requirements. The automated system consisted of a programmable logic controller, PV power supply system, man-machine interface, regulated air system, four Hasting's irrigation valves and valve controllers. The solar power supply system consisted of two deep cycle batteries, a regulator, solar panels and a support structure. Similar systems have since become available for commercial use (Photocomm, 1996).

By applying water on an intermittent, rather than continuous basis, surge flow irrigation allows for a more uniform infiltration rate, reducing advance time and lowering percolation losses. The authors reported application efficiencies of 80 to 90% were possible for border strip and furrow irrigation. The surge flow controller requires less energy to operate than a sprinkler system making it better suited to PV application. Unfortunately the viability of an automated control system for remote locations in developing countries is questionable. It represents a significant increase in system complexity and expense that is not justifiable in the context of a less developed economy.

Corrugation and border strip irrigation are both similar in setup to furrow irrigation except the furrows are replaced by much narrower corrugations or wider border strips. A border strip is about 7 m wide with a check dam running the length of both sides. Irrigation efficiencies can be relatively high and compatibility with a PV water supply is similar to that of furrow irrigation. The main difference is that both corrugation and border strip irrigation are used for closely spaced crops or crops which cover the entire field, such as grasses. Return on investment for these crops is generally low and it is unlikely that the cost of the PV water supply system would be recovered.

2.4.4 Supersurface (Sprinkler) Irrigation

Sprinkler irrigation systems spray water down on the plants from above in a manner that simulates natural rainfall. In most systems water is distributed through a network of underground pipes to sprinkler nozzles which protrude above the soil surface. Other systems use long pipes attached to large wheels which are rolled over the field and spray water down on the plants from above. Still others distribute water through a network of elevated pipes which spray water by gravity onto the crops.

The overall irrigation efficiency is much higher with sprinkler irrigation than with surface irrigation. The piped distribution system and controlled method of water application virtually eliminate conveyance and deep percolation losses, and allow for a more uniform distribution of water over the field. Evaporation losses may be higher, but overall losses are significantly reduced. The advantages of sprinkler irrigation are listed below.

- Crop yield and quality are high.
- The water application rate can be highly controlled.
- Deep percolation losses and drainage problems are reduced.
- Water distributed with a high degree of uniformity.
- Fertilizers can be distributed via the water supply.
- The plant root zone is aerated with the water supply.
- Good soil conditions are maintained.
- Expensive land levelling is eliminated.
- Soil erosion is reduced.
- Labour costs are reduced.
- Regular washing of plants helps control pests.
- Frost can be controlled through the use of warm water.

The main disadvantage of sprinkler systems is the high capital investment required. The control and distribution systems are expensive and high quality pipes must be used because the water is under pressure. The water quality must also be high as it is applied directly to the plants. Excessively saline water damages plant foliage. Marginal or recycled water can not be used for health reasons (Sharma and Sharma, 1990). The cost of water treatment must be factored into the total system cost.

Lower cost, fully portable sprinkler systems are available and in less developed countries. In a fully portable system, the pump, mains, and laterals are movable and can be rotated to water different portions of the field. This increases labour but reduces equipment costs. Semi-portable systems are also available in which the pump and mains are permanent with movable laterals. Figure 2.15 shows a portable sprinkler system manufactured by a company in Calcutta.

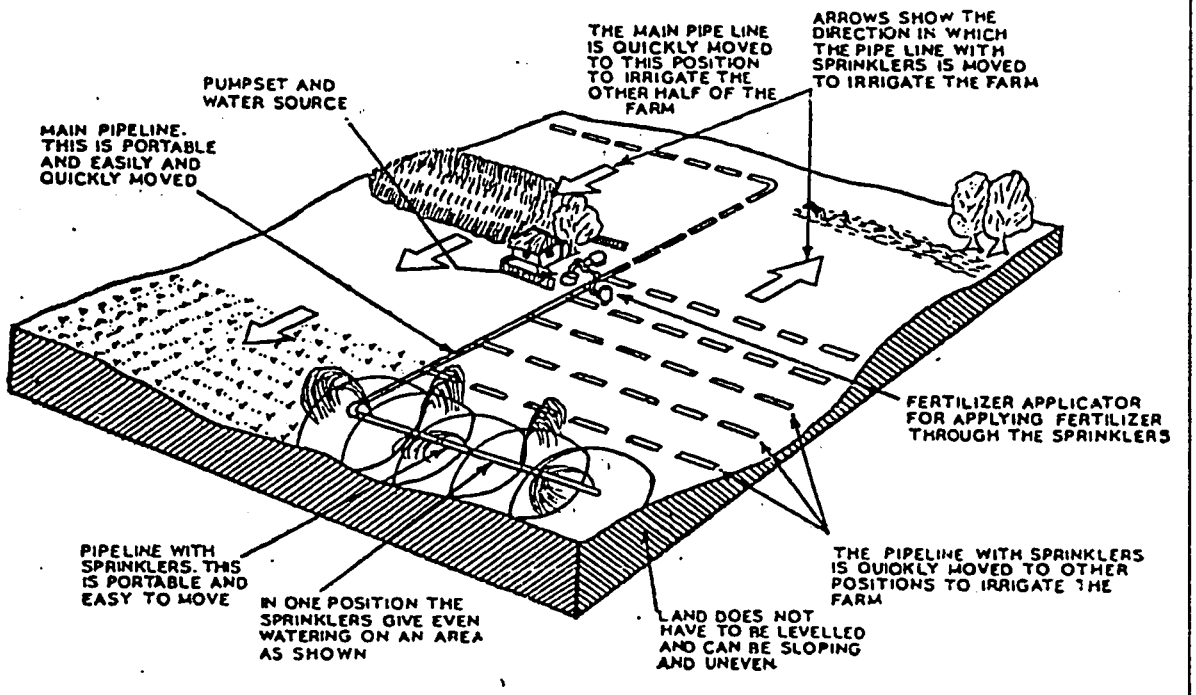


Figure 2.15 Portable Sprinkler Irrigation System (Sharma and Sharma, 1990)

The main disadvantage of sprinkler systems for use with a PV water supply system is the high water pressure requirement. The increased pumping head increases the energy requirements of the system which significantly increases the cost of the solar array. This is not the only problem. As with furrow irrigation, the flow rate required by a sprinkler irrigation system is much higher than the average delivery rate from a PV pump. In addition, irrigation water is applied during daylight hours when evaporation losses are highest. The best solution is to build some form of storage into the system so that water can be applied at night, at higher flow rates, but this increases the system complexity and cost.

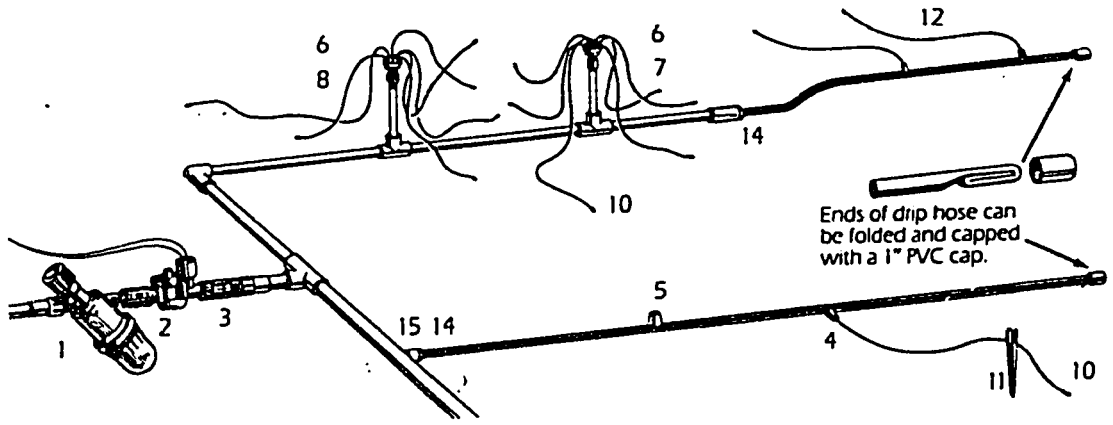
2.4.5 Subsurface Irrigation

In subsurface irrigation water is directed under the ground directly to the root zone, minimizing evaporation and runoff losses. Water can be directed through open ditches, mole drains, tile drains or, in the case of drip irrigation, through pipes, drip tape or diffusive tubing.

Natural subsurface irrigation occurs in low lying lands with a high water table. This is a very economical means of raising crops, but finding suitable land is difficult since the water table must be high enough to reach the plant root zone without waterlogging. These conditions can be mimicked by raising the water table through addition of water via deep ditches, mole, or tile drains. Again, this requires a specific set of natural conditions. A top layer of permeable soil capable of lifting water from the water table to the root zone by capillary action, and either a high water table which can be artificially raised or an underlying impermeable layer on which an artificial water table can be built. This method of irrigation is expensive, water intensive, and not at all suited to PV irrigation.

Drip or trickle irrigation systems consist of a network of mains and laterals attached to emitters, drip tape, or diffusive tubing. These systems deliver water at a much lower flow rate and under lower pressure than sprinkler systems. Water is discharged directly to the plant root zone rather than being distributed throughout the entire soil matrix. Field capacity conditions can therefore be maintained in the direct vicinity of the plant root zone, reducing plant water stress and increasing yields. Figure 2.16 shows the layout of a typical drip irrigation system. Figure 2.17 shows typical wetting patterns around a single point emitter in course textured, sandy soil, medium textured loam, and fine textured clay.

Overall irrigation losses are minimal with a drip irrigation system. Conveyance losses are minimized as water is distributed via contained pipes. The controlled method of water application virtually eliminates deep percolation losses and runoff. Evaporation losses are lower than those associated with both surface and sprinkler irrigation since only the shaded soil around the plant is wetted. Table 2.3 compares typical efficiencies of drip and surface irrigation.



1. Filter 2. Automatic Valve 3. Pressure Regulator 4. Emitter 5. Emitter
6. Multiple Outlet Emitter or Drip Manifold 7. Microtubing 8. Microtubing
9. Hole Punch 10. Insect Cap 11. Microtube Stake 12. Microtubing
13. Mistake (or Goof) Plugs 14. Compression Adapter 15. Tapered Pipe Adapter

Figure 2.16 Typical Drip Irrigation System (Melby, 1995)

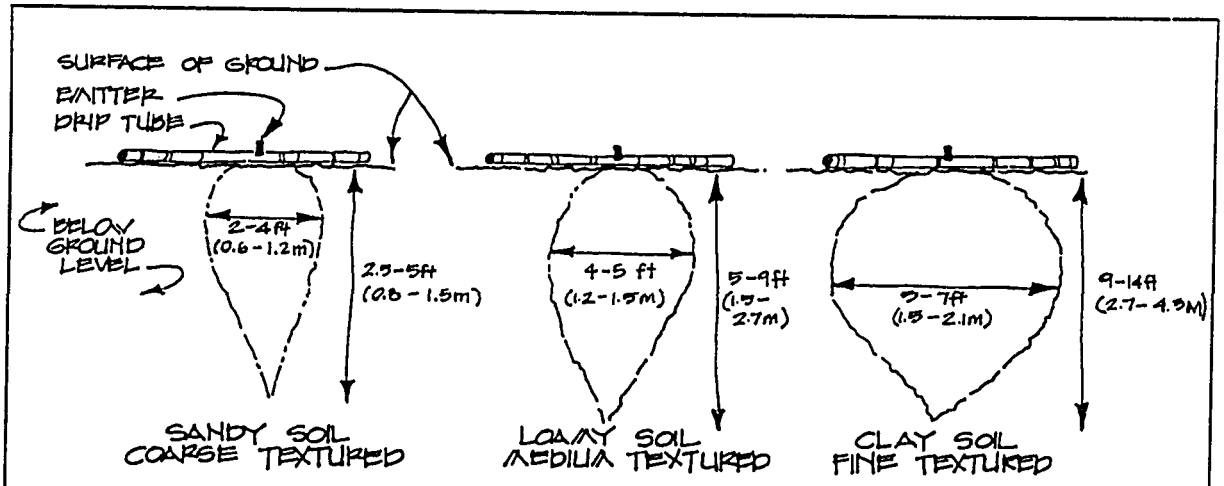


Figure 2.17 Soil Wetting Pattern around a Single Point Emitter (Melby, 1995)

	Efficiency (%)	
	Surface	Drip
Conveyance	60-70	100
Application	50-60	95
Surface Evaporation Losses	30-40	10
Overall Efficiency	30-45	85-95

Table 2.3 Drip Irrigation Efficiency vs. Surface Irrigation Efficiency (Singh et al., 1995)

The main advantages of drip irrigation over other types of irrigation are listed below.

- Application efficiency can be as high as 95%, compared to typical efficiencies below 60% for surface irrigation.
- Water savings are estimated at 30 to 80% over surface irrigation methods (Khanha, 1993; Sivanappan, 1995).
- Labour savings are estimated at 60 to 90% over surface irrigation methods (Khanha, 1993).
- Drip systems operate at lower pressure heads than sprinkler systems. This means lower energy requirements and less expensive distribution systems.
- Evaporation losses are much lower than those associated with either surface or

sprinkler irrigation systems, so daytime application of water is less of a concern.

- Low quality (saline or brackish) water can be used without harming the crop.
- Weed growth is reduced because water goes only to the desired plants.
- Surface runoff and soil erosion are virtually eliminated.
- Plant yield and vigour generally increase through maintenance of optimal air-soil-water ratios.
- Non-uniform and highly sloping land can be used without expensive land levelling.
- Water distribution is more uniform even under high land slopes.
- Water supply to the field is easily regulated.
- Fertilizers can be distributed with the water directly to the plant root zone and volume requirements dramatically reduced.
- Deep percolation of and volatization of fertilizers is reduced.
- Fertilizer costs drop and environmental friendliness increases.
- Though best suited to course sandy soils, drip irrigation is adaptable to most crops and soil types and all climatic conditions.
- Record yields have been obtained even under adverse conditions of high land and water source salinity, high temperature, and low relative humidity (Sharma and Sharma, 1990).

Drip irrigation is preferred over sprinkler irrigation for PV systems for a number of reasons. The pressure requirements are lower, significantly reducing the cost of the distribution system and the PV array. Water requirements are lower because water is applied more precisely and evaporation losses are reduced. Reduced evaporation losses also lower concern over daytime application of water. Finally, water delivery rates for drip emitters are more compatible with PV pumping systems. Like PV pumps, drip emitters are designed to deliver a low flow over the entire day. (Sprinkler heads are typically rated in litres per minute, drip emitters in litres per hour and PV pumps in litres per day.)

Drip irrigation is preferred over surface irrigation for PV systems because of the higher water use efficiency, more compatible water delivery rates and significant labour savings. Because water delivery rates are more compatible, storage needs are significantly reduced. The need for automation or excessive labour is also reduced. The pipes fill at the beginning of the day when the systems starts up and drain at the end of the day. Valves can be worked manually to direct water to different areas if required, but the farmer does not have to constantly monitor and guide the flow of water.

The main drawback of a drip irrigation system is the expense. Drip systems tend to be less expensive than sprinkler systems because the lower pressure requirements mean lower cost polyvinyl chloride pipe can be used for the distribution system (Sharma and Sharma, 1990). Even so, systems designed in developed countries tend to be quite complex and capital intensive in an attempt to increase efficiency and reduce labour requirements. Emitters may have added features like porous plugs to prevent clogging or pressure compensation to ensure a constant flow rate regardless of pressure differences at various points in the system. Electronic control of the irrigation schedule is another common feature in many drip irrigation systems, with a tensiometer relaying information back to a vacuum valve which controls the supply of water to the line. This control and feedback equipment can be powered by a separate array and battery in a PV system.

Fortunately, these complex control systems and emitter designs are not essential to the drip irrigation process and systems sold in less developed countries tend to include only the basic components in an attempt to reduce capital costs. Basic systems such as these have been shown to be cost effective in India with payback periods ranging from 5 months to 1.5 years (Sivanappan, 1995; Suryawanshi, 1995).

Less expensive methods of drip irrigation are also available. Perforated drip tape or permeable drip tubing can be used in place of laterals with individual emitters.

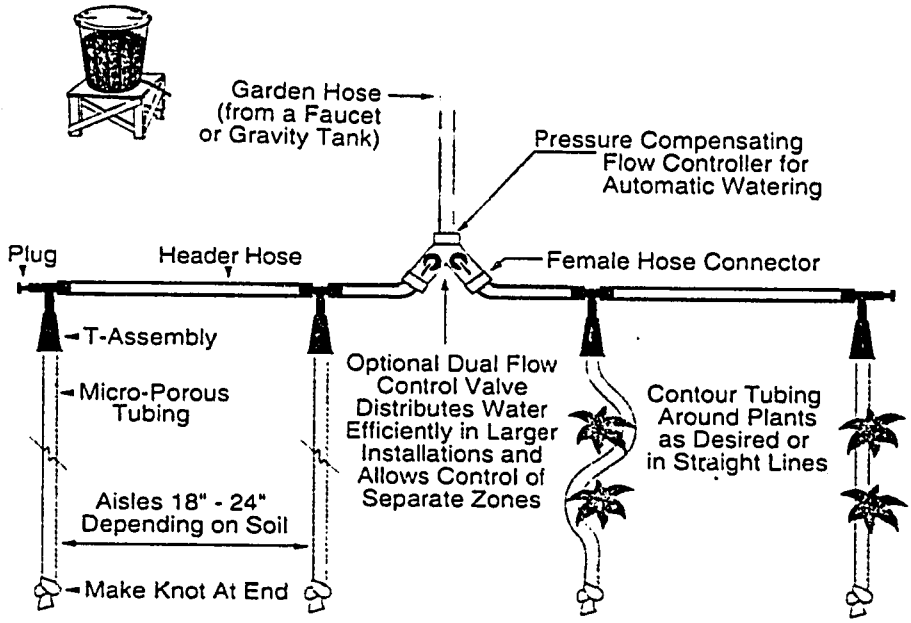


Figure 2.18 Micro-Porous Tubing Schematic (International Irrigation Systems, 1996)

Permeable tubing is less prone to clogging than both perforated tape and traditional emitters. It also operates at a lower pressure head making it well suited to use with a PV powered water supply. Figure 2.18 shows a schematic layout of a permeable tube system.

In general, drip irrigation systems are best suited to widely spaced, high value horticultural crops. Different types of drip systems are better suited to different crops. Single point emitters work best for orchards and large plants or shrubs and perforated or porous tubing works best for row crops such as vegetables or cotton.

Drip irrigation is ideal for use with a PV water supply system because of the high water use efficiency, low flow rates, and low pressure requirements. The main drawback of a drip irrigation system is that initial capital costs are high relative to other irrigation methods. This must be weighed against increases in yield and water use efficiency to ensure economic viability.

2.5 PHOTOVOLTAICS AND IRRIGATION IN INDIA

This section is intended to give the reader background to special issues relevant to India regarding photovoltaics and irrigation. The section begins by looking at energy generation and agriculture in rural areas of India. Having established the importance of remote irrigation systems for India, Sections 2.5.3 and 2.5.4 gives some background information on the solar industry in general and solar water pumping in particular. This is followed by Section 2.5.5 which discusses government incentives for PV irrigation systems. Sections 2.5.6 and 2.5.7 look at problems with current methods of irrigation used in India and how drip irrigation can help solve these problems. Section 2.5.8 discusses government incentives for the use of drip irrigation systems. Government incentives are important when considering financing since PV drip irrigation systems are inherently capital intensive.

2.5.1 Energy Generation in India

Energy is the fuel for economic growth and India, like most developing countries, places a high priority on expanding its power generating capacity. Since India began organized economic planning in 1950/51 power generation capacity has increased from just over 1,700 MW to over 55,000 MW at the end of the seventh Five Year Plan in 1990/91. Additional capacity planned for the eighth and ninth Five Year Plans (to the year 2000) is approximately 100,000 MW but uncertainties remain as to how these commitments will be met given the current financial and environmental constraints (Kumar and Varadarajan, 1993). Current studies estimate capacity shortfalls between 27% and 60% by the year 2021 (MacRae, 1995).

In 1991 the government of India opened the doors to private participation in the energy sector and has encouraged joint ventures with foreign companies in this area. This has raised concerns over unrestrained environmental emissions given India's current dependance on coal-based technologies. In 1992 the Canadian Energy Research Institute undertook a joint study with the Tata Energy Research Institute in India to examine the optimal mix of technologies (MacRae, 1995). Various energy generation scenarios were evaluated based on estimated capacity shortfalls, environmental emissions and total electric power systems cost. Large cost savings and reduced emissions resulted from the use of Integrated Resource Planning which recommended all supply and demand side options be considered on a least cost basis. This scenario allowed for 1,900 MW of energy from alternative sources by the year 2001 and 37,900 MW by the year 2021.

The need for alternative sources of energy is highest in rural areas. Approximately 74% of India's 884 million people live in rural areas (1991 census figures, World Resources Institute, 1994). The demand for energy in rural areas of India is expected to reach about 1,200 billion kWh by the year 2000 (Saha et al., 1988). Although India places a high priority on rural electrification, the government realises that long extensions of the electrical grid are not always economically justified. Rural energy needs are commonly met through gas or diesel powered generators but these fuels must be imported and the country is reluctant to become dependant on outside sources which are often unstable, a fact that was highlighted during the Gulf crisis of 1991 (Kumar and Varadarajan, 1993). A great deal of emphasis has therefore been placed on development of alternative energy supplies for rural areas. With its high insolation levels, India naturally views solar energy as having great potential for energy supply to its rural population.

2.5.2 Energy and Irrigation

Agriculture contributes approximately 50% of the gross national product in India (Singh et al., 1995) and the development of irrigation schemes is another high priority. Before organized economic planning began in 1950/51, the area under irrigation was estimated at 21 million hectares, by 1993/94 the area under irrigation was about 47.5 million hectares (World Resources Institute, 1994; FAOSTAT, 1995). This is less than one third of the total cropped area, but it produces approximately two thirds of the nations crop output (Dhawan, 1985).

In some rural areas 40 to 50% of the utility load is for irrigation pumping (Cabraal, 1993). Energy consumption in 1993/94 for irrigation and dewatering was estimated at 63,500 MkWh for pumps and state tube wells and 2,100 MkWh for lift irrigation schemes, approximately 21% of the total energy consumption of 307,000 MkWh for all of India. The number of pumpsets energized under the rural electrification program was expected to increase from approximately 5,700,000 in 1984/85 to over 11,200,000 in 1994/95 (Central Electricity Authority, 1991).

The government has placed a high priority on the electrification of rural pumpsets because of the importance of irrigation for increasing agricultural productivity, but the economics of these long power line extensions are often unfavourable. Electricity in India is currently priced at less than the marginal cost of generation and supply (MacRae, 1995). When the added cost of long power line extensions is taken into account the situation becomes even more unfavourable. Bhattacharjee (1984) estimated that it cost between 50,000 and 100,000 Rs/kW to energize an irrigation pump in a rural area. Costs increase with distance to the electric grid and ruggedness of the terrain.

Transmission and distribution losses are currently estimated at 23% overall in India (MacRae, 1995). Again, the situation is worse for long power line extensions. In addition, long lines through rural areas are frequently tapped by farmers to energize pumps and irrigate their fields illegally during the night (Cabraal, 1993). This practice is extremely dangerous for the farmer and represents an additional cost for the utility in supplying power to rural areas.

Under India's eighth Five Year Plan public sector outlays for irrigation were estimated at Rs. 325,000 million (1990/91 prices), of which Rs. 40,000 million was to go to pump set energization under the Rural Electrification Program. It is estimated an additional Rs. 400,000 million were spent in private investments on pumps. Total spending on minor irrigation pumping schemes thus outweighs spending on both medium and major gravity fed schemes. If the economics of using solar pumps for irrigation proves favourable, the potential market is enormous.

2.5.3 The Solar Industry

The solar industry in India officially started in 1976 with the formation of the public sectors undertaking Central Electronics Limited (CEL), followed closely by Bharat Heavy Electricals Limited (BHEL), and Rajastan Electronics and Instruments Limited (REIL). The government sponsored research and development through these organizations for products which were to be marketed commercially. Unfortunately in rural, unelectrified areas of India the only market sector that could afford solar power was the government itself and the industry stagnated.

The first major private sector demand for PV power came from the oil industry, looking for backup power for offshore oil rigs. As the industry expanded a number of

private sector firms started up though public sector firms still dominate. Some private sector companies, set up as joint ventures with Italian, US or UK firms, are dedicated entirely to export manufacture. Still others manufacture balance of systems components or focus on PV systems integration and sales. In 1993 there were approximately 20 companies in the PV business in India and the industry was expanding at a rate of 50% per annum compared to international rates of only 10-15% (Bhattacharya, 1993b) .

2.5.4 Solar Water Pumping

By December of 1985, 310 PV water pumping systems had been installed by CEL, most of which used 300 Wp arrays couple to brushed DC motors and centrifugal (monoblock) surface pumps. The pumps moved between 30 and 40 m^3 of water per day through heads of up to 5 m under typical Indian conditions. They were intended mainly for irrigation and water supply (CEL, 1986). By the late 1980s over 500 solar pumping systems had been installed in India, primarily by CEL, and India had more solar water pumping systems than in any other country in the world (Derrick et al., 1989). By the early 1990s the Department of Non-conventional Energy reported over 1200 PV water pumps had been installed (Chant and Kachru, 1994). In 1993, Bhattacharya estimated that about 1700 PV water pumps had been installed in India overall.

Many of the pumps installed for irrigation purposes had been improperly sized and poorly designed (Bhattacharya, 1993). This combined with the failure of the electronic control systems has given solar irrigation pumps a bad reputation. India had pushed forward with PV pumps before the technology had developed sufficiently, and this set the industry back overall by establishing a poor reputation.

One area where the PV irrigation systems did prove successful was in the state of Tripura in the north-east of India. Again, these pumps were direct connected, surface centrifugal pumps designed to lift water approximately 5 m from shallow wells. The success of the pumps was largely attributed to the high water table in the area. The pumps were installed in 1977 and when last reported on (Bhattacharjee, 1984) were still working well and playing an important role in increasing the standard of living of the community.

The Rajiv Gandhi National Drinking Water Mission (NDWM) began experimenting with solar water pumping for domestic water supply in rural areas in 1986. Most of these pumps are used in deep wells where the water table is 50 to 100 m below the surface, out of reach of a conventional hand pump. Out of 100 pumps installed under this program, 76 are still working satisfactorily, with most problems occurring in harsh desert and coastal areas (Deshpande, 1992).

2.5.5 Government Incentives for PV Irrigation Pumps

Problems with past installations of PV water pumping systems combined with high capital costs have set back the PV industry in spite of current advances in technology and higher long term benefit/cost ratios under certain conditions. Rural areas of India tend to be very poor and small farmers do not have the luxury of weighing long term costs and benefits. Securing capital is difficult and few farmers are willing to invest what capital they have in a new and unproven technology. The government has therefore created a number of incentives for the solar industry. The success of these ventures has secured international support, and the program is now rapidly expanding. The most notable federal initiatives in the irrigation sector have come from the Ministry of Non-conventional Energy Sources (MNES) and the Indian Renewable Energy Development Agency (IREDA).

2.5.5.1 *The Indian Renewable Energy Development Agency (IREDA)*

The Indian Renewable Development Agency (IREDA) is a public sector undertaking, born in 1987. Its main purpose is the development of the commercial markets for renewable energy through loans to private and public companies, cooperatives, trusts and societies for the purchase of equipment. The organization had a loan recovery rate of 88% in 1993 and profitability has been rising rapidly since 1990/91. In 1993 the organization finalized agreements with the World Bank to mobilise US$ 195 million towards development of commercial markets for wind energy, small hydro and photovoltaics under the "India Alternate Energy Project". This plan was to be financed with loans and grants from the International Development Agency (IDA), the Swiss Development Corporation (SDC), the Danish International Development Agency (DANIDA), and the Global Environment Trust Fund (GET). Total project cost was estimated at US$ 280 million with the outstanding balance to be covered by local sources. Through this project, the loans were to be made available to industry for large scale purchases and manufacturing to reduce the overall cost of renewable energy projects. Companies involved in this project were required to formalize agreements with financial institutions to pass savings on to individual end users through soft loans.

Under the program manufacturers were entitled to interest rates of 15.50% and end users to rates of 10.3%, both with a 0.5% rebate for timely payments. Loans to both parties were to be repaid over an eight year period following a two year moratorium. Loans were to be determined on a project to project basis with a ceiling of Rs 1.5 crores (15,000,000 Rs). At least 25% of the total project cost was to be covered by the loan recipient.

2.5.5.2 *The Ministry of Non-conventional Energy Sources (MNES)*

The initial market for the PV industry in India was generated by the Department of Non-conventional Energy Sources (DNES), which became a Ministry in its own right in 1993. The main focus of this ministry is on demonstration projects for renewable energy, most of which are heavily subsidized. These projects are designed to promote the technology by establishing a positive reputation and gathering performance data for local conditions. The MNES currently sponsors a number of demonstration projects, mainly in village electrification and solar lanterns.

In 1993 the MNES signed a memorandum of understanding with IREDA for the deployment of 50,000 solar PV powered water pumps to be installed over a 5 year period starting in 1994, with 1,000 pumps scheduled for the first year.

Under this program PV pumping systems were to be subsidized at 170 Rs/W_p, to a maximum of 170,000 Rs or 70% of the total system cost whichever was less. Two categories of pumping systems were considered in the ranges of 560-600 W_p and 840-900 W_p. Preference would be given to pumps located in clusters for ease of maintenance and training. The study tended to focus on areas where the water table was within 2 to 5 m of the ground surface. This is the result of previous World Bank studies which suggested irrigation pumps were only viable at low heads and the success of the low head surface pumps installed in Tripura (Raja, 1993).

The balance of costs were to be covered by soft loans managed by IREDA either directly or through a financial intermediary. Loans were made available to manufacturers at an interest rate of 10.3% per annum with a 0.5% rebate for timely repayment. These loans were designed to enable manufacturers to expand their capacity and improve facilities. Loans were also made available to end users at a rate of 5% per annum, to be

repaid in ten annual installments beginning at the end of the first year.

The farmer wishing to buy a pump for irrigation purposes, thus has a subsidy of up to 170,000 Rs. available through MNES, and an additional 80,000 Rs. soft loan available through IREDA. If the total system cost is below 250,000 Rs the farmer will not have to make any initial down payment (Suta, 1993).

2.5.6 Irrigation Methods

Different types of irrigation are practised in various regions of India. In south India irrigation is dominated by tanks and canals designed to protect the main season crop against drought. Irrigation in northern India is dominated by private tubewells. In the western regions, Gujarat and Rajastan, both dugwells and tubewells play a major role (Dhawan, 1985). Northern Indian farmers, especially in the Punjab region are notoriously successful in spite of semi-arid conditions. Here, private ownership of the pump gives the farmers complete control over the irrigation schedule and the use of a ground water source ensures year round water availability. This has unfortunately resulted in severe depletion of ground water resources. In the mid to late 1980s the ground water table in the area dropped 0.8 m per year (World Resources Institute, 1994).

Regardless of the water source, the method of water application used in India is almost exclusively surface irrigation. Flood and furrow irrigation are by far the most common methods used. Water application efficiency is generally low (below 50%) even for furrow irrigation. Precision land levelling and other measures used to increase the efficiency of furrow irrigation, are expensive and rare. Many of the major canal systems are unlined with high seepage losses. Farmers relying on canal irrigation schemes often over- irrigate their crops when water is available to them because they are not certain when

their next turn will come. Holsambre (1995) estimates many farmers are using almost 3 times the actual crop water requirements.

Improper irrigation techniques have caused a number of problems in India including a buildup of salinity in the soil matrix, waterlogging and depletion of the ground water table. Approximately 3 million hectares (6.3% of the total irrigated area) show a build up of salts in the soil surface. A 1991 study by the Soil Salinity Research Institute estimates the problem is even larger, affecting 8.5 million hectares (17.9%). Estimates of land area affected by waterlogging range between 1.6 and 8.5 million hectares (3.4 to 17.9%). As for ground water depletion, 620 of the 3,841 administrative blocks in India are either fully or over-exploiting their ground water resources. Salinity problems are most severe in Uttar Pradesh and Gujarat; waterlogging in Haryana, Punjab, West Bengal, Andhra Pradesh and Maharashtra; and ground water depletion in Punjab, Haryana, Gujarat and Tamil Nadu. (World Resources Institute, 1994)

2.5.7 Drip Irrigation in India

Drip irrigation was introduced in India on an experimental basis in the 1970s and 1980s, and was adopted by progressive farmers in Maharashtra, Andra Pradesh, Tamil Nadu, Karnataka and Kerala but it is only in the last 4 or 5 years that the systems have been adopted on a large scale (Sivanappan, 1995). In 1993/94 the total irrigated area in India was estimated at 47.5 million ha (World Resources Institute, 1994), the area under drip irrigation was estimated at 70,000 ha (Saskena, 1995; Sivanappan, 1995). The eighth Five Year Plan budgeted Rs 2,000 million to expand the total area under drip irrigation to 180,000 ha (Chauhan, 1995).

The use of drip irrigation systems is spreading most rapidly in the southern and western states. Maharashtra, in the west, is the largest state in India with a land area approximately one third the size of the country. Drought occurred three times in the last ten years in Maharashtra and many farmers adopted drip irrigation to cope. With encouragement from the central and state government, approximately 31,000 ha has been brought under drip irrigation since 1987 as shown in Table 2.4. The state has a planned target of 10,000 additional hectares a year (Magar, 1995).

Tamil Nadu is the southern most state in India. Ninety-five percent of all surface water resources and 75% of all ground water resources have already been harnessed in Tamil Nadu and the ground water tables is declining rapidly in many areas. Here 5,357 ha are under some form of micro irrigation, 0.25% of the total net irrigated area. The use of drip irrigation in Tamil Nadu is increasing, while sprinkler irrigation is on the decline (Somasundaram et al., 1995).

Drip irrigation addresses all problems associated with current methods of irrigation used in India. The efficient use of water eliminates waterlogging problems and conserves precious ground water resources. Salts do not build up in the direct vicinity of the plant root (though they do build up at the perimeter of the wetted area) and saline water can be used without damage to crops. Drip irrigation also helps satisfy at least two of the main goals of India's irrigation program in that water is conserved during times of drought and arid land can be brought into productivity. As with PV water pumping the main drawback to the use of drip irrigation systems is the capital cost.

Year	No. of Farmers	Total Area (ha)	Average Farm Size (ha)	Expenditure (1,000 Rs)
State Scheme				
86/87	354	431	1.22	2,364
87/88	2,161	1,504	0.70	14,036
88/89	3,172	3,396	1.07	25,640
88/90	5,567	4,953	0.89	44,375
90/91	7,044	6,346	0.90	55,197
91/92	7,481	6,508	0.87	61,381
92/93	4,045	3,298	0.82	32,175
Central Scheme				
91/92	1,012	871	0.86	9,270
92/93	5,060	3,693	0.73	37,980
Total	35,896	30,999	0.86	282,418

Table 2.4 Area under Drip Irrigation in Maharashtra
(Magar, 1995)

2.5.8 Government Initiatives in Drip Irrigation

Subsidies for drip irrigation systems have been offered by different agencies in different parts of India since the mid 1980s. The percentage capital cost covered by the subsidy varies, though it normally ranges between 50% and 75%. The central government offers subsidies through the Ministry of Agriculture (Magar, 1995) and the Ministry of Water Resources (Chauhan, 1995) these programs are administered by different agencies in various states. Loans for the remainder of the cost are advanced through the nationalized banks under a refinancing scheme organized by the National Bank of Agriculture and Development (NABARD). The loans are offered at a rate of interest of 10% per annum (Saskena, 1995) or 12% per annum (Ravi Babu et al., 1995).

Subsidies up to 50% are available in Maharashtra (Khanha, 1993). Here, both the state and central governments have provided subsidies under various schemes since 1986. At this time, inadequate production of cereals and pulses resulted in a shortage of

food grain and the state responded with a massive campaign for the diversification of agricultural land. Through the Employment Guarantee Scheme's (EGS's) watershed development program subsidies were made available for the conversion of land under traditional crops to horticultural crops. After 1991 subsidies were offered through the central government scheme (Magar, 1995).

The situation is similar in Tamil Nadu, where subsidies have been available through various state and central government programs since 1985. At present there are 3 or 4 agencies administering the subsidies, including the Agricultural Engineering Department of Tamil Nadu University. Under this scheme 50% of the system cost is covered up to 500 US$ per hectare per farmer. The dealer must provide a two year performance guarantee, a five year guarantee against manufacturing defects, a supply of spares throughout the life of the systems and a security deposit of Rs 1,000. They must also provide a dealer network and after sales service and training at the district level (Somasundaram, 1995).

Capital subsidies of up to 50% are also known to be available in Haryana (Khanha, 1993), Rajastan (Singh et al., 1995), and Andra Pradesh (Cabraal, 1993). Recommendations have been made to offer a uniform 50% subsidy all over India (Khanha, 1993).

2.6 SUMMARY

The current study focuses on the use of privately owned photovoltaic (PV) water pumping systems for irrigation by the drip method. This chapter provided a detailed background to the study. The first section of this chapter discussed the solar resource and how this variable power supply affects the system design. The second section discussed the components of a PV water pumping system in detail. The third section discussed the relative advantages and disadvantages of various remote water pumping options. The fourth section discussed methods of irrigation and their compatibility with a PV pumping system. The suitability of drip irrigation for use with PV water pumps was highlighted.

The final section of this chapter discussed the situation in India with respect to PV water pumping and drip irrigation. PV irrigation systems are particularly well suited to conditions in India because they eliminate the need for long extensions of power lines to rural areas. Using drip irrigation conserves ground water resources, eliminates waterlogging and topsoil erosion problems, and allows the use of saline water.

The main drawback of a PV drip irrigation system is the expense. Methods of financing available to local Indian farmers were discussed in the final section of this chapter. Determining the economic and financial viability of a PV drip irrigation system is the main focus of the following study.

CHAPTER 3

PHOTOVOLTAIC DRIP IRRIGATION FOR INDIA: ECONOMICS AND SIZING

The economic viability of a solar irrigation system depends on the amount of sunlight available, the water pumping requirements, the total head, the relative cost of other water pumping options, the resulting crop yield, and the expected returns. The water pumping requirements depend on the local reference crop evapotranspiration rates, the type of crop, the amount of water that can be expected from other sources (such as rainfall), the method of irrigation, and the size of the farms to be irrigated. Local reference evapotranspiration rates depend mainly on climatic variables: wind, relative humidity, temperature, and solar radiation levels. Economic viability is determined in two stages. First, a comparative evaluation of various remote water pumping systems is done to determine the least cost option. This evaluation is done over the life of the system and includes all recurring costs for maintenance and operation. Second, the net benefits of the irrigation system are measured in terms of increased agricultural production over the life of the system.

This chapter begins with a brief look at other studies on the economic viability of photovoltaics (PV) for irrigation, pointing out any changes that have occurred since the studies were conducted and showing how these studies have guided the current work.

Sections 3.2 to 3.7 look at meteorologic, geologic, hydrogeologic and geographic

data for India. This information is used to determine the amount of energy available to power a PV system, the water pumping requirements, and the suitability of various crops to different areas. Section 3.2 looks at solar insolation levels in India. The amount of energy available to power the system strongly influences the overall economics for any PV application. In Section 3.3 reference crop evapotranspiration levels are calculated for a number of stations across India. This data is used to determine water pumping requirements. In Section 3.4 the dependable levels of water available from other sources (such as rainfall) are calculated. Sections 3.5 and 3.6 look briefly at the soils and hydrogeology of India. Section 3.7 looks at typical farm sizes.

Once background data for India is established the study moves on to a comparative evaluation of different remote water pumping options. Section 3.8 discusses sizing of various remote pumping systems. Section 3.9 compares life cycle costs for different remote water pumping systems using North American data. Life cycle costs include the initial capital investment as well as recurring costs for maintenance and operation. This data is used to determine the range of economic viability for a PV pump. Section 3.10 compares North American costs to those in India where data is available.

Section 3.11 discusses different crops grown in India and the suitability of these crops to irrigation with a PV drip system. In Section 3.12 a sample crop is chosen for study. Crop evapotranspiration rates and irrigation water requirements are calculated for different areas of India. Net economic benefits for a PV drip system are then calculated and compared to net benefits from surface irrigation with a diesel pump. The economic study is intended as a comparison of real long term costs for both technologies. A financial study is also included. This study considers all available subsidies and loans and looks at both long term and yearly costs and benefits accruing directly to the end user. PV systems are inherently capital intensive and long term economics are irrelevant to the farmer if money is not available to purchase the system in the first place.

3.1 THE ECONOMICS OF PHOTOVOLTAIC (PV) IRRIGATION: LEARNING FROM PAST STUDIES

The first major economic comparison study looking specifically at PV water supply for irrigation was completed by Sir William Halcrow and Partners in 1983. The results are reviewed in detail in Appendix A. The study compared the cost of irrigating a 2 ha farm with 6 mm/day of water via solar (PV), wind, diesel, kerosene, animal, or human powered pumps. PV systems using both drip and furrow irrigation were considered. The study considered long term costs over a 30 year period, taking into account recurring costs for fuel, maintenance and parts replacement.

Figure 3.1 shows the variation in unit water costs with static lift for all pumping

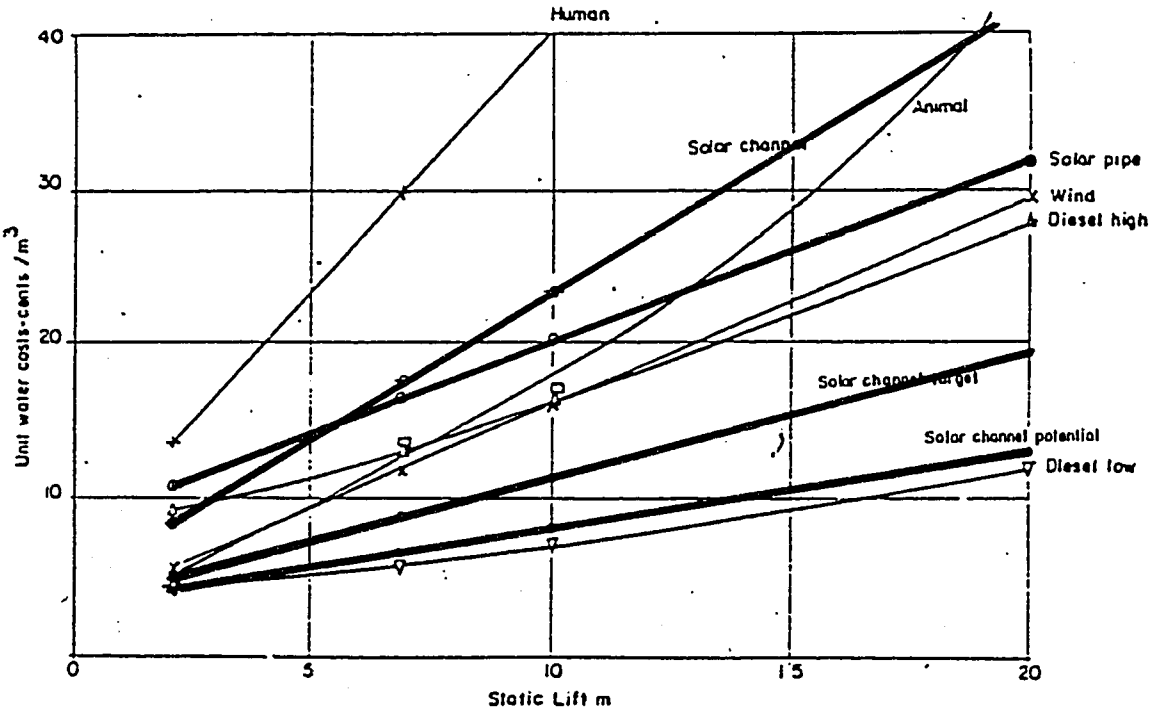


Figure 3.1 Unit Water Cost vs. Static lift for Various Pumping Systems (2 ha Farm) (Sir William Halcrow and Partners, 1983)

options, except kerosene pumps. Kerosene pumps were eliminated early in the study because of high maintenance costs and short life expectancies. These pumps last about 2 years under continuous operation and must therefore be replaced approximately 15 times over a 30 year period. Where labourers had to be paid to work the pumps, the economics of hand pump irrigation were unacceptable for labour costs over 0.50 $US/day. Animal powered pumps were considered reasonably cost effective at low lifts, though the cost of irrigating with both hand pumps and animal powered pumps increased rapidly with static lift. Two cases were considered for diesel pumps. The low case representing the best that could be expected under good conditions in developing countries if the engines were well maintained and properly tuned. The high case representing standard, realistic performance of small engine pumps under typical field conditions in developing countries. Low case diesel was found to be the least cost option over the full range of heads studied, though wind, PV, and animal powered systems were more cost effective than high case diesel at low heads.

The cost of irrigating with PV power at then current prices (1983) are shown in red for both furrow and drip irrigation. PV drip irrigation systems were reasonably comparable to wind and high case diesel over the entire range of heads. At low heads, PV systems using furrow irrigation with lined distribution channels were less expensive than drip systems. At higher heads, pumping costs increased significantly, along with need to increase system efficiency via drip irrigation. The cross-over point between solar irrigation with piped distribution and solar irrigation via furrows and lined channels occurred at approximately 6 m. Above this point drip irrigation was found to be the least expensive option, below this point furrow irrigation was less expensive.

A sensitivity analysis showed that the major variables influencing the unit cost of water for a PV system were farm size, insolation levels, static head, annual variation in water demand, subsystem efficiency, field application efficiency, capital costs and the

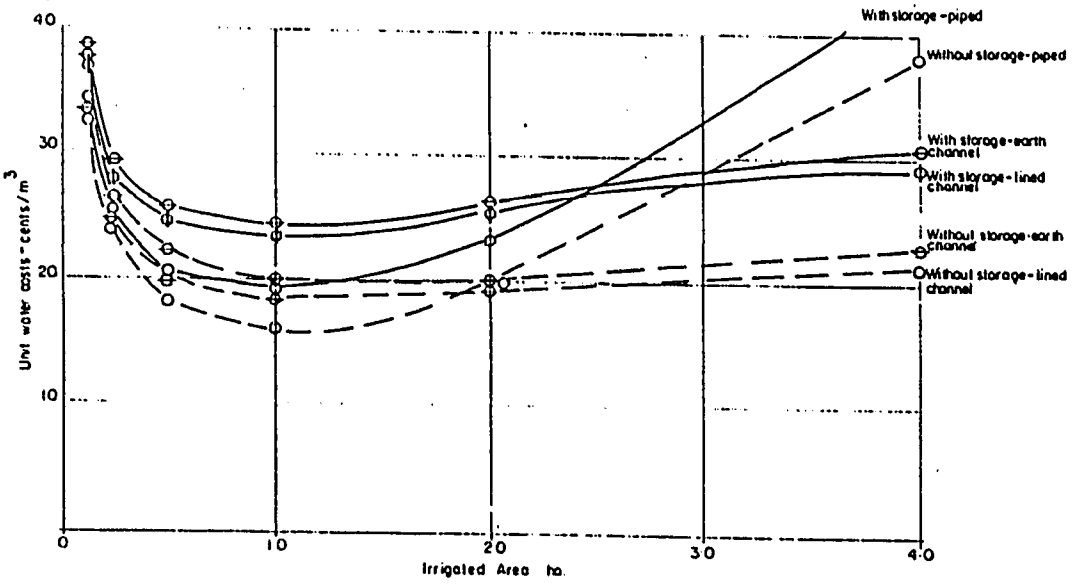


Figure 3.2 Unit Water Cost vs. Farm Size for PV Pumping Systems with a 7m Static Lift (Sir William Halcrow and Partners, 1983)

discount rate used . Figure 3.2 shows the variation in unit water costs with farms size for PV systems with a 7 m static lift. The least expensive systems used piped water distribution without storage for farms between 0.5 and 2 ha. The effect of other variables is discussed in more detail in Appendix A. Decreases in insolation levels had a major effect on overall system costs. Undersizing the pipe diameter in a drip system also had a significant effect on cost. The comparative viability of a solar system against other remote pumping options was dependant on average wind speed, the cost of diesel, the cost of labour for hand pumping and the assumed discount rate.

The study assumed that water must be delivered to the crop at 10 cents/m^3 (1983 US$) for overall economic viability. This was considered a reasonable estimate for most crops. Referring back to Figure 3.1, this criteria was satisfied for most 2 ha systems at low static lifts. For lifts over 6 m only low case diesel met this criteria. For lifts over 18 m none of the systems met this criteria implying that irrigation costs must be subsidized beyond this point. From Figure 3.2 the lowest unit water cost for PV systems with a 7 m static lift is

approximately 16 cents/m^3 (1983 US$) for farms just over 1 ha in size using piped distribution.

At the time this study was done capital costs for PV systems were expected to decrease significantly. Costs had already dropped from 30 US$/$W_p$ in 1975 to 10 US$/$W_p$ in 1983 and further increases in production and technology breakthroughs were thought to be just over the horizon. Estimated future costs for PV systems using furrow irrigation are shown in blue on Figure 3.1. The target case (expected in 1987) assumes an array cost of 5 US$/$W_p$. The potential case (expected somewhere between 1993 and 1998) assumes an array cost of 2 US$/$W_p$. Pump and balance of systems component costs were also expected to decrease. As the cost of the solar pumping systems dropped, the need to maintain high irrigation efficiencies through piped distribution also dropped. With reduced pricing, furrow irrigation was sufficient over the range of lifts studied. Target case solar systems (1987) with furrow irrigation and lined channels were expected to provide water for under 10 cents/m^3 to lifts of 9 m, and would be cheaper than all other systems with the exception of low case diesel. Potential case solar systems (1993 to 1998) with furrow irrigation and lined channels were found to be competitive with low case diesel over the whole range of lifts studied and could deliver water for less than 10 cents/m^3 at heads up to 14 m.

With the days of the "potential case" now upon us, it has become timely to review this study and see if the results are as predicted. Since 1983 sales volumes for solar products have increased, module efficiencies have increased slightly, and pump designs have been refined. In spite of these advances, the expected price drops have not materialized. Current module prices in 1995 run about 7.4 to 8.5 US$/$W_p$ retail and 5.2 to 6.0 US$/$W_p$ for high volume sales. "Target case" prices have not been achieved, much less "potential case" prices.

Since hoped for price reductions have not materialized, the goal of replacing diesel irrigation pumps with PV pumps seems far off. That being said, the benefits of PV irrigation systems in terms of the environment and reduced dependance on fossil fuels cannot be ignored. Instead, of trying to replace diesel pumps in general, it seems more appropriate to identify a specific niche for PV irrigation, concentrating on crops with low irrigation water requirements and high returns. This effectively raises the 10 cent/m^3 criteria for economic viability.

In addition, because hoped for price reductions have not materialized, the benefits of increased water use efficiency with drip irrigation systems should not be ignored. In the 1983 case study drip irrigation became less expensive than channel irrigation at heads over 6 m. The study assumed an application efficiency of 0.5 for surface methods and 0.85 for drip methods. Assumed water savings were due only to the increased application efficiency of drip systems. Reductions in the crop evapotranspiration rate for widely spaced crops were not considered. Doorenbos and Pruitt (1977) state that reductions in crop evapotranspiration rates up to 60% have been observed for widely spaced crops under high evaporation conditions on light, sandy soils. In addition to decreased water requirements a number of studies of drip irrigation in India have shown increased yields, and therefore increased economic benefits. These yield increases and waters savings should be taken into account.

Appendix B contains a full review of literature on the use of photovoltaics for irrigation. Recent studies of PV irrigation systems in developed countries have indeed focused almost entirely on water and labour saving drip irrigation methods. Unfortunately this research trend has not been followed in less developed countries. Taking their lead from recommendations made in the original World Bank study, studies in less developed countries have focused almost exclusively on the use of PV pumps for low head channel irrigation, often with disappointing results.

Using World Bank funding Pakistan (on the north-west border of India) evaluated 37 PV pumps for irrigation in the late 1980s. The results of the Pakistan assessment are illustrated in Figure 3.3. At 1989 prices PV systems were more economical than diesel systems only for farms under 0.6 ha. If module prices dropped to 52 Rs/W_p the systems would still be economical for only for farm sizes up to 0.85 ha. Current module prices in India are approximately 200 Rs/W_p (differences between the Indian and Pakistan rupee are insignificant). Though initially enthusiastic about the systems, the Pakistan study concluded that the technology was too expensive and even with the proposed World Bank subsidy farmers would not be convinced to buy a PV system.

One of the biggest problems with the marketability of PV pumps was the low flow rate. Farmers tended to discuss irrigation pumps in terms of peak flow rates. Peak flow rates from a PV pump are typically much lower than those from a standard diesel or electric irrigation pump since PV pumps are designed to deliver a low flow over the entire

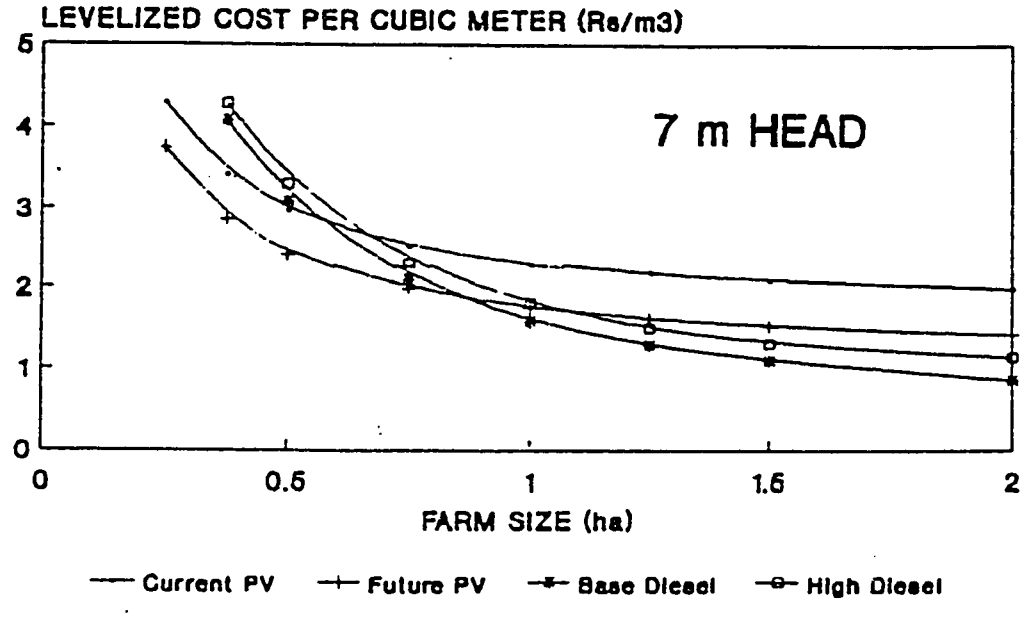


Figure 3.3 Unit Water Costs vs. Farm Size for PV and Diesel Irrigation Systems (Pakistan Rs.) (World Bank, 1989)

day. Farmers recognized immediately that with a solar pump they have to work significantly longer hours to irrigate the same area. Researchers realized that changes in farming practices would be needed before PV pumps could be used effectively (World Bank, 1989).

Countries like India have a large potential market for the use of PV pumps in irrigation. Their is a heavy emphasis on agriculture generally and irrigated agriculture in particular. Access to electricity is low, solar insolation levels are high and farm sizes are typically very small. It is important that PV pumps are promoted in combination with the appropriate irrigation technology or India, like Pakistan, will find these new pumping systems generally unsuitable.

3.2 INSOLATION DATA

The one universal data requirement for sizing any type of photovoltaic system is the amount of available solar radiation. Variations in the solar resource and their subsequent effect on photovoltaic system sizing were discussed briefly in the study background. The derivation of global solar radiation on a horizontal surface is discussed in detail in Section 3.2.1 Section 3.2.2 discusses tilt factors which are applied to the data to give global solar radiation on an optimally tilted array surface.

3.2.1 Global Solar Radiation on a Horizontal Surface, G

Sizing a photovoltaic system requires an estimate of global solar radiation on the tilted array surface (G_s) available to power the system. G_s is found by multiplying the global solar radiation on a horizontal surface (G) by a tilt factor for the area. Total global solar

radiation on a horizontal surface (G) is made up of 3 components: direct (G_I), diffuse (G_D) and reflected (G_R) radiation. The relative proportions of G_I, G_D and G_R must be known in order to calculate the tilt factor and thus the required quantity, G_s. Direct and diffuse radiation comprise 95% of the total global solar radiation, and are thus the most important variables.

Unfortunately, G is not measured at a large number of stations across India but must be inferred from measurements of sunshine hours, n, from a Campbell-stokes sunshine recorder. In the "Handbook of Solar Radiation for India", Mani and Rangarajan (1982) developed a regression relationship between G and the ratio of actual sunshine hours to maximum possible sunshine hours, n/N. The relationship was calculated based on a regression of data from a widely distributed network of 16 stations where G and n were measured over periods varying between 8 and 21 years.

Maximum possible sunshine hours, N, is dependant on the month and station latitude. The regression relationship used a modified version of N, N', which assumes that the Campbell-stokes recorder is burned only when the sun rises above 5° on the horizon. N' is calculated according to Equation 3.1 below, where ϕ is the station latitude and δ the mean declination for the month.

$$N' = \frac{\arccos\left(\frac{\cos 85 - \sin\phi \sin\delta}{\cos\phi \cos\delta}\right)}{7.5} \qquad (3.1)$$

A modified version of G, G', is also used. G' is the global solar radiation which first strikes the ground before undergoing multiple reflections with the cloud free atmosphere and the cloud base. The relationship between G and G' is given in Equation 3.2 below. The albedo (fraction of incident radiation reflected by a surface) of the cloud free atmosphere is assumed to be approximately 0.25, and that of the cloud base 0.60. The

albedo of the ground surface, λ, is assumed to be approximately 0.20. Average values of λ for India range from 0.15 to 0.25.

$$G-G'=G\lambda[0.25\frac{n}{N'}+0.60(1-\frac{n}{N'})] \quad \textbf{(3.2)}$$

The regression relationship between G' and n/N' is given by Equation 3.3.

$$\frac{G'}{R_{ET}}=a+b(\frac{n}{N'}) \quad \textbf{(3.3)}$$

where R_{ET} is the daily sum of extraterrestrial solar radiation on a horizontal surface and a and b are regression parameters. Appendix C lists the correlation coefficients for the regression for all 16 stations.

In their subsequent volume "Solar Radiation over India", Mani and Rangarajan estimated global solar radiation on a horizontal surface for 145 station across India based on measured values of n and the previously determined parameters a and b. Where gaps in the data existed n was estimated from total cloud cover in fractions of the sky (D) using the following regression relationship.

$$(1-\frac{n}{N'})=0.310D+0.476D^2+0.100D^3 \quad \textbf{(3.4)}$$

Appendix D lists the monthly averages of the daily sum of global solar radiation on a horizontal surface (G) in kWh/m^2 for all 145 stations. The stations are listed in alphabetical order with latitude, longitude and elevation. Also included are maps showing the distribution of global radiation (G) over India for different months.

3.2.2 Tilt Factors

Global solar radiation on a horizontal surface is multiplied by a tilt factor to obtain global solar radiation on a solar array angled towards the sun, G_s. Tilt factors are dependant on the ratios of direct (G_I), diffuse (G_D) and reflected (G_R) radiation, and vary with station latitude, elevation and the angle of inclination of the array surface. G_I, G_D and G_R (direct, diffuse and reflected radiation on a horizontal surface) must be estimated separately and converted to G_{IS}, G_{DS} and G_{RS} (direct, diffuse and reflected radiation on a tilted surface) though separate equations. These individual components are then added together to give G_s the global solar radiation on a titled surface. The tilt factor is then set equal to G_s/G.

Appendix E lists tilt factors for all 145 stations for arrays angled at latitude, latitude + 15° (winter tilt angle), and latitude - 15° (summer tilt angle). It is assumed that the arrays used will have 3 manual tilt settings, and will be adjusted seasonally as required. The final table in Appendix E lists the optimal tilt factor for each month, chosen from 1 of the previous 3 tables.

Appendix F lists the solar radiation for each station on array tilted at the optimal angle. This was calculated by multiplying global solar radiation on a horizontal surface from Appendix D with the optimal tilt factor listed in the final table of Appendix E. Table 3.1 lists solar radiation on an optimally tilted array (G_s) for the 42 stations where reference crop evapotranspiration was evaluated.

St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Mean Daily Radiation on an Optimally Tilted Surface (kWh/m2) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	6.78	7.07	6.92	6.92	6.76	5.98	5.31	5.18	5.99	6.98	7.30	6.81
2	4	Ahmadabad	23.1	72.6	55	7.46	7.64	6.80	7.04	7.30	6.39	4.92	4.67	5.69	7.14	7.59	7.52
3	5	Akola	20.7	77.0	282	7.75	7.67	6.89	6.96	6.93	5.91	4.51	4.58	5.11	6.51	7.22	7.23
4	7	Allahabad	25.5	81.7	98	6.76	7.28	6.72	6.99	7.06	5.87	5.24	5.04	5.75	6.89	7.30	7.00
5	8	Amini Divi	11.1	72.7	4	6.10	6.40	6.40	6.04	5.03	3.97	3.82	4.27	4.95	4.87	5.39	5.60
6	9	Amritsar	31.6	74.9	234	5.93	6.39	6.22	6.82	7.23	6.77	6.34	6.31	6.36	6.90	6.86	6.04
7	14	Bangalor	13.0	77.6	897	6.85	7.10	6.73	6.57	6.11	4.95	4.22	4.61	4.89	5.24	5.92	6.19
8	21	Bhopal	23.3	77.4	503	7.58	7.68	6.91	6.98	7.17	5.96	4.46	4.23	5.29	7.01	7.67	7.25
9	24	Bikaner	28.0	73.3	224	7.31	7.46	7.34	7.64	7.88	7.74	7.00	6.83	7.33	7.75	7.49	7.20
10	26	Bombay	19.1	72.9	14	7.12	7.17	6.75	6.81	6.84	5.44	4.36	4.45	5.10	6.45	7.14	7.13
11	26	Bombay	19.1	72.9	14	7.12	7.17	6.75	6.81	6.84	5.44	4.36	4.45	5.10	6.45	7.14	7.13
12	27	Calcutta	22.7	88.5	6	6.15	6.36	6.03	6.27	6.10	4.78	4.65	4.60	4.68	5.36	6.13	6.09
13	27	Calcutta	22.7	88.5	6	6.15	6.36	6.03	6.27	6.10	4.78	4.65	4.60	4.68	5.36	6.13	6.09
14	34	Cuttack	20.5	85.9	24	7.25	7.22	6.59	6.55	6.79	5.17	4.59	4.82	5.00	5.98	6.97	7.24
15	36	Dharwar	15.4	75.1	679	7.39	7.35	6.82	6.42	6.11	4.73	3.89	4.33	4.86	5.61	6.52	7.04
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	5.20	5.00	5.37	4.83	4.99	4.49	4.69	5.22	4.59	5.38	5.96	5.72
17	39	Gannavaram	16.5	80.8	24	7.09	7.27	6.47	6.65	6.52	5.07	4.83	5.09	5.16	5.76	6.36	6.42
18	40	Gauhati	26.1	91.6	54	6.04	6.46	5.90	6.00	5.81	4.75	4.88	5.07	4.99	5.93	6.51	6.31
19	41	Goa	15.5	73.8	55	7.36	7.53	6.84	6.90	6.73	4.94	4.51	4.93	5.42	6.24	7.21	7.25
20	56	Hyderabad	17.5	78.5	545	7.43	7.60	6.79	6.85	6.86	5.54	4.72	5.08	5.30	6.27	6.90	7.03
21	59	Indore	22.7	75.8	567	7.56	7.68	6.99	7.17	7.35	5.99	4.56	4.25	5.30	7.03	7.60	7.30
22	61	Jagadalpur	19.1	82.0	553	7.20	7.26	7.06	6.82	6.44	5.28	4.26	4.31	4.73	5.85	6.64	6.98
23	62	Jaipur	26.8	75.8	390	7.33	7.58	6.98	7.07	7.00	6.08	5.18	5.19	6.31	7.52	7.96	7.58
24	69	Jodhpur	26.3	73.0	224	7.43	7.69	6.93	7.23	7.37	6.90	6.06	6.05	6.61	7.50	7.85	7.58
25	76	Kodaikanal	10.2	77.5	2345	7.30	7.59	7.10	6.64	6.14	5.14	4.53	5.00	5.13	5.03	5.44	6.23
26	79	Kota	25.2	75.5	257	7.69	7.90	7.16	7.24	7.46	6.72	5.40	5.15	6.16	7.30	7.73	7.71
27	86	Madras	13.0	80.2	16	6.67	7.23	6.79	6.72	6.38	5.58	5.09	5.28	5.41	5.50	5.67	5.84
28	89	Minicoy	8.3	73.0	2	6.38	6.50	5.98	5.71	5.11	4.28	4.26	4.94	4.89	5.20	5.73	5.62
29	92	Nagpur	21.2	79.1	311	7.28	7.42	6.67	6.69	6.75	5.40	4.29	4.30	5.01	6.53	7.33	7.22
30	97	New Dehli	28.6	77.2	216	6.46	6.95	6.33	6.63	6.48	5.59	5.44	5.53	5.91	6.96	7.35	6.64
31	99	Okha	22.5	69.1	7	7.25	7.43	6.72	6.79	6.81	5.74	4.82	4.84	6.04	7.08	7.42	6.57
32	100	Ollukara	10.5	76.3	22	7.04	6.99	6.60	6.19	5.30	4.43	4.01	4.34	4.85	5.28	6.01	6.17
33	105	Patna	25.5	85.3	52	6.68	6.96	6.62	6.77	7.06	6.05	5.45	5.53	5.61	6.43	7.01	6.74
34	107	Port Blair	11.7	92.7	79	5.93	6.44	6.02	5.80	4.27	3.50	3.51	3.58	3.69	4.47	5.28	5.61
35	108	Pune	18.5	73.9	563	7.34	7.50	6.92	6.92	6.92	5.68	4.53	4.68	5.25	6.27	7.01	7.09
36	123	Shillong	25.6	91.9	1598	5.24	6.18	5.87	5.75	5.45	4.17	4.10	4.14	4.31	4.94	5.18	5.24
37	124	Silicuri	24.8	92.9	40	6.31	6.33	6.22	6.07	5.67	4.81	4.94	5.02	5.12	5.50	6.15	6.27
38	127	Srinagar	34.1	74.8	1587	3.28	4.23	4.81	5.55	6.26	6.56	6.37	6.26	6.13	6.23	5.82	4.03
39	134	Trivandrum	8.5	77.0	64	7.24	7.28	6.82	6.30	5.90	5.15	5.16	5.70	5.85	5.74	6.02	6.60
40	135	Tuticorin	8.8	78.2	4	7.28	7.43	6.94	6.90	6.59	6.24	6.21	6.43	6.23	6.32	6.46	6.25
41	142	Veraval	20.9	70.4	8	7.45	7.63	7.38	6.90	7.16	6.31	4.93	4.89	6.13	7.06	7.44	7.43
42	144	Vishakhapatnam	17.7	83.2	3	7.26	7.45	6.55	6.62	6.56	4.99	4.55	5.12	5.23	6.02	6.73	6.94

Table 3.1 Average Monthly Solar Radiation on an Array Tilted at the Optimal Angle (G_s)

3.3 REFERENCE CROP EVAPOTRANSPIRATION (ET_o)

Irrigation water pumping requirements are calculated from crop evapotranspiration rates (ET_{crop}), which are in turn calculated from reference crop evapotranspiration rates (ET_o). The crop evapotranspiration rate (ET_{crop}) is equal to the crop coefficient (kc) multiplied by the reference crop evapotranspiration rate (ET_o). Where direct field measurements of ET_o are not available, the modified Penman equation is considered the most accurate method available for estimating it. The modified Penman equation uses monthly averages of mean daily climatic data on temperature, wind, humidity, and sunshine to calculate ET_o.

The modified Penman equation is given by Equation 3.5 below, taken from the "Food and Agriculture Organization of the United Nations (FAO) Irrigation and Drainage Paper No. 24" (Doorenbos and Pruitt, 1977). Monthly values of reference crop evapotranspiration were calculated for 42 stations across India where all data requirements were available.

$$ET_o = c[W \cdot R_n + (1-W) \cdot F(u) \cdot (ea - ed)] \qquad (3.5)$$

where ET_o = reference crop evapotranspiration (mm/day)

c = adjustment factor

W = temperature related weighting factor

R_n = net radiation in equivalent evapotranspiration (mm/day)

F(u) = wind related function

ea = saturation vapour pressure at mean air temperature (mbar)

ed = actual mean vapour pressure of the air (mbar)

The calculation of reference crop evapotranspiration rates by the Penman method requires data on solar radiation, temperature, relative humidity and winds. Sources of

climatic data used in the evaluation of the Penman equation are discussed in Section 3.3.1. Calculation of the individual components of the equation are discussed separately in Sections 3.3.2 to 3.3.5. The results are evaluated in Section 3.3.6.

3.3.1 Data Sources and Stations

Data for evaluation of the Penman equation was obtained from 3 different sources: "Solar Radiation Over India" (Mani and Rangarajan, 1982), "Wind Energy Data for India" (Mani and Mooley, 1983), and the World WeatherDisk™ (WeatherDisc Associates Inc., 1990). The first 2 sources are Government of India publications prepared by the Commission for Additional Sources of Energy. The third source is based on data from the National Climatic Data Center in Asheville, North Carolina, and the National Center for Atmospheric Research in Boulder, Colorado.

"Solar Radiation Over India" contains average monthly radiation data and some climatic data for 145 stations across India. Actual sunshine hours (n) were obtained from this source, along with relative humidity data and maximum and minimum temperatures. "Wind Energy Data for India" contains monthly wind data for 354 stations across India. The World WeatherDisk™ contains monthly temperature and precipitation data for 55 stations.

Station latitude, longitude and elevation from each source were entered into a spreadsheet and sorted by latitude and longitude in order to identify corresponding or close stations. Exact matches on latitude, longitude and elevation were found for 19 stations. Stations were considered reasonably close if latitude and longitude were within 0.5° and elevation was within 100 m. An additional 23 stations were identified using this criteria. Table 3.2 lists latitude, longitude and elevation for all 42 stations. Where discrepancies

ST# Eto	ST# Sun	ST# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Solar Data	Rel. Humid.	Wind Data	Temp. Data	Precip. Data
1	3		Agra	27.2	78.1	169	•	•			
		3	Agra Airport	27.2	78.0	169			•	•	•
2	4	5	Ahmadabad Airport	23.1	72.6	55	•	•	•	•	•
3	5		Akola	20.7	77.0	282	•	•		•	•
		9	Akola Airport	20.7	77.1	309			•		
4	7	13	Allahabad Airport	25.5	81.7	98	•	•	•	•	•
5	8	19	Amini Divi	11.1	72.7	4	•	•	•	•	•
6	9	21	Amritsar	31.6	74.9	234	•	•	•	•	•
7	14	37	Bangalore Airport	13.0	77.6	897	•	•	•		
			Bangalore	13.0	77.6	921				•	•
8	21		Bhopal	23.3	77.4	503	•	•			
		59	Bhopal Airport	23.3	77.4	523			•		
			Sagar	23.9	78.8	551				•	•
9	24	64	Bikaner	28.0	73.3	224	•	•	•	•	•
10	26		Bombay	19.1	72.9	14	•	•			
		69	Bombay-Colaba	18.9	72.8	11			•	•	•
11	26	70	Bombay-Santacruz	19.1	72.9	14	•	•	•	•	•
12	27		Calcutta	22.7	88.5	6	•	•			
		75	Calcutta-Alipore	22.5	88.3	6			•	•	•
13	27	76	Calcutta-Dum Dum	22.7	88.5	6	•	•	•	•	•
14	34		Cuttack	20.5	85.9	24	•	•			
		97	Cuttack	20.5	85.9	27			•	•	•
15	36		Dharwar	15.4	75.1	679	•				
	36		Dharwar (Gadag)	15.4	75.6	650		•			
		48	Belgaum Airport	15.9	74.6	747			•	•	•
16	38	112	Dibrugarh Airport (Mohanbari)	27.5	95.0	111	•	•	•	•	•
17	39	126	Gannavaram Airport	16.5	80.8	24	•	•	•		
			Masulipatam	16.2	81.1	3				•	•
18	40	127	Gauhati Airport	26.1	91.6	54	•	•	•	•	•
19	41		Goa	15.5	73.8	55	•	•			
		131	Goa-Panjim	15.5	73.8	60			•		
			Goa/Panjim	15.5	73.8	57				•	•
20	56	153	Hyderabad-Begampet	17.5	78.5	545	•	•	•	•	•
21	59	156	Indore Airpot	22.7	75.8	567	•	•	•	•	•
22	61	158	Jagadalpur	19.1	82.0	553	•	•	•	•	•
23	62	159	Jaipur Airport	26.8	75.8	390	•	•	•	•	•
24	69		Jodhpur	26.3	73.0	224	•	•			
		172	Jodhpur	26.3	73.0	217			•		
25	76		Kodaikanal	10.2	77.5	2345	•	•			
		194	Kodaikanal	10.2	77.5	2343			•	•	•
26	79		Kota	25.2	75.5	257	•	•			
		200	Kota Airport	25.2	75.9	274			•		
			Kota	25.2	75.9	257				•	•
27	86	209	Madras - Minambakkam	13.0	80.2	16	•	•	•	•	•
28	89	231	Minicoy	8.3	73.0	2	•	•	•	•	•
29	92		Nagpur	21.2	79.1	311	•	•			
		239	Nagpur Airport (Sonegaon)	21.1	79.1	310			•	•	•
30	97	250	New Dehli-Safanjung	28.6	77.2	216	•	•	•	•	•
31	99	256	Okha	22.5	69.1	7	•	•	•		
			Dwarka	22.4	69.1	11				•	•
32	100		Ollukara	10.5	76.3	22	•				
	100		Ollukara (Cochin)	9.9	76.2	3		•			
		122	Fort Cochin	10.0	76.2	3			•	•	•
33	105		Patna	25.5	85.3	52	•	•			
		271	Patna Airport	25.6	85.1	60			•		
			Patna	25.6	85.2	53				•	•
34	107	278	Port Blair	11.7	92.7	79	•	•	•	•	•
35	108		Pune	18.5	73.9	563	•	•			
		281	Pune Airport	18.6	73.9	593			•		
			Poona	18.5	73.9	559				•	•
36	123		Shillong	25.6	91.9	1598	•	•			
		314	Shillong	25.6	91.9	1600			•		
			Shillong	25.6	91.9	1500				•	•
37	124		Silicuri	24.8	92.9	40	•				
	124	320	Silicuri Airport (Khumbigram)	24.9	93.0	97		•	•		
			Silchar	24.8	92.8	29				•	•
38	127		Srinagar	34.1	74.8	1587	•	•		•	•
		325	Srinagar Airport	34.0	74.8	1666			•		
39	134		Trivandrum	8.5	77.0	64	•	•		•	•
		340	Trivandrum Airport	8.5	77.0	8			•		
40	135	342	Tuticorin	8.8	78.2	4	•	•	•		
			Panam	9.3	79.3	11				•	•
41	142	352	Veraval	20.9	70.4	8	•	•	•	•	•
42	144	353	Vishakhapatnam	17.7	83.2	3	•	•	•	•	•

Table 3.2 Stations Used for Calculation of Reference Crop Evapotranspiration

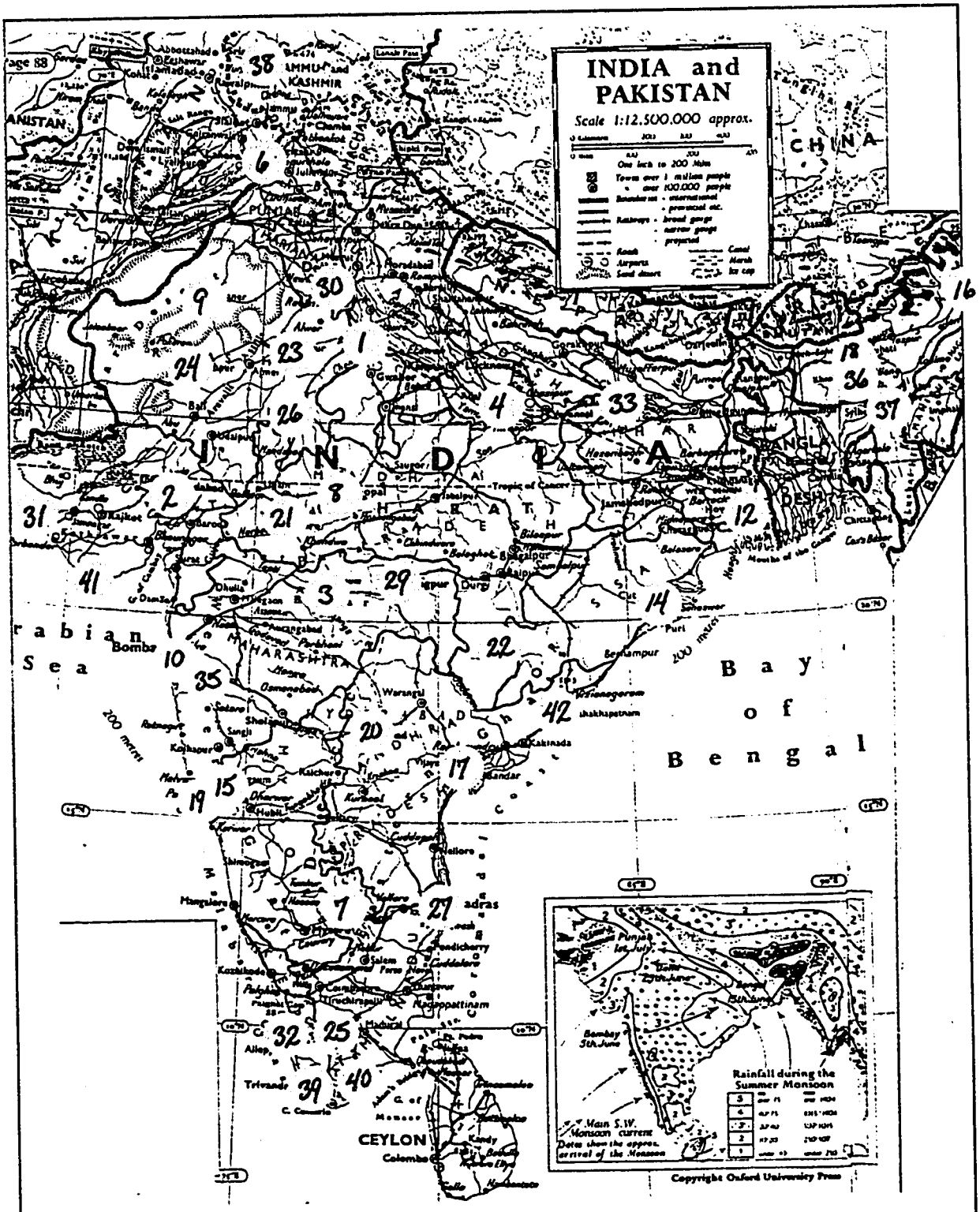


Figure 3.4 Stations used for Calculation of Reference Crop Evapotranspiration

existed between stations latitude, longitude and elevation are listed for each source. The type of data obtained at each station is marked by an asterisk in the final columns. The Table also lists the corresponding station numbers used in the texts "Solar Radiation over India" and "Wind Energy Data for India". Figure 3.4 shows the station locations on a map of India.

Mean monthly wind and climatic data listed in "Solar Radiation Over India" and "Wind Energy Data for India" are averaged over the 10 year period from 1958 to 1967 except for a very few stations where gaps in the data existed. The World WeatherDisk™ contained data dating back to the 1700's for some locations. To ensure consistency with solar and wind data, temperature data from the World WeatherDisk™ was averaged over the same 10 year period from 1958 to 1967. This data was analysed using a simple Fortran program listed in Appendix G.

3.3.2 Saturation Vapour Pressure Deficit (ea-ed)

The saturation vapour pressure deficit (ea-ed) is equal to the mean saturation vapour pressure (ea) minus the actual vapour pressure (ed). Referring back to the Penman equation (Equation 3.5), the reference crop evapotranspiration (ET_o) increases as the saturation vapour pressure deficit increases.

Tables used for the calculation of saturation vapour pressure deficit (ea-ed) are listed in Appendix H. Tables are listed in reverse working order, with the desired result (ea-ed) at the front. Each table is therefore calculated from the tables which follow it. All calculations are performed 504 times, once for each month for 42 stations.

The mean saturation vapour pressure (ea) is calculated based on the mean

temperature (T) for the month. The mean temperature was determined using data from the World WeatherDisk™ and the computer program listed in Appendix G. The resulting mean temperature data is listed on the final page of Appendix H. The mean saturation vapour pressure was interpolated from the "Saturation Vapour Pressure (ea) Table" (Doorenbos and Pruitt, 1977) included in Appendix H.

The actual vapour pressure (ed) was calculated by the formula below, where RH is the average relative humidity for the month.

$$ed = ea\frac{RH}{100} \qquad (3.6)$$

Average relative humidity (RH) for each month and each station is included in Appendix H. This data was calculated from 24 hour data for 35 stations and from data measured 2 to 6 times daily for the remaining 9 stations. This data was obtained from "Solar Radiation Over India" (Mani and Rangarajan, 1982).

3.3.3 Net Radiation (R_n)

Reference crop evapotranspiration (ET_o) increases as total net radiation (R_n) increases (see Equation 3.5). Total net radiation (R_n) was calculated using the method outlined in Doorenbos and Pruitt (1977). Tables used for the calculation of R_n are listed in reverse working order in Appendix J.

The calculation of R_n begins with estimation of extra terrestrial radiation (R_a). R_a is dependant on the month and latitude. It is similar to R_{ET} used in the calculation of global solar radiation on a tilted surface, but for the purposes of the modified Penman equation R_a is given in equivalent evaporation or mm/day. R_a was obtained by linear interpolation

of data from the "Extraterrestrial Radiation (R_a) Table" (Doorenbos and Pruitt, 1977).

Shortwave radiation (R_{sw}) is dependant on R_a and the ratio of actual sunshine duration (n) to maximum possible sunshine duration (N). Actual sunshine duration was obtained from the text "Solar Radiation Over India" (Mani and Rangarajan, 1982). N was obtained by linear interpolation of data from the Maximum Possible Sunshine Duration Table (Doorenbos and Pruitt, 1977). R_{sw} was calculated according Equation 3.7 from Doorenbos and Pruitt (1977).

$$R_{sw}=(0.25+0.50\frac{n}{N})R_a \qquad \textbf{(3.7)}$$

Net shortwave radiation (R_{ns}) is related to R_n by Equation 3.8 below, where λ_{crop} is the reflectiveness of the crop surface, assumed to be 0.25 as recommended by Doorenbos and Pruitt (1977) for most crops.

$$R_{ns}=(1-\lambda_{crop})R_{sw} \qquad \textbf{(3.8)}$$

Net longwave radiation (R_{nl}) is a function of temperature (T) vapour pressure (ed) and the ratio n/N. R_{nl} is given by Equation 3.9.

$$R_{nl}=f(T)f(ed)f(\frac{n}{N}) \qquad \textbf{(3.9)}$$

f(T) was found by linear interpolation from the "Temperature Function (f(T)) Table" (Doorenbos and Pruitt, 1977). f(ed) and f(n/N) were calculated by Equations 3.10 and 3.11.

$$f(ed)=0.34-0.44\sqrt{ed} \qquad \textbf{(3.10)}$$

$$f(\frac{n}{N})=0.1+0.9\frac{n}{N} \tag{3.11}$$

Total net radiation (R_n) is equal to the difference between net shortwave radiation, and net longwave radiation.

$$R_n=R_{ns}-R_{nl} \tag{3.12}$$

3.3.4 Wind Function (F(u))

The wind function, F(u), is given by Equation 3.13 below, where u is the mean daily wind run in km/day corrected to a 2 m height. The wind function (F(u)) increases as the mean daily wind run (u) increases, and reference crop evapotranspiration (ET_o) increases as F(u) increases (see Equation 3.5). The table on the first page of Appendix K, lists monthly values of F(u) for 42 stations across India.

$$F(u)=0.27(1+\frac{u}{100}) \tag{3.13}$$

Mean daily wind speeds in km/hr were obtained from the text "Wind Energy Data for India" (Mani and Mooley, 1983). Wind speed is measured with either a rotating cup anemometer or pressure tube anemometer. Measuring devices are typically located 10 m above the ground on flat, open terrain. Where this is impossible the measuring devices are installed at heights which represent as closely as possible what the wind at 10 m height would be with no obstructions. Wind data and anemometer height are listed on the final page of Appendix K. All wind data is averaged over the 10 year period from 1958 to 1967, except for the following stations: Agra (1960-1969), Amini Divi (1963-1969), Goa-Panjim (1964-1969), Jaipur (1960-1969), Kanniyakumari (1961-1967), and Okha (1963-1969).

The modified Penman equation requires average 24 hour wind runs at a 2 m height. Correction factors must be applied to data measured at other heights. Correction factors (CF) were obtained from Doorenbos and Pruitt (1977) for anemometer heights (h) up to 6 m. This data was extrapolated using a regression on the logs of h and CF. For values of h less than 6 m, CF was interpolated from the table in Doorenbos and Pruitt. For h over 6 m, CF was calculated based on the regression analysis. A graph of correction factors used for heights up to 18 m is attached in Appendix K, along with a table showing the regression parameters and original and calculated values of CF. Monthly averages of mean daily wind run in km/day corrected to a 2 m height (u) are listed on the second page of Appendix K.

3.3.5 Weighting Factor (W)

Tables used for calculation of the weighting factor for temperature related effects (W) are attached in Appendix L. W is determined using the monthly average of the median daily temperature and the station elevation. W increases as temperature and elevation increase. Referring back to Equation 3.5, increases in W magnify the effect of total net radiation (R_n) on reference crop evapotranspiration (ET_o) and decrease the effect of wind (F(u)) and saturation vapour pressure deficit (ea-ed).

W is interpolated from the "Weighting Factor (W) Table" (Doorenbos and Pruitt, 1977). Minimum and maximum temperatures were obtained from hourly measurements listed in "Solar Radiation Over India" (Mani and Rangarajan, 1982). The median temperature is the middle value between the minimum and maximum temperatures.

$$T_{med} = \frac{(T_{min} + T_{max})}{2} \qquad (3.14)$$

3.3.6 Adjustment Factor (c)

The Penman equation assumes medium to high radiation and maximum humidity levels, moderate daytime winds, and a 2:1 ratio of daytime to night time winds. If these conditions are not met an adjustment factor (c) is applied. The adjustment factor for each month was interpolated from the "Adjustment Factor (c) Table" (Doorenbos and Pruitt, 1977) based on the average daytime windspeed (u_{day}), the maximum relative humidity (RH_{max}), the average level of shortwave radiation (R_{sw}), and the ratio of day time to night time winds (U_{day}/U_{night}). The adjustment factor (c) generally increases with increases in u_{day}, RH_{max}, R_{sw} and U_{day}/U_{night}. Referring back to the modified Penman equation (Equation 3.5), reference crop evapotranspiration (ET_o) increases in direct proportion to increases in c. Tables used for calculation of the adjustment factor (c) are attached in Appendix M.

Average day time wind speeds in km/hr for the period 8:30 to 17:30 were obtained from the text "Wind Energy Data for India" (Mani and Mooley, 1983). Day time winds (u_{day}) were corrected to 2 m height (as discussed in the previous sub-section) and converted to m/s. Average night time wind speeds (u_{night}) for the period 17:30 to 8:30 were calculated from the corrected mean daily wind speed (u) in m/s (calculated in Section 3.3.5) and the corrected day time wind speeds (u_{day}) in m/s using Equation 3.15 below.

$$u_{night} = \frac{24u - 9u_{day}}{15} \qquad (3.15)$$

Average day time winds were not available for Stations 1 (Agra), 7 (Bangalore) 23 (Jaipur), 35 (Pune), and 38 (Srinagar). For these stations day time wind (u_{day}) was averaged from measurements taken at 8:30, 11:30, and 17:30 for Stations 3, 7, 35, and 38; and 8:30, 11:30, 14:30 and 17:30 for Station 23. Night time wind (u_{night}) was averaged from measurements taken at 23:30 and 5:30 for Stations 1, 7, and 38; 23:30, 2:30, and

5:30 for Station 35; and 20:30, 23:30, 2:30, and 5:30 for Station 23.

Maximum relative humidity (RH_{max}) for each month was obtained from the text "Solar Radiation Over India" (Mani and Rangarajan, 1982). Maximum relative humidity was picked from data measured 24 times daily at 35 stations and 2 to 6 times daily for the remaining 9 stations. This data was included in Appendix H. Shortwave radiation (R_{sw}) was calculated in Section 3.3.3 from tables in Appendix J.

3.3.7 Comparison of Calculated Base Crop Evapotranspiration to Other Sources

Table 3.3 lists average monthly values of reference crop evapotranspiration (ET_o) calculated by the Penman method (Equation 3.5) for 42 stations across India. To ensure that calculated values of ET_o were reasonable they were compared to values estimated from the map in Figure 3.5. Table 3.4 compares calculated values of annual reference crop evapotranspiration to annual reference crop evapotranspiration estimated from the map in Figure 3.5. Annual reference crop evapotranspiration is the sum of monthly averages of daily evapotranspiration rates times the number of days in the month. The comparison is done for 14 stations across India. Differences range from 2 to 30%, with an average of approximately 14%. This was considered acceptable due to the very general nature of the comparison.

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Reference Crop Evapotranspiration, ETo (mm/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	2.87	4.34	6.02	7.73	8.64	8.67	6.21	5.00	5.55	4.98	3.51	2.55
2	4	Ahmadabad	23.1	72.6	55	4.42	5.49	6.60	7.97	9.29	7.71	4.87	4.27	5.06	5.73	4.78	4.13
3	5	Akola	20.7	77.0	282	4.97	5.97	6.72	8.18	9.58	8.09	4.70	4.40	4.91	5.65	5.03	4.17
4	7	Allahabad	25.5	81.7	98	2.86	4.32	6.12	7.62	8.39	7.70	5.36	4.54	5.10	4.83	3.56	2.64
5	8	Amini Divi	11.1	72.7	4	5.26	6.08	6.86	6.85	6.07	4.71	4.50	4.72	5.54	4.94	4.75	4.70
6	9	Amritsar	31.6	74.9	234	1.90	3.02	4.55	6.86	8.63	8.67	6.69	5.82	5.31	4.42	2.82	1.88
7	14	Bangalor	13.0	77.6	897	4.84	5.77	6.77	7.01	6.62	4.91	4.17	4.39	4.30	4.23	4.04	3.99
8	21	Bhopal	23.3	77.4	503	4.04	5.59	6.87	8.30	10.56	8.86	4.59	3.80	4.80	5.68	4.55	3.59
9	24	Bikaner	28.0	73.3	224	2.66	3.95	5.79	7.73	9.55	10.70	8.49	7.24	6.99	5.60	3.56	2.60
10	26	Bombay	19.1	72.9	14	4.91	5.71	6.57	7.10	7.31	5.26	3.67	3.69	4.32	5.33	5.18	4.65
11	26	Bombay	19.1	72.9	14	4.95	5.84	6.92	7.85	8.10	5.54	3.82	3.76	4.39	5.41	5.23	4.67
12	27	Calcutta	22.7	88.5	6	3.36	4.53	6.20	7.10	7.16	4.78	4.31	4.15	4.04	4.21	3.76	3.12
13	27	Calcutta	22.7	88.5	6	3.41	4.55	5.90	7.15	7.26	4.84	4.40	4.17	4.09	4.23	3.83	3.17
14	34	Cuttack	20.5	85.9	24	3.76	4.91	6.14	6.96	7.66	5.42	4.08	4.17	4.28	4.46	4.01	3.47
15	36	Dharwar	15.4	75.1	679	5.24	5.57	6.38	6.62	6.57	4.74	3.46	3.78	4.20	4.62	4.92	4.55
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	2.22	2.88	4.19	4.21	4.40	4.08	4.19	4.45	3.77	3.61	2.83	2.20
17	39	Gannavaram	16.5	80.8	24	4.87	6.13	6.81	7.47	8.40	6.80	5.32	5.31	5.01	5.02	4.85	4.38
18	40	Gauhati	26.1	91.6	54	2.64	3.62	4.98	5.60	5.42	4.45	4.60	4.60	4.25	4.14	3.12	2.44
19	41	Goa	15.5	73.8	55	5.36	6.14	6.74	7.28	7.25	4.53	3.78	4.25	4.54	5.18	5.65	5.04
20	56	Hyderabad	17.5	78.5	545	4.93	6.37	7.25	8.20	9.32	7.66	5.40	5.22	5.03	5.42	4.81	4.47
21	59	Indore	22.7	75.8	567	4.16	5.43	6.98	8.71	11.20	9.07	4.84	3.96	5.24	5.76	4.49	3.86
22	61	Jagadalpur	19.1	82.0	553	3.96	5.36	6.48	7.16	7.33	5.38	3.72	3.63	3.98	4.55	4.16	3.63
23	62	Jaipur	26.8	75.8	390	3.20	4.30	5.83	7.23	8.31	8.03	5.41	4.64	5.52	5.24	3.82	3.08
24	69	Jodhpur	26.3	73.0	224	3.74	4.80	6.33	7.93	10.14	10.04	7.04	6.07	6.49	5.89	4.60	3.60
25	76	Kodaikanal	10.2	77.5	2345	3.70	4.50	5.00	4.52	3.95	3.34	2.80	3.07	3.13	2.84	2.80	3.12
26	79	Kota	25.2	75.5	257	3.62	5.08	6.38	8.74	10.44	9.80	6.23	4.90	5.69	5.75	4.46	3.45
27	86	Madras	13.0	80.2	16	5.02	6.19	7.06	7.57	7.66	7.00	5.98	5.72	5.58	4.92	4.40	4.16
28	89	Minicoy	8.3	73.0	2	5.33	5.86	6.17	6.20	5.69	4.70	4.69	5.30	5.23	5.12	5.01	4.62
29	92	Nagpur	21.2	79.1	311	4.27	5.83	6.99	8.23	9.93	7.59	4.67	4.15	4.75	5.49	4.66	3.88
30	97	New Dehli	28.6	77.2	216	2.73	4.40	5.89	7.86	8.79	8.57	6.08	5.20	5.46	4.99	3.68	2.64
31	99	Okha	22.5	69.1	7	4.90	5.31	6.07	6.52	7.47	6.15	4.76	4.46	5.57	5.31	5.33	4.76
32	100	Ollukara	10.5	76.3	22	5.43	6.08	6.61	6.11	4.78	3.58	3.18	3.50	4.03	4.27	4.65	4.60
33	105	Patna	25.5	85.3	52	3.23	4.49	6.28	8.34	8.91	7.33	5.44	5.04	5.01	4.77	3.90	2.94
34	107	Port Blair	11.7	92.7	79	4.96	5.77	6.23	6.31	4.68	3.96	3.86	3.91	3.85	4.31	4.53	4.59
35	108	Pune	18.5	73.9	563	5.02	6.25	7.79	9.00	9.67	6.92	4.32	4.31	4.86	5.71	5.03	4.40
36	123	Shillong	25.6	91.9	1598	2.03	2.84	3.99	4.79	4.61	3.41	3.37	3.25	3.08	2.90	2.25	1.89
37	124	Silicuri	24.8	92.9	40	3.21	4.06	5.40	5.64	5.28	4.26	4.40	4.31	4.27	3.98	3.43	2.93
38	127	Srinagar	34.1	74.8	1587	0.88	1.37	2.37	3.50	4.81	5.93	5.80	5.20	4.18	2.80	1.52	0.88
39	134	Trivandrum	8.5	77.0	64	5.13	5.75	6.03	5.43	5.00	3.79	3.81	4.53	4.79	4.27	4.12	4.44
40	135	Tuticorin	8.8	78.2	4	5.76	6.62	6.94	7.18	7.11	7.35	7.50	7.52	7.26	6.00	5.19	4.94
41	142	Veraval	20.9	70.4	8	5.22	6.08	6.77	7.03	7.30	6.60	4.43	4.25	5.54	6.03	5.59	5.11
42	144	Vishakhapatnam	17.7	83.2	3	5.36	6.94	7.27	8.11	8.32	6.09	5.03	5.45	5.04	5.29	5.26	4.78

Table 3.3 Reference Crop Evapotranspiration (ETo) calculated using the Penman Method

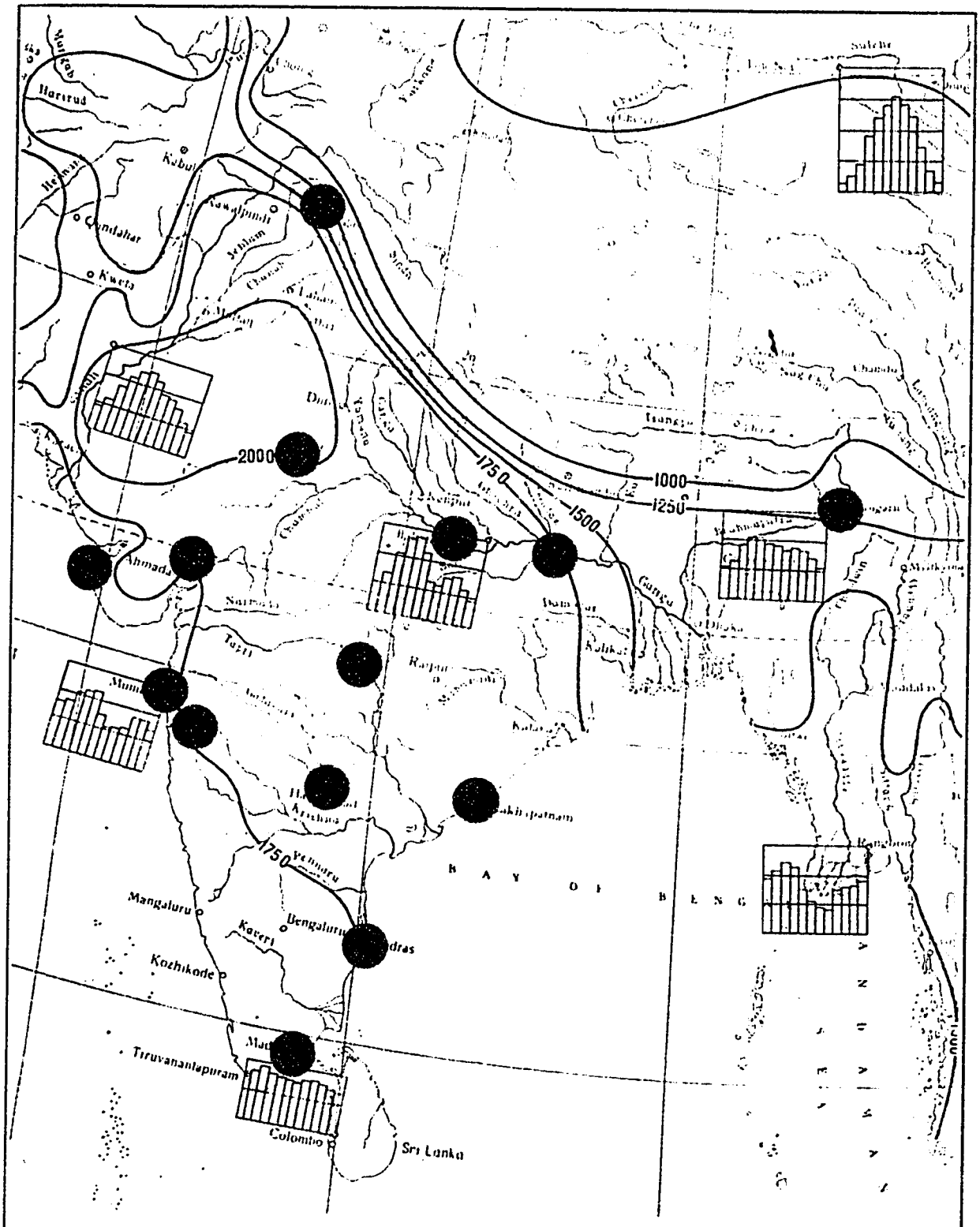


Figure 3.5 Annual Evapotranspiration Levels for India (mm)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Annual ETo (mm/yr) Calculated	Estimated from Map	Percent Difference
2	4	Ahmadabad	23.1	72.6	55	2138	1760	17.7
4	7	Allahabad	25.5	81.7	98	1918	1800	6.2
10	26	Bombay	19.1	72.9	14	1936	1740	10.1
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	1310	1200	8.4
20	56	Hyderabad	17.5	78.5	545	2251	1800	20.1
23	62	Jaipur	26.8	75.8	390	1965	2010	-2.3
27	86	Madras	13.0	80.2	16	2166	1750	19.2
29	92	Nagpur	21.2	79.1	311	2141	1850	13.6
31	99	Okha	22.5	69.1	7	2026	1700	16.1
33	105	Patna	25.5	85.3	52	1998	1750	12.4
35	108	Pune	18.5	73.9	563	2228	1760	21.0
38	127	Srinagar	34.1	74.8	1587	1197	1260	-5.2
40	135	Tuticorin	8.8	78.2	4	2414	1700	29.6
42	144	Vishakhapatnam	17.7	83.2	3	2216	1800	18.8

Table 3.4 Verification of Calculated Values of Reference Crop Evapotranspiration

The map in Figure 3.5 also shows graphs of the monthly distribution of evapotranspiration as a percentage of total evapotranspiration for Stations 4 (Allahabad), 10 (Bombay), 16 (Dibrugarh) and 40 (Tuticorin). Figure 3.6 compares these graphs with similar graphs showing the monthly distribution of ET_o calculated using the Penman method. The monthly distribution is similar in all four cases. This was taken as further confirmation of the validity of calculated values of reference crop evapotranspiration (Et_o).

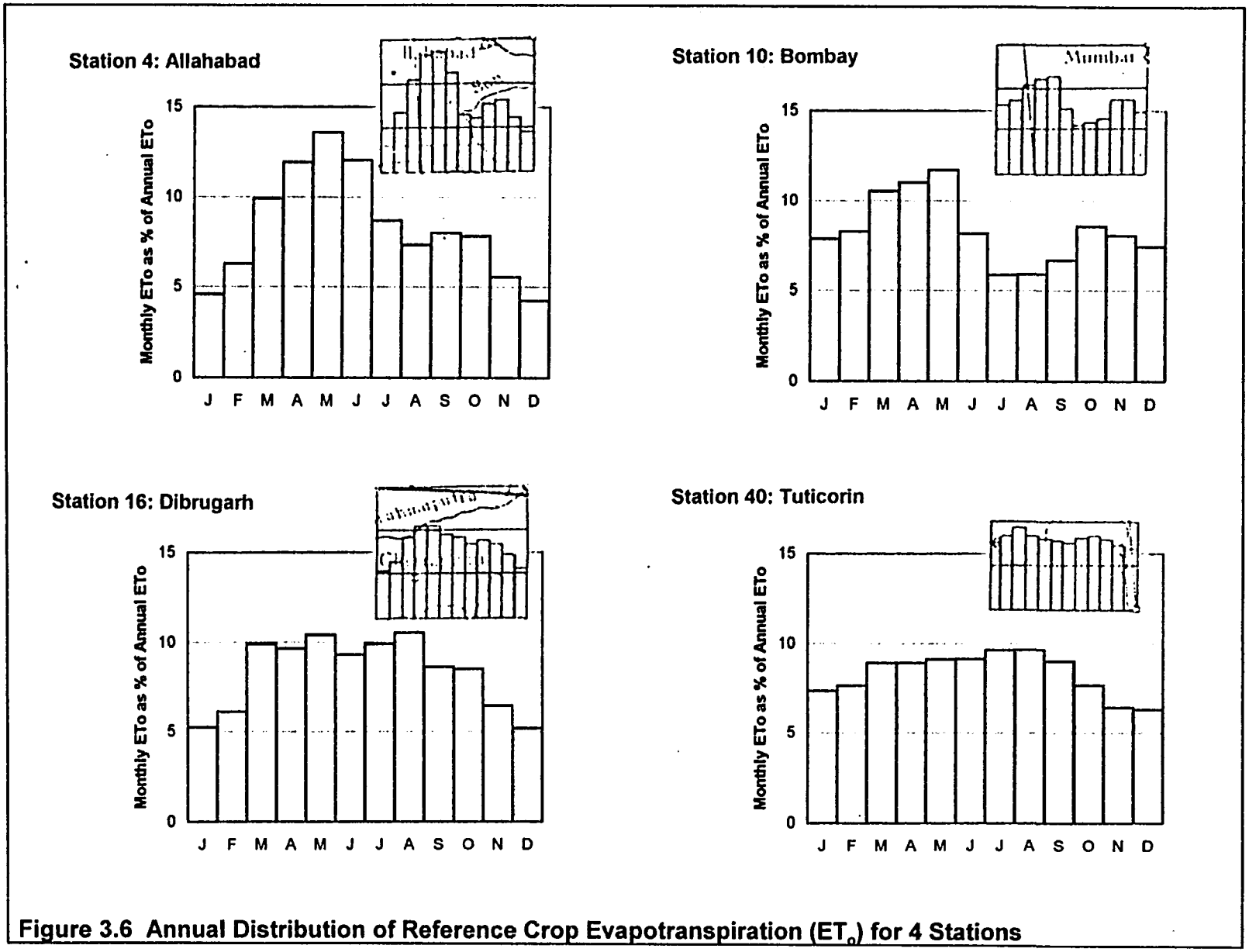


Figure 3.6 Annual Distribution of Reference Crop Evapotranspiration (ET_o) for 4 Stations

3.4 WATER CONTRIBUTIONS FROM OTHER SOURCES

The net irrigation requirement for any crop is equal to the crop water requirement minus water contributions from other sources. The most significant source of water is rainfall. Section 3.4.1 discusses the calculation of effective rainfall for various regions. Section 3.4.2 discusses potential water contributions from ground water, dew, and snowfall.

3.4.1 Effective Precipitation

Rainfall data for all stations was obtained from the World WeatherDisk™ (1990). Only three of the 42 stations had less than 20 years of data: Stations 11 (Bombay/ Santa Cruz), 13 (Calcutta/Dum Dum) and 15 (Begaum/ Samra). In all three cases nearby stations had data going back over 100 years. Station 19 (Goa/Panjim) had between 22 and 24 years of data for each month. All other stations had at least 63 years of data. Half of the 42 stations considered had a data series of over 100 years. Summary statistics for each station can be found in Appendix N.

When sizing an irrigation system only dependable levels of rainfall should be considered. Doorenbos and Pruitt (1977) recommend using rainfall with a return period of 3 out of 4 years or 4 out of 5 years, ie. rainfall with a 75% or 80% probability of exceedance. For this study effective rainfall was considered to be that with an 80% probability of exceedance.

Four methods of estimating rainfall with an 80% probability of exceedance were tested on five stations chosen randomly to represent various climatic regions of India. The five stations chosen were Srinagar in the northern mountainous region, Agra in the central

region, Bikaner in the west-central region, Madras on the south-east coast, and Panam on the southern most tip. Two months were chosen from each station for detailed examination, one each from the wet and dry seasons. The number of data points for each case ranged between 87 and 175. The four methods used to determine rainfall with an 80% probability of exceedance are described below.

1) For the first method rainfall with an 80% probability of exceedance was assumed equal to the twentieth percentile (k) of the data, ie. 20% of the data points were below k and 80% were above k. If k was not a multiple of $1/(N_m-1)$, where N_m is the number of data points in the rainfall data series, k was interpolated. This method was considered to be relatively accurate for large data sets.

2) In the second, third and fourth methods an attempt was made to fit the data to a probability density function. Method 2 followed that described by Doorenbos and Pruitt (1977). Data was sorted in descending order and ranked. The rank number (m) was set to 1 for the highest value. The plotting position (M) was set equal to $100m/(N_m+1)$. M versus rainfall are plotted on log-normal probability paper and fitted with a straight line. Rainfall with an 80% probability of exceedance was then picked from the graph. Figure 3.7 shows a sample plot for October in Srinagar. For periods with little or no rainfall M was adjusted to M_p given by Equation 3.16, where p is the fraction of the data series with zero rainfall. For example, Bikaner in December has a rainfall record of 103 years, 57 of which have zero rainfall, p is therefore 0.553.

$$M_p = p + (1-p)M \qquad (3.16)$$

The method described by Doorenbos and Pruitt (1977) assumes the rainfall data is normally distributed. Where rainfall data showed a poor fit to a straight line, the square root or log of the rainfall data was plotted. A better fit was obtainec by

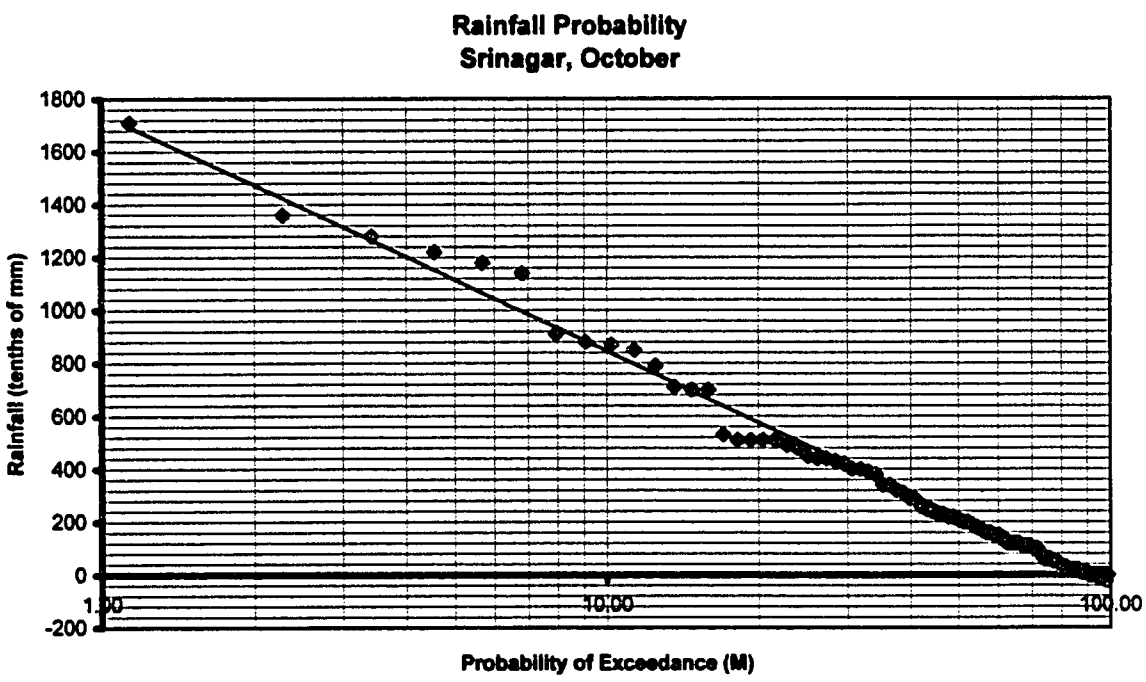


Figure 3.7 Log-Normal Probability Plot for Srinagar (October)

plotting the square root of the rainfall data for Bikaner (December) and Madras (April). Appendix P contains data and log normal plots for the five tests stations.

3) Since the method described by Doorenbos and Pruitt (1977) generally assumes data is normally distributed, an attempt was made in Method 3 to verify this hypothesis. First, rainfall data was divided into approximately 20 class intervals and a frequency histogram plotted for each station. The frequency histogram was used for comparison with a normal probability density function having the same mean (μ) and standard deviation (σ) as the data. The equation for the normal probability density function is given below (Scheaffer and McClave,1986).

$$f_n(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(x-\mu)^2/2\sigma^2} \qquad (3.17)$$

where $f_n(x)$ is the probability of occurance in any given year of a rainfall event x. Note that x can be both negative and positive for the normal probability density function, while a rainfall event must be zero or higher. The cumulative normal distribution function is defined by Equation 3.18 (Scheaffer and McClave,1986).

$$F_n(X) = \int_{-\infty}^{X} f(x)dx \qquad \textbf{(3.18)}$$

where $F_n(X)$ is the probability of a random rainfall event being less than or equal to event X. When $F_n(X)$ is equal to 0.2, there is a 20% chance of a random rainfall event being less than or equal to event X, or an 80% chance of it exceeding event X. Appendix Q contains rainfall frequency histograms with superimposed normal probability density functions and cumulative normal probability distribution functions for all five test stations. In some test cases X at $F_n(X)=0.2$ was less than zero and X (the rainfall event with an 80% probability of exceedance) was therefore assumed to be zero. Figure 3.8 shows a sample frequency histogram of actual rainfall data and a normal probability density function fitted to the data for Panam (May). Figure 3.9 shows the cumulative probability distribution function for the same station and month.

4) Method 4 is similar to Method 3 in that the data was fitted to a probability density function, in this case the gamma probability density function. This function is given by Equation 3.19 (Scheaffer and McClave, 1986) for all values of x greater than 0, where α and β are parameters that determine the shape of the curve.

$$f_g(x) = \frac{1}{\Gamma(\alpha)\beta^{\alpha}} x^{\alpha-1} e^{-x/\beta} \qquad \textbf{(3.19)}$$

When α equals 1, the function reduces to the exponential. Both α and β are positive. They are defined by the equations $\mu=\alpha\beta$ and $\sigma^2=\alpha\beta^2$, where μ and σ^2 are

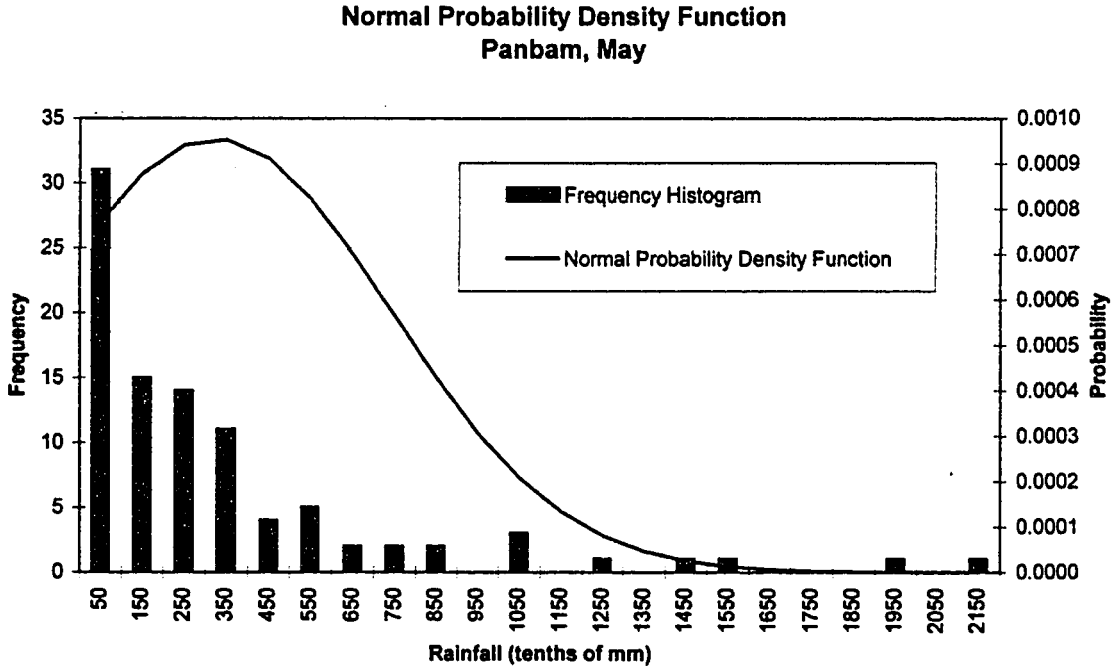


Figure 3.8 Frequency Histogram and Normal Probability Density Function for Panam (May)

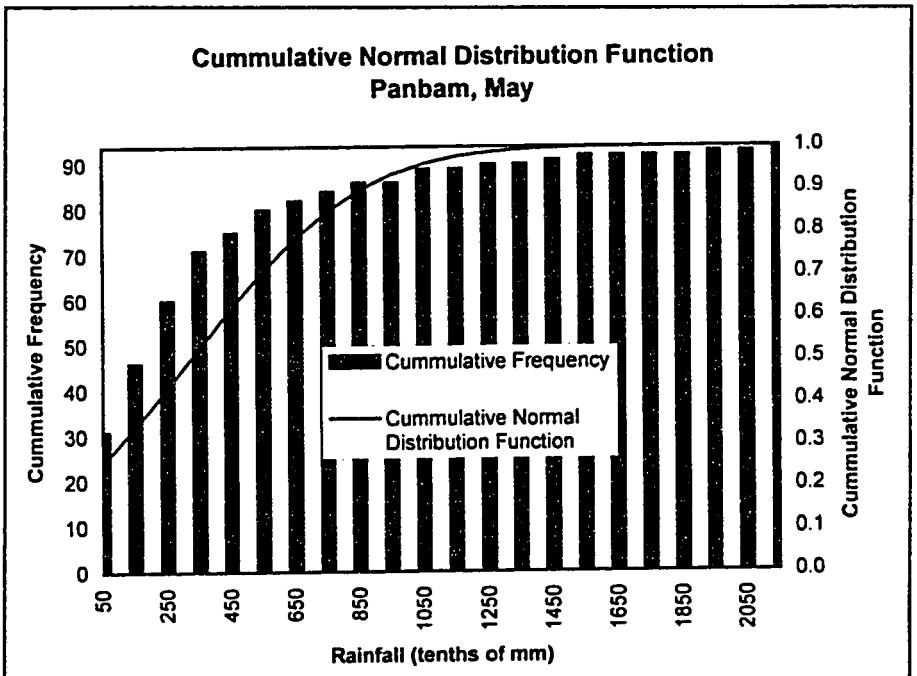


Figure 3.9 Cumulative Normal Distribution Function for Panam (May)

the sample mean and variance. Where x is less than or equal to zero, $f_g(x)$ is equal to zero. The cumulative gamma probability distribution function ($F_g(X)$) is defined in the same way as the cumulative normal probability distribution function, though with the gamma distribution function X is always greater than or equal to zero. Figure 3.10 and 3.11 show the frequency histogram with superimposed gamma probability density function and the cumulative gamma distribution function respectively for Madras (October). Figures for all test stations can be found in Appendix R.

The resulting graphs for Methods 2, 3, and 4 can be found in Appendices P, Q, and R respectively. Though some of the data sets were easily fit to a straight line in Method 2, others were highly skewed and this could not be corrected by taking either the log or square root of the data. The skew is very visible in the wet season for 4 of the 5 stations: Agra (August), Madras (October), Srinagar (March) and Panam (November). A straight line fitted to the data tended to over-estimate rainfall with an 80% probability of exceedance in two of the four cases mentioned. Looking at the graphs generated in Method 3, the normal probability density function seems to show a reasonable fit to the frequency histograms for the same wet season cases, while the dry season curves seem to fit poorly. The gamma probability density function used in Method 4 shows a good fit to the data in all cases.

Table 3.5 shows estimates of effective rainfall at an 80% probability of exceedance for the 4 methods and ten test cases. Method 1 shows the rainfall event which was actually exceeded 80% of time. This value is significant because of the unusually long length of the data series. In spite of the fact that the gamma probability density function showed a good fit to the frequency historgrams, it consistently over-estimated the rainfall event with an 80% probability of exceedance by a small margin in the critical dry months compared to Method 1 and all other methods. Methods 2 and 3 tended to (though not

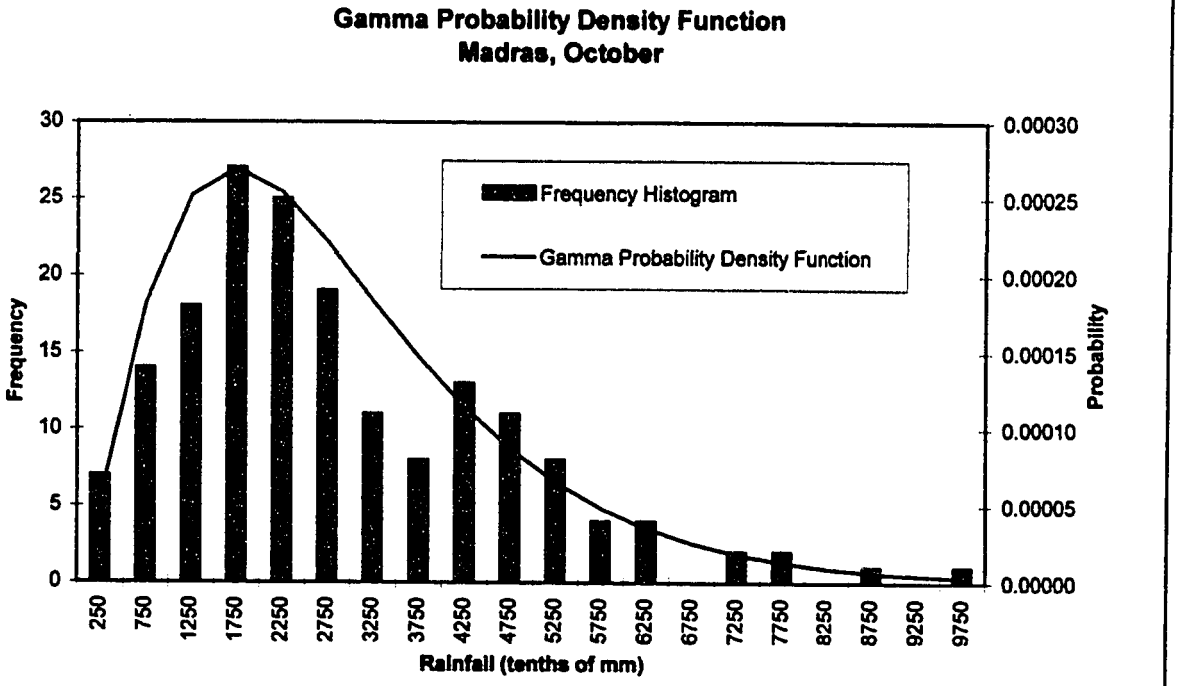


Figure 3.10 Frequency Histogram and Normal Probability Density Function for Madras (October)

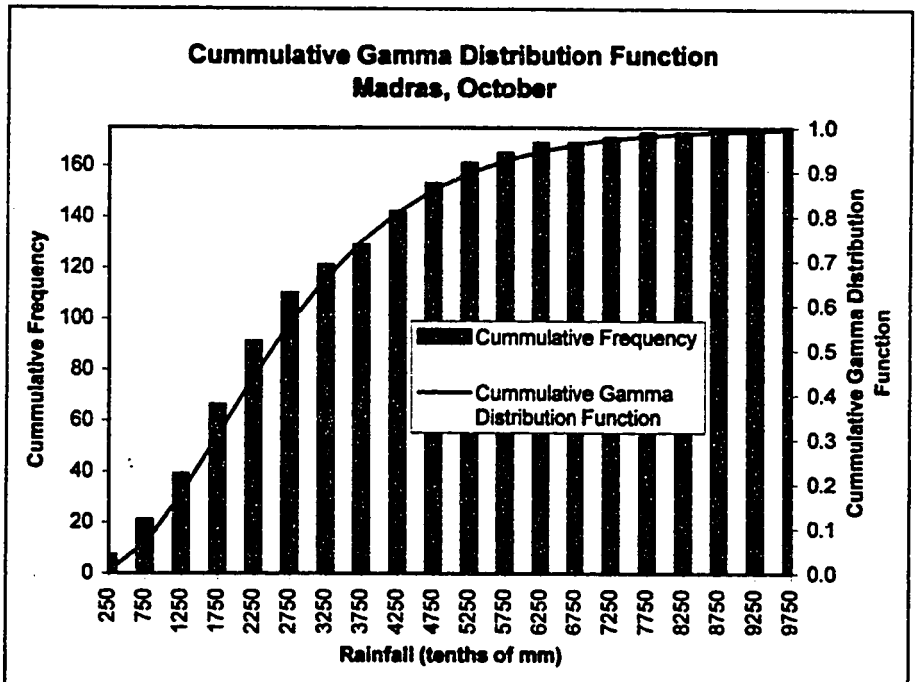


Figure 3.11 Cumulative Normal Distribution Function for Madras (October)

ETo St#	Station Name	Month	N	Rainfall with an 80% Probability of Exceedance (mm)			
				Method 1	Method 2	Method 3	Method 4
1	Agra	Jan	124	0	1.7	2.7	0
		Aug	125	129	120.4	119.7	112.4
9	Bikaner	Jun	103	4.5	4.3	6.6	5
		Dec	103	0	0	0	0
27	Madras / Minanbakkam	Apr	175	0	0	0.1	0
		Oct	175	142	133.7	133.9	133.9
38	Srinagar	Mar	92	58	54.5	54.1	58
		Oct	87	0	2.5	5.7	4.2
40	Pamban	May	94	0	0	3.1	1.6
		Nov	95	180	169.8	168.4	148.6

Table 3.5 Comparison of Results of Effective Rainfall Case Studies

consistently) overestimate rainfall during the wet season. This is generally not critical since not consistently) overestimate rainfall during the wet season. This is generally not critical since irrigation requirements rarely exceed monsoon rains.

Appendix S lists the estimates of effective rainfall with an 80% probability of exceedance for all months and all stations by both the normal and gamma probability distribution functions (Methods 3 and 4). These results are juxtaposed against the twentieth percentile of the data series (Method 1) for ease of comparison. The results generally follow those of the test cases. The maximum difference between the two methods was 17.8 mm for September in Ahmadabad. The average difference was 1.5 mm. Since neither method could be considered perfect, the minimum value was chosen in each case. This ensures a conservative (worst case) estimate and also seems to reflect the data most accurately. The final estimates of effective rainfall for all months and all stations can be found in Table 3.6.

St# Eto	Station Name	Lat(N)	Long(E)	Elev(m)	Effective Rainfall (mm) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	Agra	27.2	78	169	1.7	0.0	0.0	0.0	0.0	6.9	120.6	119.7	35.5	0.0	0.0	0.0
2	Ahmadabad	23.1	72.6	55	0.0	0.0	0.0	0.0	0.0	1.7	95.4	65.5	1.2	0.0	0.0	0.0
3	Akola	20.7	77	282	0.0	0.0	0.0	0.0	0.0	76.6	137.3	83.3	56.1	0.0	0.0	0.0
4	Allahabad/Bamhrauli	25.5	81.7	98	0.0	0.0	0.0	0.0	0.0	13.9	180.0	171.6	75.6	0.0	0.0	0.0
5	Amini	11.1	72.7	4	0.0	0.0	0.0	0.0	18.8	257.6	172.4	89.4	60.4	77.0	16.4	0.0
6	Amritsar/Rajasansi	31.6	74.9	234	6.4	10.5	6.7	0.0	2.1	5.5	117.0	89.3	8.5	0.0	0.0	0.0
7	Bangalore	13	77.6	921	0.0	0.0	0.0	7.0	62.5	42.1	50.6	69.3	87.6	75.1	0.0	0.0
8	Sagar	23.9	78.8	551	0.0	0.0	0.0	0.0	0.0	50.3	247.8	223.7	77.0	0.0	0.0	0.0
9	Bikaner	28	73.3	224	0.0	0.0	0.0	0.0	0.0	4.3	24.5	24.2	0.0	0.0	0.0	0.0
10	Bombay/Colaba,India	18.9	72.8	11	0.0	0.0	0.0	0.0	0.0	319.9	409.2	189.2	111.9	0.0	0.0	0.0
11	Bombay/Santa Cruz	19.1	72.9	14	0.0	0.0	0.0	0.0	0.0	351.7	749.2	313.4	113.3	17.4	0.0	0.0
12	Calcutta/Alipore	22.5	88.3	6	0.0	0.0	0.6	16.1	57.5	160.0	232.2	237.1	142.8	55.2	0.0	0.0
13	Calcutta/Dum Dum	22.7	88.5	6	0.0	0.0	6.1	5.1	38.8	149.3	213.8	212.5	179.9	57.0	0.0	0.0
14	Cuttack	20.5	85.9	27	0.0	0.0	0.0	1.2	30.0	128.4	222.7	207.3	162.8	57.7	0.0	0.0
15	Belguam/Samra	15.9	74.6	747	0.0	0.0	0.0	10.4	34.3	97.7	144.0	102.1	56.9	31.2	17.2	0.0
16	Dibrugarh/Mohanbari	27.5	95	111	12.8	28.8	51.2	139.5	197.6	343.9	403.8	329.6	221.1	69.7	3.0	0.5
17	Masulipatam	16.2	81.1	3	0.0	0.0	0.0	0.0	0.0	50.6	95.2	86.2	93.8	92.1	10.8	0.0
18	Gauhti	26.1	91.6	54	0.0	2.7	16.6	83.2	159.9	222.8	218.4	177.1	103.1	28.3	0.7	0.0
19	Goa/Panjim	15.5	73.8	57	0.0	0.0	0.0	0.0	0.0	629.6	689.9	335.0	109.7	22.8	0.0	0.0
20	Begampet	17.5	78.5	545	0.0	0.0	0.0	0.0	3.9	55.3	103.3	83.4	84.5	24.5	0.0	0.0
21	Indore	22.7	75.8	567	0.0	0.0	0.0	0.0	0.0	59.8	170.0	137.6	68.9	0.0	0.0	0.0
22	Jogdalapur	19.1	82	553	0.0	0.0	0.2	23.4	28.0	145.2	264.6	261.3	157.9	36.3	0.0	0.0
23	Jaipur/Sanganer	26.8	75.8	390	0.0	0.0	0.0	0.0	0.0	4.2	108.9	81.1	13.3	0.0	0.0	0.0
24	Jodhpur	26.3	73	224	0.0	0.0	0.0	0.0	0.0	0.3	38.5	33.4	0.0	0.0	0.0	0.0
25	Kodaikanal	10.2	77.5	2343	0.0	0.0	6.1	63.8	100.5	62.6	65.9	94.6	98.8	163.3	125.5	43.6
26	Kota	25.2	75.9	257	0.0	0.0	0.0	0.0	0.0	19.3	151.8	128.2	33.9	0.0	0.0	0.0
27	Madras/Minambakkam	13	80.2	16	0.0	0.0	0.0	0.0	0.0	19.7	50.5	64.5	60.3	133.7	154.9	18.9
28	Minicoy	8.3	73	2	0.0	0.0	0.0	14.0	88.4	204.5	137.9	115.3	83.0	97.0	71.7	9.0
29	Nagpur/Sonegaon	21.1	79.1	310	0.0	0.0	0.0	0.0	0.0	113.3	237.4	171.8	98.1	0.0	0.0	0.0
30	New Dehli-Safarjung	28.6	77.2	216	1.0	0.0	0.0	0.0	0.2	9.0	105.8	84.6	30.5	0.0	0.0	0.0
31	Dwarka	22.4	69.1	11	0.0	0.0	0.0	0.0	0.0	0.0	34.1	7.2	0.0	0.0	0.0	0.0
32	Fort Cochin	10	76.2	3	0.0	0.0	9.2	64.6	150.7	547.2	404.4	202.1	134.9	190.2	80.3	0.0
33	Patna	25.6	85.2	53	0.0	0.0	0.0	0.0	0.4	66.8	188.9	186.5	114.8	3.1	0.0	0.0
34	Port Blair	11.7	92.7	79	0.0	0.0	0.0	10.0	231.5	357.4	266.2	271.3	330.8	201.5	114.8	37.0
35	Poona	18.5	73.9	559	0.0	0.0	0.0	0.0	2.0	46.3	89.1	50.8	58.3	20.6	0.0	0.0
36	Shillong	25.6	91.9	1500	0.0	5.6	15.1	58.6	173.6	291.8	212.7	218.8	202.7	84.2	0.0	0.0
37	Silchar	24.8	92.8	29	0.0	11.8	60.7	193.8	254.5	431.5	378.6	371.2	259.0	93.6	0.0	0.0
38	Srinagar	34.1	74.8	1587	29.3	36.1	54.1	49.0	32.8	13.8	18.7	27.0	7.3	2.5	0.0	6.0
39	Trivandrum	8.5	77	64	0.0	0.0	6.8	58.1	65.1	187.7	116.0	60.2	42.3	157.8	77.7	10.0
40	Panam	9.3	79.3	11	0.0	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	96.5	168.4	63.8
41	Veraval	20.9	70.4	8	0.0	0.0	0.0	0.0	0.0	10.0	90.8	13.5	0.0	0.0	0.0	0.0
42	Vishakhapatnam	17.7	83.2	3	0.0	0.0	0.0	0.0	0.0	44.1	68.9	67.7	93.0	101.1	5.6	0.0

Table 3.6 Effective Rainfall (mm)

3.4.2 Dew, Snow and Ground Water

The contributions of dew, snow and ground water to overall irrigation requirements were ignored for various reasons. The contribution of dew is typically small and generally ignored. Snowfall was ignored as very few places in India receive significant quantities of snow. The contribution of ground water to irrigation requirements can be estimated from Figure 3.12. The ground water contribution is insignificant for most soils, unless the ground water table is within one metre of the surface. Estimating the contribution from ground water would require precise data on soil type and depth to ground water table. This information was not available and was not considered necessary for the general nature of this study.

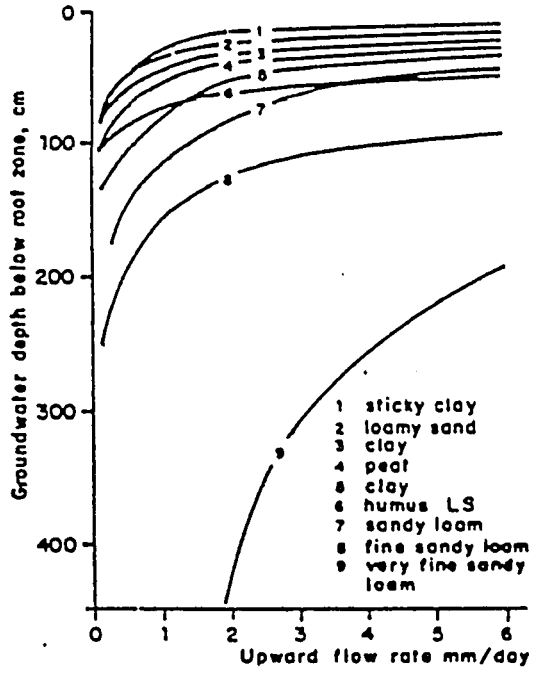


Figure 3.12 Ground Water Contribution to Irrigation Requirements
(Doorenbos and Pruitt, 1977)

3.5 SOILS

The map in Figure 3.13 shows the major soil types found in India. The northern plain is comprised mainly of alluvial soils. These soils are the most productive in India and are suitable for most crops including groundnut, rice, wheat, cotton, sugarcane, maize, jute, millet, vegetables and fruit. The soil texture ranges from fine to course, with finer soils being more productive. Some areas with this type of soil have problems with waterlogging and secondary salinity buildup. (Louis Berger Int., 1988) Moving from west to east across

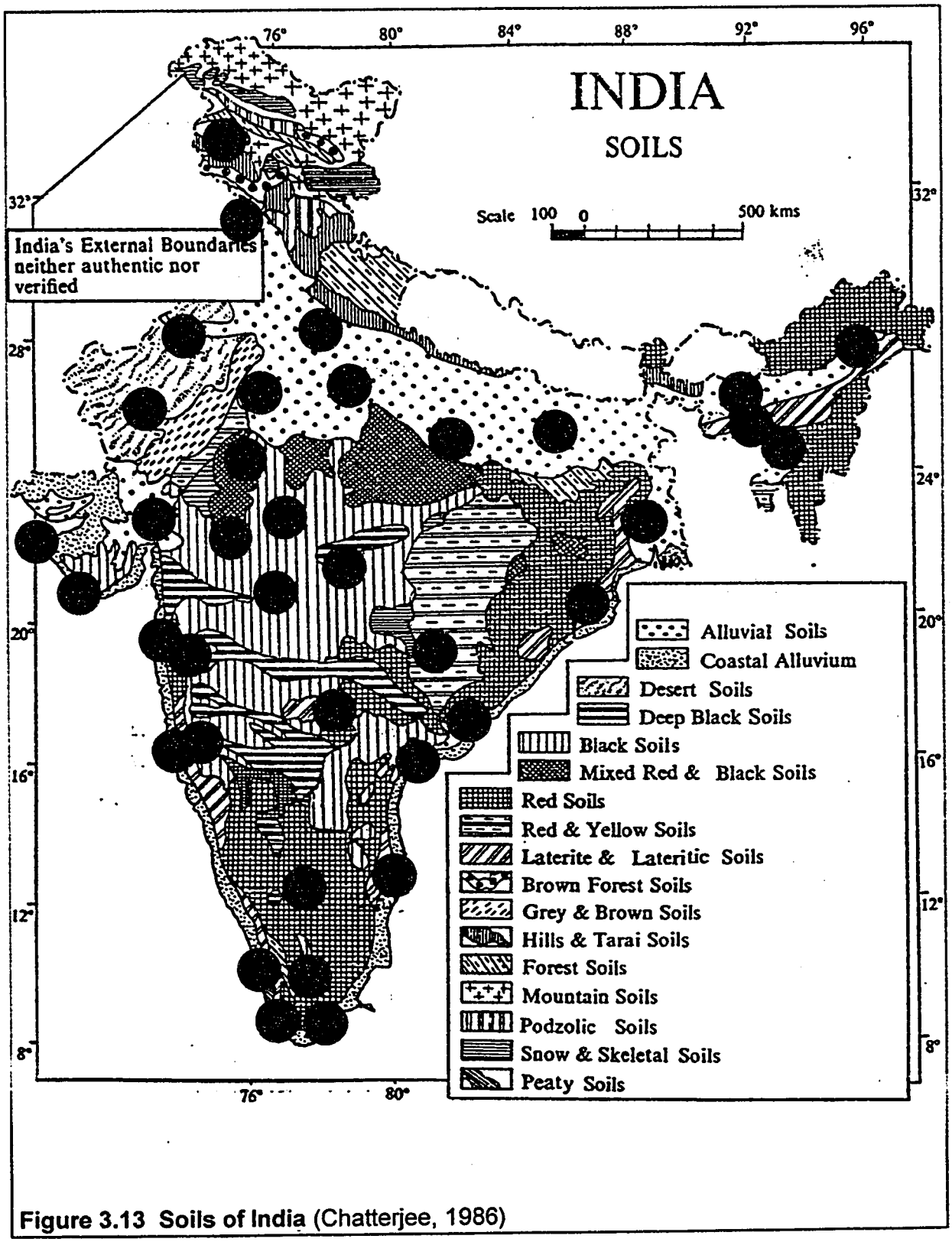


Figure 3.13 Soils of India (Chatterjee, 1986)

and secondary salinity buildup. (Louis Berger Int., 1988) Moving from west to east across the plain, the soils in the Punjab and Haryana region are mostly loams or sandy loams. In Uttar Pradesh they are mixed with the most fertile soils in the north east. In northern Bihar the soils range from sandy loam to clay loam, in south Bihar, from a light greyish loam to heavy black clay. In the Assam valley, the most easterly portion of India, the soils are mainly sand to sandy loam. Coastal alluvium, bordering most of the southern peninsula is sandy with low water holding capacity and low nutrient content. (Coward, 1980)

Black soils occupy a large area of the northern Deccan region. These soils develop under semi-arid and sub-humid conditions. They are heavy and alkaline with low permeability and high water holding capacity. Clay contents ranges from 30 to 80 % and texture ranges from clayey to clay loam. Deep black soils extend about 6 m down with poor drainability and occasional moisture stress. These soils are suited to cotton, millet and wheat under unirrigated conditions and rice, sugarcane and soybean under irrigated conditions. (Coward, 1980; Louis Berger Int., 1988)

Red and yellow soils are derived from granite, gneisses and schists under subtropical conditions. They occur in combination with laterites and black soils on undulating terrain. They generally range in texture from loam to clay loam, but can incorporate loamy sand and heavy clays in the extreme. The fertility and depth varies considerably. They are well drained and capable of producing a variety of field crops as well as rice, coffee, tea, cocoa and cardamum if properly irrigated and fertilized. (Coward, 1980: Louis Berger Int., 1988)

Laterite and lateritic soils are generally infertile with low levels of nitrogen, phosphoric acid, potash, lime, and magnesia (Coward, 1980). With careful fertilizer application and good cultivation practices, these soils have been used for rice, sugarcane,

cocoa, banana and cashew. Lower level lateritic soils range from heavy loams to clays, though higher level laterites are thin and gravelly. (Louis Berger Int., 1988)

Desert soils occupy a large part of wester Rajastan. These soil range from fine sandy to loamy fine sand and occasionally sandy loam. They have low water retention capacity and poor nutrient levels. A select number of crops are grown in this arid to semi-arid region, under controlled application of fertilizers and irrigation. (Louis Berger Int., 1988)

Thin, infertile skeletal soils are found in the highest regions of the Himalayas. Podzolic soils form under acid conditions in the western Himalayas. Piedmont and terai soils at the foot of the Himalayas. Organic forest soils are found in the moist, temperate regions of the lesser Himalayas. Hill and mountain soils form at various altitudes, often have a high degree of organic material and can be very fertile. (Coward, 1980)

3.6 DEPTH TO WATER TABLE

A rough estimate of the depth to water table was obtained from a 1986 map of India showing "Changes in Pre Monsoon Water Level Depths" (Figure 3.14). This map indicates areas where the water table is within 0-2 m of the surface, 2-5 m, 5-10 m, 10-15 m, 15-25 m, 25-50 m, and over 50 m. These represent worst case pre-monsoon scenarios where water levels are at their lowest. Areas of rising and falling ground water table are also marked.

Stations 2 and 14 on the southern and western coasts have a depth to water table of less than 2 m. Stations 2, 7, 12, 17, 23, 27, 33, 35, 37, 40 and 42 have a depth to water table less than 5 m. These are mainly in coastal regions or low lying areas near the mouth of the Ganges river. Stations 3, 4, 6, 8, 10, 16, 19, 20, 21, 22, 25, 26, 29, 31 and 41 have

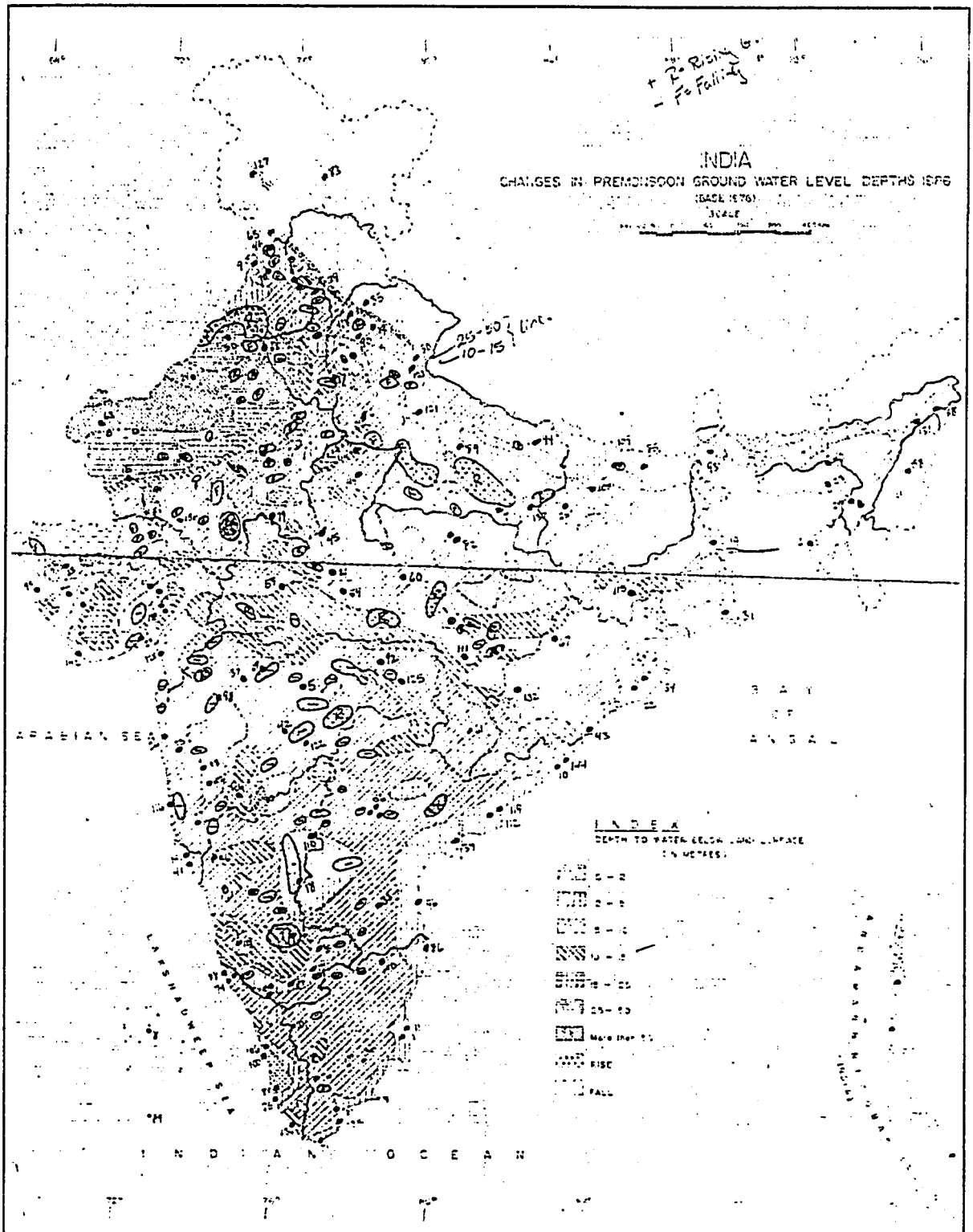


Figure 3.14 Depth to Ground Water Table (Sharma, 1993)

a depth to water table less than 10 m. Stations 1, 15, 30 and 39 have a depth to water table less than 15 m. Stations 9 and 24 in the desert region of Rajastan have a depth to water table ranging from 25 to 50 m.

The cost of irrigating with a PV pump rises rapidly with total head. It is therefore assumed that surface water sources will be used whenever possible. Depths to ground water table are given as an estimate of the potential for ground water resource utilization, since the use of ground water sources ensure year round availability of irrigation water. When the depth to ground water table is less than 5 m the potential for ground water resource utilization is high. Below this point the cost of lifting water with a PV pump is still within a reasonable range and less expensive open dug wells may be used. Above this point PV water pumping costs rise dramatically and more expensive tube wells are required.

3.7 FARM SIZES

Tables 3.7 and 3.8 list the average number and size of operational holdings by major size groups for each state, where marginal farms are less than 1 ha, small farms are 1 to 2 ha, semi-medium farms are 2 to 4 ha, medium farms are 4 to 10 ha and large farms are over 10 ha. These tables were taken from the 1985-86 Agricultural Census. Note from Table 3.8 that the average farm size for India is 1.69 ha. Referring back to Section 3.1 (Figure 3.2) unit water costs for PV pumps were lowest for farms between 0.5 and 2 ha. From Table 3.7 approximately 57.8% of all operational holdings in India are less than 1 ha in size, with another 18.4% between 1 and 2 ha.

	Marginal	Small	Semi-Medium	Medium	Large	All Holdings
Andra Pradesh	4461	1714	1254	657	146	8232
Assam	1451	546	324	92	6	2419
Bihar	8976	1327	951	404	52	11710
Gujarat	801	737	785	678	145	3146
Haryana	502	265	281	239	60	1347
Himachal Pradesh	463	155	92	36	6	752
Jammu & Kashmir	875	187	98	23	1	1184
Karnataka	1792	1293	1035	646	153	4919
Kerala	3993	282	104	25	4	4408
Madhya Pradesh	2733	1613	1593	1292	373	7604
Maharashtra	2488	2104	1957	1317	236	8102
Manipur	67	48	21	3		139
Meghalaya	59	51	46	13	1	170
Nagaland	8	19	19	42	36	124
Orissa	1868	910	583	204	21	3586
Punjab	256	208	291	260	74	1089
Rajastan	1358	920	979	986	501	4744
Sikkim	13	10	8	5	1	37
Tamil Nadu	5498	1260	649	261	39	7707
Tripura	211	70	27	3		311
Uttar Pradesh	13782	2964	1582	602	55	18985
West Bengal	4343	1175	516	94	1	6129
Others	149	64	57	34	7	311
ALL INDIA	56147	17922	13252	7916	1918	97155

Source: Agricultural Census 1985-86

Table 3.7 Statewise Number of Operational Holdings by Major Size Groups

	Marginal	Small	Semi-Medium	Medium	Large	All Holdings
Andra Pradesh	0.46	1.43	2.70	5.88	16.38	1.72
Assam	0.41	1.39	2.69	5.23	78.08	1.31
Bihar	0.37	1.41	2.73	5.67	15.99	0.93
Gujarat	0.52	1.47	2.85	6.08	14.48	3.16
Haryana	0.46	1.45	2.81	5.90	15.00	2.76
Himachal Pradesh	0.43	1.43	2.76	5.71	16.81	1.30
Jammu & Kashmir	0.38	1.36	2.67	5.58	32.43	0.86
Karnataka	0.48	1.46	2.78	6.01	15.45	2.41
Kerala	0.20	1.35	2.61	5.31	42.40	0.40
Madhya Pradesh	0.44	1.46	2.79	6.10	16.75	2.91
Maharashtra	0.50	1.49	2.82	5.97	15.28	2.64
Manipur	0.54	1.37	2.58	5.11	15.87	1.24
Meghalaya	0.54	1.32	2.53	5.43	14.25	1.76
Nagaland	0.40	1.27	2.55	6.21	16.37	7.45
Orissa	0.49	1.40	2.69	5.72	16.22	1.47
Punjab	0.54	1.50	2.89	6.11	16.66	3.77
Rajastan	0.47	1.44	2.85	6.42	19.34	4.34
Sikkim	0.51	1.37	2.83	6.02	23.17	2.72
Tamil Nadu	0.37	1.41	2.74	5.78	18.39	1.01
Tripura	0.51	1.62	2.71	5.08	59.33	1.02
Uttar Pradesh	0.36	1.39	2.73	5.61	15.37	0.93
West Bengal	0.42	1.49	2.68	5.18	160.14	0.92
Others	0.44	1.42	2.77	5.91	20.00	2.11
ALL INDIA	0.39	1.43	2.77	5.96	17.21	1.69

Source: Agricultural Census 1985-86

Table 3.8 Average Size of Operational Holdings by Major Size Group

3.8 SIZING A REMOTE WATER PUMPING SYSTEM

Pump sizings are based on daily water requirements in the critical month (Q_{crit}). For a diesel, hand, or animal powered pump the critical month is the month with the maximum irrigation water requirement. For a wind, solar, or water powered pump the critical month is the month with the maximum ratio of water required to wind power, water power, or solar insolation available.

If Q_{max} is the daily water requirement for the critical month in m^3/day and τ_d the maximum daily run time in hrs/day, the flow (Q) required in m/s is given by Equation 3.20.

$$Q=\frac{Q_{crit}}{3600\tau_d} \tag{3.20}$$

The maximum daily run time (τ_d) varies with the type of system. Diesel, animal, and hand pumping systems are generally limited by the length of the average working day, approximately 8 hours for a diesel pump, 6 to 8 hours for a hand pump, and 5 to 8 hours for an animal pump (Thomas, 1988).

The hydraulic power (P_h) required to move water at a given flow rate against a given head is determined by the formula below, where P_h is the hydraulic power required in kW, γ is the specific weight of water in kN/m^3, and H is the total head in m. The specific weight of water is approximately 9.789 kN/m^3 at 20°C.

$$p_h=\gamma HQ \tag{3.21}$$

According to Thomas (1988) the maximum hydraulic power available from a hand pump is approximately 36 W and from an animal powered pump 210 W. Saxena and Ilysas (1987) reported Persian wheels (animal powered pumps) delivered 20 to 22 m^3/hr

of water at a 1.5 m lift or 8 to 10 m^3/hr at a 9 m lift. This corresponds to a hydraulic power of 82 W to 90 W at low heads and 196 to 245 W at higher heads.

The engine power required to run the pump (P_r) is equal to the hydraulic power (P_h) is divided by the pump efficiency (ϵ_p). The pump efficiency varies with the head and flow conditions but is generally between 0.5 and 0.6 for a properly sized pump. P_r and P_h are measured in kW.

$$P_r = \frac{P_h}{\epsilon_p} \tag{3.22}$$

The smallest diesel engines suitable for water pumping applications are approximately 2.5 kW (3.5 hp) (Thomas, 1988) or 3.7 kW (5 hp) (Helikson et al., 1990). The diesel engine size (P_d) is equal to P_r or the smallest available engine size, whichever is greater. If P_r is smaller than 2.5 kW, a 2.5 kW engine is used. If P_r is considerably smaller than 2.5 kW an alternative power supply should be considered.

Table 3.9 shows a sample calculation for sizing a diesel system with a water pumping requirement of 30 m^3/day and a total pumping head of 15 m. This would be typical of a small farm using drip irrigation on a crop with a low water requirement. The engine power required (P_r) in this case is considerably smaller than 2.5 kW.

Diesel System Sizing:	
Critical Month Flow Req'd, Q_{crit} =	30 m^3/day
Max Run Time per Day, T_d =	8 h/day
Required Flow, $Q = Q_{crit}/3600T_d$ =	0.00104 m^3/s
Head, H =	15 m
Specific Weight of Water, Y =	9.789 kN/m^3
Hydraulic Power Req'd, $P_h = YHQ$ =	0.153 kW
Pump Efficiency, E_p =	0.5
Engine Power Required, $P_r = P_h/E_p$ =	0.306 kW
Diesel Engine Size, $P_d = P_r$ or 2.5 kW =	2.5 kW

Table 3.9 Sample Sizing for a Diesel System

The nomographs shown in Figure 3.15 can be used as an approximate estimate of the required array size for a solar pumping system. A sample sizing

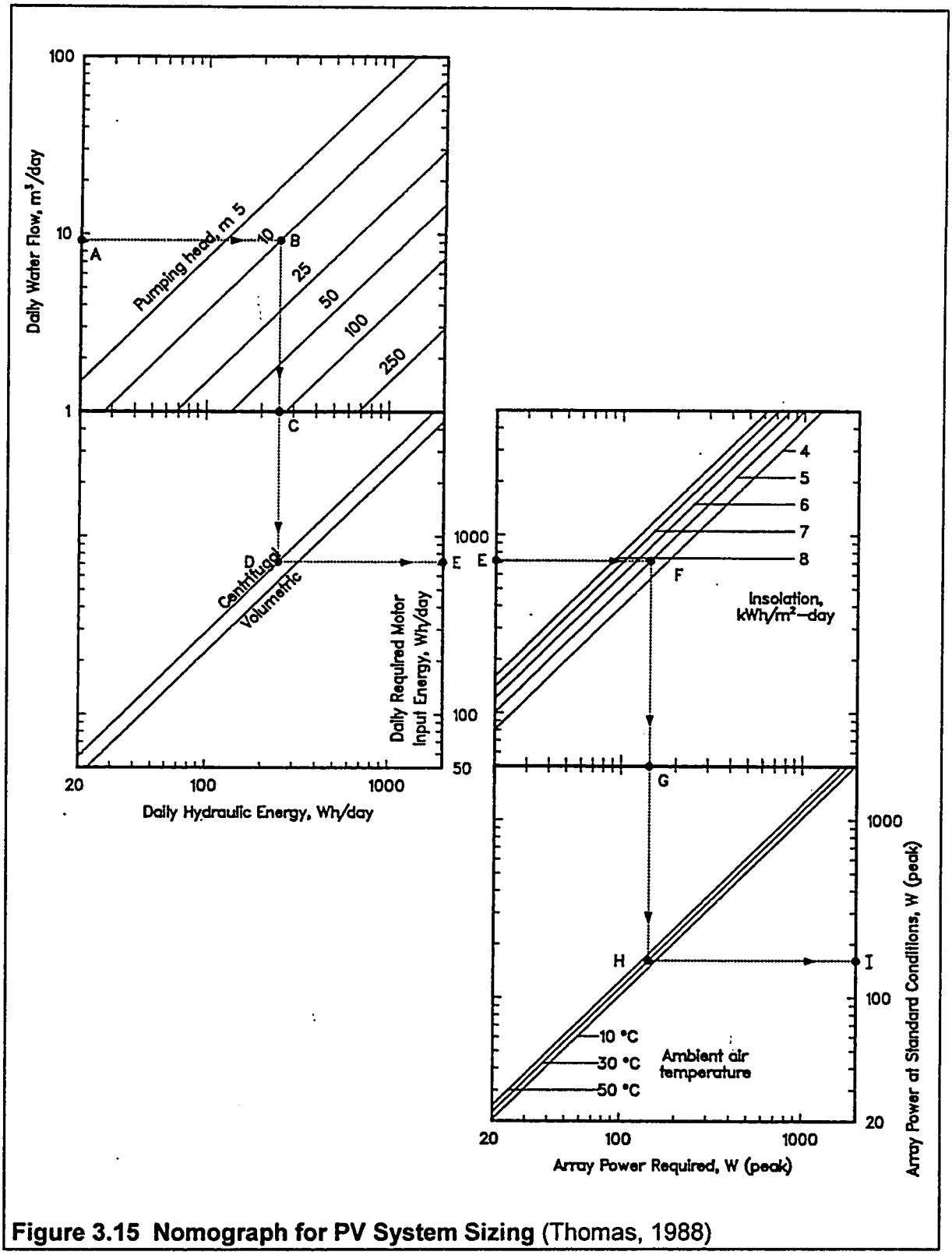


Figure 3.15 Nomograph for PV System Sizing (Thomas, 1988)

is shown for a centrifugal pump with a required flow of 10 m^3/day at a 10 m head. The array sizing assumes insolation levels of 5 kWh/m^2 in the critical month and an ambient air temperature of 30°C. The resulting array size is approximately 110 W_p. These nomographs should be used as an approximate guide only since individual component efficiencies vary throughout the day as insolation levels change. More accurate sizings can be done by the system supplier.

3.9 LIFE CYCLE COST COMPARISON

Cost comparisons for remote water pumping systems should take into account all capital costs for the system as well as recurring operations and maintenance costs. The life cycle cost comparison is preformed over the useful life of the system component with the longest expected lifespan. Solar panels are expected to last 30 years or more with little degradation. This claim is backed by working examples of panels produced over 30 years ago. Modules are warrantied for up to 20 years. Sir William Halcrow and Partners (1983) compared the effects of using a 20 and 30 year period of analysis and found little difference between the two. Using a 20 year period of analysis has since become standard in the industry and will therefore be used in this study.

For a PV water pumping system capital costs tend to be high but recurring costs over the life of the system are low. There are no fuel or operating costs. Some minor maintenance and repair work is required. Most of this work (such as wiring checks and cleaning the array surface) can be handled by the pump owner. The cost of replacing worn parts is low because the most expensive component (the array) has no moving parts to wear out. The pump/motor subsystem will typically need to be replaced every 5 to 10 years or 1 to 3 times over a 20 year period.

Diesel engines, though likely to cost less initially, will probably need to be completely rebuilt or replaced every 7 to 10 years in addition to replacing the pump/motor subsystem every 5 to 10 years. Diesel systems also have recurring fuel and lubricant costs and higher maintenance costs.

Hand and animal powered pumps also tend to be inexpensive initially, but have large operating costs. Hand pumps require a labourer who must be paid to operate the pump. Persian wheels require animals that must be fed and cared for. Both types of pump require constant maintenance and repair.

A number of studies have been done already comparing long term costs of PV water supply systems to other remote pumping options. Thomas (1988) identified the range shown in Figure 3.16 as being generally viable for PV drinking water supply systems. Studies done for drinking water supply systems do not consider the cost of labour for hand pump operation. These studies assume that each household gathers its own water. When the cost of labour for irrigation pumping is factored in the region of economic viability for PV pumps increases with hand pumps becoming less economical.

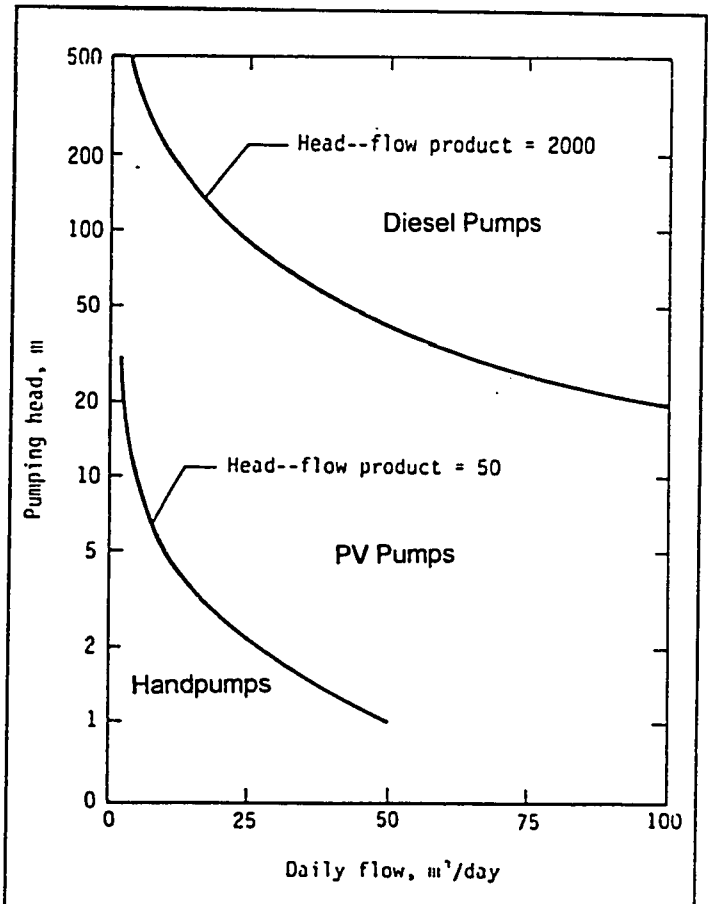


Figure 3.16 Regions of Viability for Various Pumping Options (Thomas, 1988)

Cost assumptions for PV pumping systems are shown in Table 3.10. All prices are in 1987 US$. Capital costs identified include the cost of the array, pump cost, balance of system (BOS) components and installation. BOS components include the array support structure, wiring, and other minor expenses such as switches or suction hoses. These costs are generally estimated at 15% of the array cost. The cost of array tracking devices (active or passive) should be considered separately, as should any controllers or inverters that are not included in the pump cost. Note that module prices are estimated at 8.75 US$/$W_p$ for smaller sales and 7.50 US$/$W_p$ for high volume sales. Current module prices are approximately 7.45 US$/$W_p$ for retail sales and 6.25 US$/$W_p$ for high volume sales.

PV Assumptions:	Fixed Cost (Rs)	Unit Cost (Rs/Wp)
PV Modules:		
<50 Modules		8.75
100-250 Modules		7.5
BOS (15% of Array Cost):		
<50 Modules		1.13
100-250 Modules		1.31
Pump:		
Surface	500	1
Submersible	2000	
Lineshaft turbine and Jack	2500	1
Installation:		
Array		0.5
Surface Pump	100	0.5
Submersible Pump	200	0.5
Lineshaft turbine & Jack Pump	500	0.5
Maintenance	20	0.02

Table 3.10 Cost Assumptions for PV Pumping Systems (1987 US$) (Thomas, 1988)

Data from Thomas (1988) was used to generate capital and recurring costs for various system sizes shown in Table 3.11. The only recurring costs are for maintenance, estimated at 20 US$/system plus 0.02 US$/W_p of array power. Note than installation costs are approximately 10% of equipment capital costs and annual maintenance costs are approximately 0.3% of total capital costs for larger systems.

Unit costs for a diesel pump were quoted at 1,600 US$/kW including installation and delivery (Thomas, 1988). Assuming the smallest suitable diesel engines is 2.5 kW, the

PV System Costs (1987 US$):

Wp	Surface Pumps Capital: Array BOS Pump	Pump Replace	Install	Install as % of Capital	Submersible Pumps Capital: Array BOS Pump	Pump Replace	Install	Install as % of Capital	Annual Costs	Annual Cost as % of Capital Surface	Submers
200	2676	700	300	11.2	3976	2000	400	10.1	24	0.90	0.60
300	3764	800	400	10.6	4964	2000	500	10.1	26	0.69	0.52
400	4852	900	500	10.3	5952	2000	600	10.1	28	0.58	0.47
500	5940	1000	600	10.1	6940	2000	700	10.1	30	0.51	0.43
600	7028	1100	700	10.0	7928	2000	800	10.1	32	0.46	0.40
700	8116	1200	800	9.9	8916	2000	900	10.1	34	0.42	0.38
800	9204	1300	900	9.8	9904	2000	1000	10.1	36	0.39	0.36
900	10292	1400	1000	9.7	10892	2000	1100	10.1	38	0.37	0.35
1000	11380	1500	1100	9.7	11880	2000	1200	10.1	40	0.35	0.34
1100	12468	1600	1200	9.6	12868	2000	1300	10.1	42	0.34	0.33
1200	13556	1700	1300	9.6	13856	2000	1400	10.1	44	0.32	0.32
1300	14644	1800	1400	9.6	14844	2000	1500	10.1	46	0.31	0.31
1400	15732	1900	1500	9.5	15832	2000	1600	10.1	48	0.31	0.30
1500	16820	2000	1600	9.5	16820	2000	1700	10.1	50	0.30	0.30
1600	17908	2100	1700	9.5	17808	2000	1800	10.1	52	0.29	0.29
1700	18996	2200	1800	9.5	18796	2000	1900	10.1	54	0.28	0.29
1800	20084	2300	1900	9.5	19784	2000	2000	10.1	56	0.28	0.28
1900	21172	2400	2000	9.4	20772	2000	2100	10.1	58	0.27	0.28
2000	22260	2500	2100	9.4	21760	2000	2200	10.1	60	0.27	0.28

Table 3.11 Capital and Recurring Costs for PV Pumping Systems

minimum capital cost for a diesel water pumping system would have been 4,000 US$. Maintenance costs were estimated at 200 to 900 US$ per year (independent of engine size) or 5 to 23 % of total capital costs for a small system. Annual fuel costs are dependant on the total annual water requirement (Q_y) in m^3/yr. The total run time (T_y) in hours for one year is found by Equation 3.23, where Q_d is the diesel pump flow rate in m/s.

$$T_y = \frac{Q_y}{3600 Q_d} \qquad (3.23)$$

Q_d is estimated from Equation 3.24, where P_d is the diesel engine rating in kW, ϵ_p is the pump efficiency, γ is the specific weight of water in kN/m^3, and H is the total head in m.

$$Q_d = \frac{P_d \epsilon_p}{\gamma H} \qquad (3.24)$$

Fuel consumption (F_c) was estimated at 0.5 *l*/hr per kW engine rating for engines less than

10 kW. Total annual fuel cost (A_f) is therefore equal to the run time (T_y) multiplied by the variable fuel consumption rate (F_c), the engine power (P_d), and the unit cost of fuel (C_f). Unit fuel costs were estimated at 0.20 to 1.50 US$/ℓ.

$$A_f = T_y * F_c * P_d * C_f \qquad (3.25)$$

Table 3.12 shows sample calculations of capital and recurring costs for a diesel system where the maximum daily water requirement is 30 m^3 and the total annual water requirement is 5600 m^3. Two cases were considered. The first case assumes average values for fuel and maintenance and the second case assumes a remote system where fuel and maintenance costs are at the higher end of the given range.

Diesel Assumptions: Capital Cost:	Average	Remote	
Critical Month Flow Req'd, Q_{crit} =	30	30	m^3/day
Max Run Time per Day, T_d =	8	8	h/day
Required Flow, $Q = Q_{crit}/3600T_d$ =	0.00104	0.00104	m^3/s
Head, H =	15	15	m
Specific Weight of Water, Y =	9.789	9.789	kN/m^3
Hydraulic Power Req'd, $P_h = YHQ$ =	0.153	0.153	kW
Pump Efficiency, E_p =	0.5	0.5	
Engine Power Required, $P_r = P_h/E_p$ =	0.306	0.306	kW
Diesel Engine Power, $P_d = P_r$ or 2.5 kW =	2.5	2.5	kW
Unit Cost of Diesel Pump, CAP_1 =	1600	1600	US$/kW
Capital Cost, $CAP_p = P_dCAP_1$ =	4000	4000	US$
Life of Diesel Pump System =	10	10	yrs
Annual Fuel Cost (A_f):			
Pump Output, $Q_d = P_dE_p/YH$ =	0.00851	0.00851	m^3/s
Annual Water Req'ment, Q_y =	5600	5600	m^3
Annual Run Time, $T_y = Q_y/3600Q_d$ =	182.7	182.7	hr
Fuel Consumption, F_c =	0.5	0.5	l/hr/kW
Unit Cost of Fuel, C_f =	0.5	1.5	US$/l
Annual Fuel Cost, $A_f = T_yF_cP_dC_f$ =	114.21	342.62	US$/yr
Annual Maintenance Cost, A_m =	600	900	US$/yr
Annual Operating Cost, A_p =	0	0	US$/yr
Total Annual Cost, $A_t = A_f+A_m+A_p$ =	714.21	1242.62	US$/yr

Table 3.12 Sample Calculation: Capital and Recurring Costs for Diesel Systems

Estimated costs for wind, animal, and hand pumps can be found in Table 3.13. Table 3.14 shows sample calculations for determining the number of hand or animal powered pumps required, the total capital cost of the pumps, and the annual recurring costs. The number of hand or animal pumps (Z) required is given by Equation 3.26, where γ is the specific weight of water in kN/m^3, H is the total head in m, Q the required flow rate in m/s, and P_{hp} the estimated hydraulic power output of one pump in kW.

$$Z=\frac{\gamma HQ}{P_{hp}} \tag{3.26}$$

Equation 3.27 gives the maximum flow (Q_p) from all pumps in m/s.

$$Q_p=Z\frac{P_{hp}}{\gamma H} \tag{3.27}$$

Total run time for one year (τ_y) in days is given by Equation 3.28 below, where Q_y is the total volume of water required for one year and τ_d is the maximum daily run time in hours.

$$\tau_y=\frac{Q_y}{3600\tau_d Q_p} \tag{3.28}$$

Cost Data for Wind, Hand and Animal Powered Pumps (1987$)			
	Wind	Animal	Human
Hydraulic Output per Pump (W)		210	36
Capital cost of Pump (US$/pump)			240-320
Capital cost of Pump (US$/animal)		300	
Capital cost of Pump (US$/W)		6.2	6.5-9.0
Borehole Cost (US$/m)	25-75		
Storage Tank Cost (US$/m3)	100-300		
Lifetime of Power Source (yrs)	20-30	10	
Lifetime of Pump (yrs)	5-10	10-15	5-10
Maintenance Costs (US$/yr)	50	10	50
Maintenance Costs (US$/1000 hrs)	6		
Operating Time (hrs/day)	0-24	5-8	6-8
Operating Cost ($/day/man or beast)		2.5	1

All Costs in 1987 US$

Table 3.13 Cost Assumptions for Wind, Animal and Hand Pumping Systems (Thomas, 1988)

Total costs for example PV, diesel, animal, and hand pumping systems over a 20 year period are estimated in Table 3.15. Costs calculated in Table 3.16 are not directly comparable since wattages given for the hand and animal pumps represent hydraulic power while wattages given for the PV and diesel systems represent array and

Hand and Animal Powered Pumps	Hand	Animal	
Critical Month Flow Req'd, Q_{crit} =	7	30	m^3/day
Max Run Time per Day, T_d =	8	8	h/day
Required Flow, $Q = Q_{crit}/3600T_d$ =	0.00024	0.00104	m^3/s
Head, H =	15	15	m
Specific Weight of Water, Y =	9.789	9.789	kN/m^3
Hydraulic Power Req'd, $P_h = YHQ$ =	0.036	0.153	kW
Hydraulic Power Output of 1 Pump, P_{hp} =	0.036	0.210	kW
Number of Pumps Required, Z =	1	1	
Unit Cost of One Pump, CAP_1 =	280	1302	US$
Capital Cost, $CAP_p = ZCAP_1$ =	280	1302	US$
Life of Pump =	7	10	yrs
Annual Fuel Cost, A_f =	0	0	US$/yr
Annual Maintenance Cost, A_m =	50	10	US$/yr
Annual Operating Cost (A_p):			
Pump Output, $Q_p = ZP_{hp}/YH$ =	0.00025	0.00143	m^3/s
Annual Water Req'ment, Q_y =	1300	5600	m^3
Annual Run Time, $T_y = Q_y/3600T_dQ_p$ =	184.1	136.0	days
Daily wage, w =	2.5	1	$/day
Number of Men or beasts per Pump, z =	1	4	
Annual Operating Cost, $A_p = ZzT_yw$ =	460.28	543.83	US$/yr
Total Annual Cost, $A_t = A_f+A_m+A_p$ =	510.28	553.83	US$/yr

Table 3.14 Sample Calculations for Hand and Animal Powered Pumps

engine power. Daily maximum and total annual flow rates for each system also vary. The table is intended only as a rough guide for identifying the ranges where PV systems can be considered viable and to illustrate the methodology used in calculating relative costs.

Table 3.15 shows the cash flows over the entire 20 year period for each system as well as the net present worth of each system. The net discount rate (r) is equal to the average interest rate (i) expected over the study period minus the average expected rate of inflation (q). For this example the net discount rate was set to 5%. The net present worth of each system is the sum of the present worths of payments made each year. The present worth (PW) of a single future payment (F) is found by Equation 3.29, where t is the year in which the cost occurred. The present worth of an annual payment (A) is given by Equation 3.30. (Riggs et al., 1986)

Power (W)	Present Worth (US$)	Year 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Period of Analysis (yrs) =										20	Net Discount Rate =									5%
Handpump																						
*36	1,244	280	50	50	50	50	50	50	330	50	50	50	50	50	50	330	50	50	50	50	50	50
**36	6,980	280	510	510	510	510	510	510	790	510	510	510	510	510	510	790	510	510	510	510	510	510
Animal																						
*210	2,226	1,302	10	10	10	10	10	10	10	10	10	1,312	10	10	10	10	10	10	10	10	10	10
**210	9,003	1,302	554	554	554	554	554	554	554	554	554	1,856	554	554	554	554	554	554	554	554	554	554
***210	20,421	1,302	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470	2,772	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470
PV																						
Surface																						
200	3,705	2,976	24	24	24	24	24	24	24	24	24	724	24	24	24	24	24	24	24	24	24	24
400	6,253	5,352	28	28	28	28	28	28	28	28	28	928	28	28	28	28	28	28	28	28	28	28
600	8,802	7,728	32	32	32	32	32	32	32	32	32	1,132	32	32	32	32	32	32	32	32	32	32
800	11,351	10,104	36	36	36	36	36	36	36	36	36	1,336	36	36	36	36	36	36	36	36	36	36
1,000	13,899	12,480	40	40	40	40	40	40	40	40	40	1,540	40	40	40	40	40	40	40	40	40	40
1,100	15,174	13,668	42	42	42	42	42	42	42	42	42	1,642	42	42	42	42	42	42	42	42	42	42
1,200	16,448	14,856	44	44	44	44	44	44	44	44	44	1,744	44	44	44	44	44	44	44	44	44	44
1,400	18,997	17,232	48	48	48	48	48	48	48	48	48	1,948	48	48	48	48	48	48	48	48	48	48
1,600	21,545	19,608	52	52	52	52	52	52	52	52	52	2,152	52	52	52	52	52	52	52	52	52	52
1,800	24,094	21,984	56	56	56	56	56	56	56	56	56	2,356	56	56	56	56	56	56	56	56	56	56
Submersible																						
400	8,129	6,552	28	28	28	28	28	28	28	28	28	2,028	28	28	28	28	28	28	28	28	28	28
600	10,355	8,728	32	32	32	32	32	32	32	32	32	2,032	32	32	32	32	32	32	32	32	32	32
800	12,580	10,904	36	36	36	36	36	36	36	36	36	2,036	36	36	36	36	36	36	36	36	36	36
1,000	14,806	13,080	40	40	40	40	40	40	40	40	40	2,040	40	40	40	40	40	40	40	40	40	40
1,200	17,032	15,256	44	44	44	44	44	44	44	44	44	2,044	44	44	44	44	44	44	44	44	44	44
1,400	19,258	17,432	48	48	48	48	48	48	48	48	48	2,048	48	48	48	48	48	48	48	48	48	48
1,600	21,484	19,608	52	52	52	52	52	52	52	52	52	2,052	52	52	52	52	52	52	52	52	52	52
1,800	23,710	21,784	56	56	56	56	56	56	56	56	56	2,056	56	56	56	56	56	56	56	56	56	56
2,000	25,936	23,960	60	60	60	60	60	60	60	60	60	2,060	60	60	60	60	60	60	60	60	60	60
Diesel																						
*****2500	18,199	4,000	714	714	714	714	714	714	714	714	714	4,714	714	714	714	714	714	714	714	714	714	714
******2500	24,784	4,000	1,243	1,243	1,243	1,243	1,243	1,243	1,243	1,243	1,243	5,243	1,243	1,243	1,243	1,243	1,243	1,243	1,243	1,243	1,243	1,243

* Assumes no operating costs

** Assumes operating costs of 1 US$/day/person

*** Assumes operating costs of 2.5 US$/day/animal while the animals are running the pump

**** Assumes operating costs of 2.5 US$/day/animal for the entire year

***** Average conditions for a 2.5 kW diesel pump: fuel = 0.50 US$/l, maintenance = 600 US$/yr

****** Remote conditions for a 2.5 kW diesel pump: fuel = 1.50 US$/l, maintenance = 900 US$/yr

Table 3.15 Typical Life Cycle Costs for Remote Pumping Systems (1987 US$)

$$PW = \frac{F}{(1+r)^t} \tag{3.29}$$

$$PW = A\frac{(1+r)^t - 1}{r(1+r)^t} \tag{3.30}$$

The hand pump example assumes an irrigation pumping requirement of 7 m^3/day in the critical month with a total head of 15 m. The pumps are replaced in years 7 and 14. Two cases were considered, the first assumes that operating costs are zero and the second assigns a value to the cost of running the pump. Case One is typical of a water supply situation, where individual users are gathering water for their own needs and no one is paid to run the pump. Case Two is typical of the situation encountered when hand pumps are used for irrigation. The pump owner cannot manage the irrigation process and run the pump at the same time and he must therefore pay someone else. Annual operating costs for Case Two were calculated in Table 3.14. The present worth of all costs incurred over the 20 year period increases from 1,244 US$ to 6,980 US$ when the cost of labour to run the pumps is factored in.

The Persian wheel example assumes an irrigation pumping requirement of 30 m^3/day in the critical month with a total head of 15 m. The Persian wheel is replaced in year 10. Three cases were considered for animal powered pumps. Case One assumes the farmer already owns the required number of animals. These animals would have to be fed and cared for regardless of whether or not they were being used to work the irrigation pump. The cost of their upkeep is not included in the annual operating cost. Case Two factors in the cost of caring for the animals at 1 US$/day/animal while they are working the irrigation pump. Annual operating costs for this case were calculated Table 3.14. Case Three assumes the farmer has to purchase animals to operate the irrigation

pump and these animal are not doing any other useful labour the rest of the year. Total annual operating costs for this case were calculated in a similar manner to that shown in Table 3.14; but the number of days over which the animal must be fed and cared for increases from 136 days to 365 days. Total annual operating costs for this case are 1,470 US$/yr. The unit cost of water increases dramatically when the costs of caring for the animals are factored in. Persian wheels are economical if the farmer already uses animals to do other tasks. If the farmer has to purchase animals for the sole purpose of irrigation, Persian wheels are more economical than hand pumps (in terms of cost per unit of water delivered), but not as good as other options.

The diesel example also assumes an irrigation pumping requirement of 30 m^3/day in the critical month with a total head of 15 m. The entire diesel system is replaced in year 10 for all diesel cases. Total annual costs for the diesel system for both the average and remote cases were calculated in Table 3.12. The smallest available diesel pump is considerably oversized for this application and the present worth of all costs incurred over the 20 year period are only slightly lower than worst case costs incurred with a Persian wheel. If the diesel system is located in a remote area costs are even higher than worst case Persian wheel costs.

A range of PV pumps were considered. The modules are assumed to last the full 20 years with the pump/motor subsystem being replaced in year 10 for both surface and submersible systems. Daily output for the PV pumps varies with the total pumping head and the level of insolation. At a 15 m head a well designed 600 W_p surface system should deliver approximately 30 m^3/day, a 1,000 W_p system approximately 55 m^3/day, and a 1,400 W_p system approximately 75 m^3/day over a standard solar day with insolation levels of 6 kWh/m^3. Similar submersible systems should deliver slightly more. For an irrigation water pumping requirement of 30 m^3/day, a PV water pump is the least cost option, if the cost of caring for the animals is factored into the total cost for a Persian wheel.

The relative costs of various systems on the North American market have not changed considerable since this study was done. Module prices have dropped approximately 1.3 US$/$W_p$ as discussed previously making PV systems even more economical. Surface pumps designed for use with PV systems are about the same price. Retail prices on submersible pumps designed for PV systems were quoted at approximately $3,000 to $4,000 (including controllers) compared to $2,000 suggested by Thomas (1988). The decrease in array costs compensates for the increased pump cost even for small submersible systems. The smallest diesel engine found was 5.0 kW, quoted at 5,124 US$ or 1,024 US$/kW before installation and delivery compared to $4,000 US$ for a 2.5 kW system (1,600 US$/kW) after installation and delivery quoted by Thomas (1988).

Direct information was not available for comparison of PV system costs with the cost of extending the electrical grid. Figures 3.17 and 3.18 are included here as a rough guide. The graph in Figure 3.17 was developed for use by utilities in the United States. It assumes typical costs in 1992 US$ for PV systems and grid extensions. To use this graph the average energy requirement in kWh/month is plotted against the distance to the existing electrical grid. PV systems are more economical below the dividing line where energy requirements are low and distance to the grid is high.

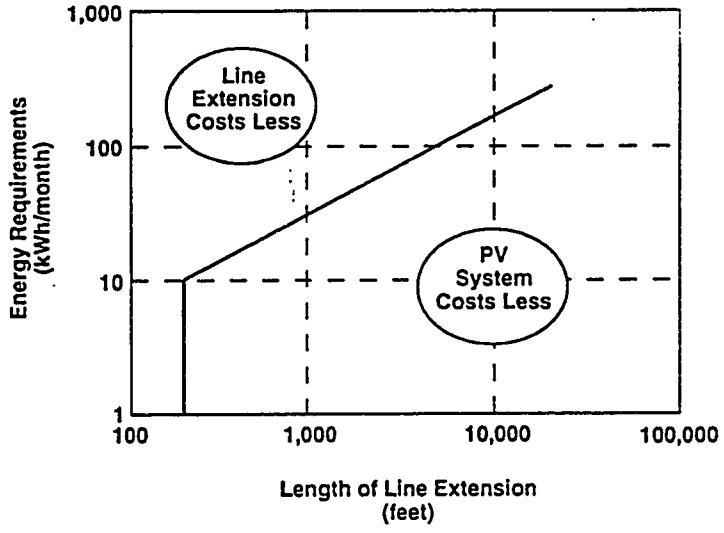


Figure 3.17 Comparative Cost of PV and Electric Systems (Stokes et al., 1993)

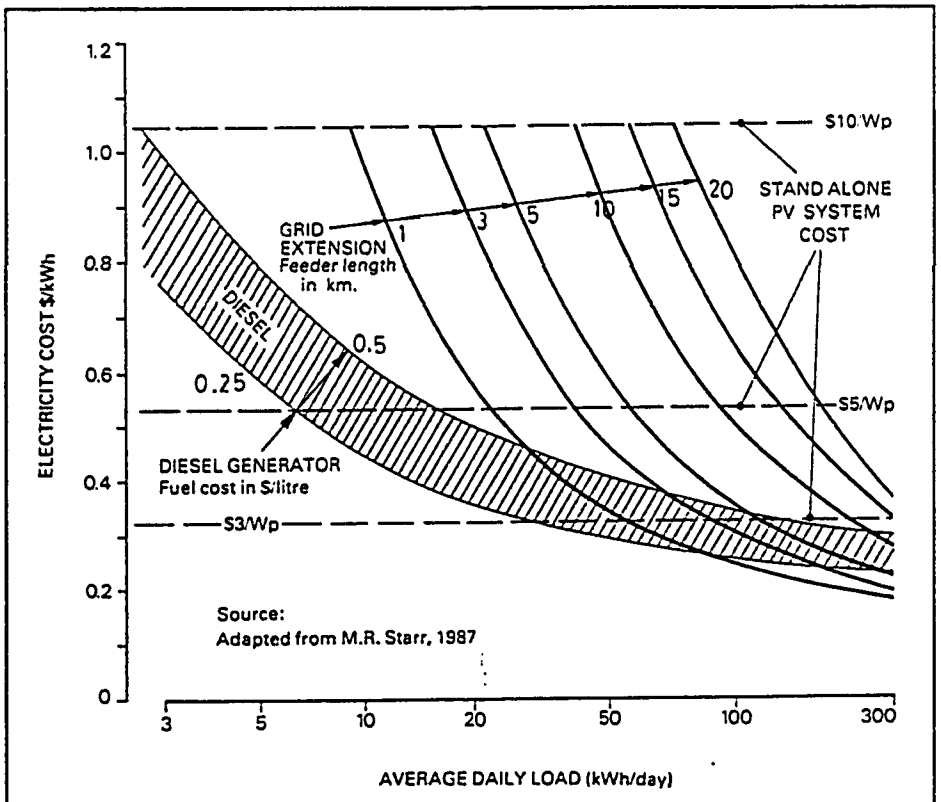


Figure 3.18 Comparative Costs of PV, Diesel and Electric Power (Derrick et al., 1989)

Figure 3.18 shows the cost of electricity in $/kWh compared to the average daily load in kWh/day, for various PV, diesel and electrical cases. This graph is not specific to any given year or location because the prices of different inputs can be varied. The graph considers Array costs of 3, 5 and 10 $/$W_p$, diesel fuel costs ranging from 0.25 to 0.5 $/*l* and grid extensions between 1 and 20 km. To use this graph a vertical line is drawn through the average daily load in kWh/day and the least cost option is chosen for the given conditions of array and fuel costs, and distance to the electrical grid.

3.10 COMPARING COSTS FOR INDIA AND NORTH AMERICA

Pricing information for PV systems was obtained during a trip to India in late 1993. The purpose of this visit was to explore opportunities for joint ventures with indigenous Indian companies for the manufacture of solar products. At the time, the World Bank had agreed to funding totalling 195 million US$ to be administered by IREDA for development of alternative energy markets in India. The PV component of the project was designed to allow local companies to import and manufacture PV components in high volume thus reducing overall costs and further to work with financing agencies to provide soft loans to end users and reduce the burden of high capital expenses. On top of this the MNES was providing subsidies for PV water pumps used for irrigation. These were both long term projects and are still ongoing. A number of meetings were arranged with various manufacturing companies, government authorities from IREDA and the MNES, international development authorities, local consulting economists, PV specialists and local Indian farmers. Much of the pricing information presented here was gleaned from these meetings as well as confidential dealer pricing and internal documents intended for limited circulation only. Direct references to commercial companies and organizations have therefore been eliminated.

Table 3.16 shows a typical cost estimate for 30 pumping systems design to fulfill the requirements of the MNES program. This estimate is based on 1993 prices in US dollars and assumes a sale of at least 30 pumps. It includes the cost of the pump/motor subsystem, the array and the BOS component, but does not include installation, shipping, tariffs, or taxes. All components are made in North America. The pumps are brushed DC surface pumps directly connected to an 816 W_p array. The array is fixed with 3 seasonal adjustments and is made up of sixteen 51 W_p modules. Note that BOS components are approximately 15% of the array cost. The systems were expected to supply approximately 65 m^3/day of water at a 10 m head under full sunlight conditions of 6 kWh/m^2. Total cost

Component	Cost	Per	Quantity	Subtotal
Pump (Surface Centrifugal)	533.62	unit	30.00	16,008.60
PV Modules (51 Wp)	310.00	unit	480.00	148,800.00
BOS Components				
Fixed Post Mount	265.56	unit	60.00	15,933.60
Post	10.16	unit	60.00	609.60
Poly Pipe	3.05	metre	384.00	1,171.20
Pump Cable	2.20	metre	118.00	259.60
Wire (AWG 10)	0.57	metre	780.00	444.60
Wire (AWG 14)	0.61	metre	120.00	73.20
Ground Wire	1.04	metre	390.00	405.60
Junction Box & Terminal Block	52.14	unit	60.00	3,128.40
Ground Rod	8.53	unit	60.00	511.80
Subtotal (BOS Components)				22,537.60
TOTAL (30 Units)				**187,346.20**

Table 3.16 Sample Quote for PV Water Pumping System (1993 US$)

was estimated at 6,245 US$ per system. At retail prices, the same system would cost approximately 7,458 US$.

A table of exchange rates for India, the United States and Canada dating back to 1985 is included in Appendix T. These rates were obtained from the most recent United Nations Statistical Yearbook (1995). The Indian government introduced trade reforms which devalued the rupee, in an attempt to increase exports in 1991. The rupee has been stable since 1993 when the government amended the Foreign Exchange Regulation Act. The average exchange rate for 1993 is 30.5 Indian rupees (Rs) Per US dollar (US$). Equivalent system costs in 1993 Indian currency would be 190,425 Rs for a sale of 30 pumps, not including import tariffs or shipping.

Duties on finished solar panels and imported water pumps are 70% and 80% respectively (Indian High Commission, 1996; Department of Foreign Affairs, 1996). Duties decrease as opportunities for local manufacture or assembly increase. Duties on imported solar cells for local module construction are between 40% and 45%. Duties on imported

silicon wafers for solar cell manufacture are 30% (Battacharya, 1993b). Adding import tariffs, the total cost for array and pump alone would increase to 9,392 US$ (286,406 Rs). BOS components could presumably be supplied locally for about two thirds the North American price, bringing system costs to approximately 9,893 US$ (301,673 Rs) Total shipping weight for 30 pumps and 480 modules is approximately 7,680 lbs (3,500 kg). Shipping costs are estimated at approximately 1,500 US$. This brings total system costs to at least 9,943 US$(Rs. 303,203).

This price can be reduced by using locally manufactured modules. The average cost of modules manufactured in India in 1993 was approximately 200 Rs/W_p. The nearest array size is 800 W_p, bringing array costs to 160,000 Rs, up 6% from North American prices, but down 38% compared to the cost with import tariffs. The drop in array size is expected to reduce pump output to approximately 63 m^3/day at a 10 m head. Total shipping weight for the pumps alone is approximately 1,440 lbs (653 kg) and shipping costs are reduced to approximately 400 US$, bringing total systems costs to 6,722 US$ (204,967 Rs).

This exact system, with an Indian made array of 800 W_p and the same model pump from the same American manufacturer was quoted at 213,000 Rs. This allows a profit margin of only 4% compared to typical North American margins of 30% or more. At higher volume sales, the pump cost could be reduced to 500 US$. With import tariffs the pump cost would be 900 US$ (27,444 Rs), bringing total system costs to 6,661 US$ (203,122 Rs). Assuming some profit margin is included already in the array cost, profit on the remaining portion of the system is approximately 23% which is assumed to be reasonable by Indian standards. The results of this analysis are summarized in Table 3.17.

Table 3.18 shows prices quoted for various pumping systems designed to fulfill the requirements of the MNES project. These are compared to retail prices for similar systems

Description of Estimate	1993 Unit Capital Cost	
	US $	Indian Rs
Retail Price (North American Market)	7,458	227,417
Discount Price for 30 Systems (North American Market)	6,245	190,425
Discount Price with Shipping & Import Tarrifs (North American Pump & Array, Local BOS Components)	9,943	303,203
Discount Price with Shipping & Import Tarrifs (North American Pump, Local Array & BOS Components)	6,722	204,967
Discount Price for 100 Pumps with Shipping and Import Tarrifs (North American Pump, Local Array & BOS Components)	6,661	203,122
Price Quoted for Indian Market	6,985	213,000

Table 3.17 Cost Estimates for Pumping Systems: India and North America (1993)

in North America. All quotes are in 1993 Rs and US$. The first set of systems uses an American made DC surface pump with Indian made modules similar to the systems described above. In general, prices on the Indian market are about 7% less than similar systems in North America. Price differences increase with system size. The second set of quotes is based entirely on foreign components from a North American distributer who went out of business earlier the same year and sold off all equipment stock. This likely accounts for the high price difference between earlier retail price quotes from the same company and prices quoted for the Indian market. Equipment sources for the third and fourth quotes are unknown and cannot be compared to North American prices. The final system is entirely Indian made. The cost of this system on the Indian market is unknown. An estimate of 9,700 US$ (295,782 Rs) was obtained for a single unit packed in seaworthy containers and ready for shipment from Bombay (Kirloskar Brothers Ltd., 1994). It is assumed that this system would cost less on the Indian market.

Based on this study PV pumping system costs in India are assumed to be similar to, or slightly less expensive than North American prices in spite of shipping requirements and high import tariffs. Appendix U contains price estimates and expected daily output for a range of PV pumping systems. Three types of pumping systems were considered:

System Description	Expected Output at 9 m Head (m3/day)	Price Quote for India (1993 Rs)	Retail Price for North America (1993 US$)	Percent Decrease in Cost for India
DC Surface Pump, 720 Wp Array	56.2	197,000	6,634	-3%
DC Surface Pump, 800 Wp Array	62.4	213,000	7,458	-6%
DC Surface Pump, 880 Wp Array	86.6	229,000	8,280	-9%
DC Surface Pump, 600 Wp Array	59.4	183,000	9,804	-39%
DC Surface Pump, 900 Wp Array Both System with Passive Tracking	90.9	239,000	14,475	-46%
Submersible Pump, 576 Wp Array	44	165,000		
Submersible Pump, 864 Wp Array	67	222,000		
DC Surface Pump, Array Size Unknown	69.3	239,000		
DC Surface Pump, 900 Wp Array with Daily Manual Tracking	87.3			

Table 3.18 Price Comparisons for PV Systems in North America and India

DC surface centrifugal pumps, DC submersible centrifugal pumps, and AC submersible centrifugal pumps. The tables are based on manufacturers data showing estimated output at specific insolation levels using the best possible system configuration for a range of heads and flows. Price estimates assume individual sales. Pump pricing is based on retail prices from North American manufacturers and distributors. Module pricing is based on best available dealer prices plus 30%, for a sales volume equal to the number of modules required for the system. BOS components are likely to be less expensive in India than in North America, and are therefore estimated at 10% of array costs (after markup) as opposed to 15% (the standard value used in North America). All prices are in 1994 US$ and equivalent 1994 Indian Rs. The India/US exchange rate for 1994 is 31.4 Rs/US$.

Note that 1994 system costs shown in Appendix U are not significantly different from those derived from 1987 data (Table 3.11), keeping in mind that BOS component costs are estimated at 10% in Appendix U instead of the usual 15%. Modules costs have dropped since 1987, but pump prices (particularly for the submersible pumps) are higher. Costs for larger systems are approximately 10% to 20% lower in Appendix U, while smaller systems

are the same price or higher.

The costs of other remote pumping options on the Indian market have been estimated from a number of sources. Table 3.19 lists estimates for diesel pumping systems obtained from a literature review. Note that the cost of a diesel system in India is considerably less than a similar system in North America. Thomas (1988) estimated the cost of a 2.5 kW diesel system at 4,000 US$. The India/US exchange rate at that time was 13.0 Rs/US$. A diesel system in India would therefore be expected to cost 51,868 Rs or 20,747 Rs/kW. Instead, estimates from the literature show diesel costs at 1,400 Rs/kW (1983) and 2,503 Rs/kW (1989) less than one tenth of the equivalent North American price. More recently, the cost of a 5.0 kW diesel engine in North America was quoted at 5,124 US$ or 1,024 US$/kW. Using the 1994 exchange rate of 31.4, a diesel engine in India would be expected to cost 32,127 Rs/kW. Instead costs were estimated at 1,187 Rs/kW (1991) and 2,682 Rs/kW (1992), again, less than one tenth of the North American price. This substantial price reduction suggests the relative viability of PV irrigation systems in India will be much lower than comparable systems in North America.

Other quotes of interest were for tube wells: 4,000 Rs for a 5 to 8 m depth (Kwant and van der Toorn, 1983), 1,500 US$ (19,440 Rs) for a 20 m well (Cabraal, 1987), and 9,700 Rs for and unknown depth in the Hyderabad area (Ravi Babu et al., 1995). Quotes

Engine Power (hp)	Engine Power (kW)	Cost (Rs.)	Unit Cost (Rs/kW)	Maintenance as % of Capital	O & M as % of Capital	Fuel Consumption (l/kWhr)	Fuel Cost (Rs/l)	Source
5.0	3.7	5,220	1,400	6.5		0.34		Kwant and van der Toorn (1983)
				10.0	20			Bhattacharjee (1985)
7.5	5.6	14,000	2,503	10.0				World Bank (Pakistan Study) (1989)
5.0	3.7	7,036	1,887		25	0.25		Sinha and Kandpal (1991)*
5.0	3.7	10,000	2,682	5.0			7.0	Raju and Associates (1992)**
							5.6	World Bank (1992)

* Diesel engine size is assumed

** Diesel engine assumed to be rated the same as pump

Table 3.19 Cost Estimates for Diesel Systems in India

Pump Power (hp)	Pump Type	Pump Cost (Rs.)	Maintenance as % of Capital	O & M as % of Capital	Electricity Rates (Rs/hp/month)	Electricity Rates (Rs/month)	Source
		6,000	5.4			75	Kwant and van der Toorn (1983)
			2.5	7.5			Bhattacharjee (1985)
				17.7			Sinha and Kandpal (1991)
5	Surface	8,000	5.0				Raju and Associates (1992)
5	Submersible	10,000	5.0				Raju and Associates (1992)
7.5		13,500			15		Ravi Babu et al. (1995)

Table 3.20 Cost Estimates for Electric Pumps in India

for electric pumps are listed in Table 3.20. The cost of purchasing a bullock for irrigation via a Persian wheel in Pakistan was estimated at 5,000 Rs and the cost of fodder for one year at 8,300 Rs (World Bank, 1989). The average wage of an unskilled male agricultural labourer in India (for hand pump irrigation) was approximately 23.3 Rs/day or 0.74 US$/day in 1990 (United Nations, 1995). Ravi Babu et al. (1995) reported labour costs of 15 Rs/day were typical in the Hyderabad area.

Appendix V lists relevant interest rates and estimated inflation rates for India dating back from 1994 to 1965. These were taken from the 1995 International Financial Statistics Yearbook, published by the International Monetary Fund and the 1994 Statistical Yearbook for Asia and the Pacific, published by the United Nations. The bank rate is set by the central bank and is the minimum rate of interest charged to chartered banks, money market dealers and investment dealers. The money market is a sector of the capital market in which short term capital is raised and invested and short term securities are traded. The lending rate is higher than either the bank or money market rates and is more reflective of the cost to consumers of taking out a loan. The interest rate for this study was set equal to the latest bank rate at 12%. This rate has been stable since 1991. The lending rate, averaging 16.4 % over the last 20 year period, would be used to determine annual payments on an loan for the financial study, but in all cases the Indian farmer is eligible for special rates ranging from 5 to 12% under various subsidy programs.

The consumer price index is also listed in Appendix V. The consumer price index is a measure of the change in retail prices of goods and services and can be used as an indicator of inflation. The estimated inflation rate was calculated using Equation 3.31 below where q_t is the inflation rate for year t and CPI_t is the consumer price index for year t.

$$q_t = \frac{CPI_t}{CPI_{(t-1)}} - 1 \qquad (3.31)$$

The average inflation rate is approximately 7.9% over the last 20 year period and 8.8% over the last 10 year period. For the purposes of this study inflation will be set to 8%. The net discount rate is the interest rate minus the general inflation rate and for this study is assumed to be 4%. Note that higher discount rates favour options which postpone payment, and lower discount rates favour options with high initial costs. Since solar energy requires a large initial investment, it tends to be favoured by a low discount rate.

A number of studies comparing long term costs of photovoltaics to other remote pumping options use a differential inflation rate for fuel under the assumption that fuel cost will inevitably rise at a faster rate than other goods. For the purposes of comparison, Appendix V also lists the general consumer price index for the last 10 years against the indexes for fuel and light and for food. The price indexes have been used to estimate the average inflation rates over the last 10 year period. Note that the average inflation rate for fuel and light is not significantly different from the overall inflation rate. This suggests that a differential fuel inflation rate is not appropriate for India.

Before proceeding further with economic comparisons of remote pumping options for India, actual water pumping requirements will be determined for a specific crop.

3.11 CROPS SUITABLE FOR PV DRIP IRRIGATION

Table 3.21 lists a number of crops that have been tested with drip irrigation systems and the results of those tests. When considering crops suitable for PV drip irrigation the most important considerations are the amount of water required and the value of the crop. From this table it is apparent that sugarcane, banana, pomegranate, masambi and groundnut all have relatively high irrigation water requirements (over 500 mm annually even under drip irrigation) and are not likely to be suitable for use with a photovoltaic pump. The crops with the lowest water requirements are watermelon, tomatoes, grapes, chillies, and cucumbers using 190 mm, 222 mm, 278 mm, 290 mm, and 343 mm respectively.

Table 3.22 (taken from the 1985-86 Indian Agricultural Census) lists average number of holdings, total area of holdings and average farm size for most major crops in India, along with the percent irrigated area for each type of crop. Of the crops with low water requirements, only grapes and chillies are considered major crops in India. There are some 22,000 vineyards in India and 1,822,000 farms growing chillies. Average farm sizes for these crops are 0.45 ha and 0.27 ha respectively. Referring back to Section 3.1 (Figure 3.2) 0.45 ha farms are closer to the range generally considered viable for PV pumps than the 0.27 ha chilly farms. In addition, grapes are a permanent crop requiring a year round water supply, a characteristic which also tends to enhance viability for a PV pump. A full 100% of all grape farms are irrigated, compared to only 37.4% of all farms growing chillies. This is likely due to the requirement for a year round water supply, but also suggests grapes may be more highly valued.

Table 3.23 shows the area covered by drip irrigation for different crops in Maharashtra, India's largest state, from 1985 to 1993. Grapes top the list with 8,617 ha under drip irrigation. This represents 27.8% of the total area of all crops under drip irrigation Maharashtra. Grapes are followed by sugarcane, orange/lemon citrus (masambi),

COST/BENEFIT ANALYSIS FOR IMPORTANT CROPS UNDER DRIP IRRIGATION

		Water Melon	Tomato	Grapes	Chillies	Cucumber	Groundnut	Masambi	Pomegranate	Banana	Sugarcane	Sugarcane
Location		Pune	Pune	Jalgaon	Pune	Pune	Pune	Dr. SK	Mahrastra	Bhadgaon	Pune	Dr RK
Data Source		MPAU	MPAU	Farm Data	MPAU	MPAU	MPAU	Sivanappan		SR Patil	Deccan Sugar	Sivanappan
Fixed cost		33,700	21,000	32,500	32,500	32,500	32,000	20,000	18,000	30,000	30,000	25,000
Life (Seasons)	a	10	10	10	6	10	5	10	5	5	5	5
Depreciation	b	3,370	2,100	3,250	5,417	3,250	6,400	2,000	3,600	6,000	6,000	5,000
Interest	c	2,022	630	1,950	1,950	1,950	1,920	1,200	1,080	1,800	1,800	1,500
Repairs & Maint	d	674	420	650	650	650	640	400	360	600	600	500
Total	e=b+c+d	6,066	3,150	5,850	8,017	5,850	8,960	3,600	5,040	8,400	8,400	7,000
Cost of Cultivation (Rs/ha)	f	16,475	10,840	51,000	8,935	16,000	6,650	3,800	17,500	34,600	11,445	11,250
Seasonal Total Cost DR (Rs/ha)	g=e+f	22,541	13,990	56,850	16,952	21,850	15,610	7,400	22,540	43,000	19,845	18,250
Seasonal Total Cost FL (Rs/ha)	h	11,790	12,120	60,000	10,600	11,300	7,450	5,400	12,500	40,000	17,375	15,000
Water used DRIP (mm)	i	190	222	278	290	343	580	640	785	970	940	1,540
Water used FLOOD (mm)	j	330	324	532	780	600	900	1,660	1,440	1,760	2,150	3,000
Yield DRIP (qt/ha)	k	580	480	325	29	280	32	150,000	109	875	1,700	1,000
Yield FLOOD (qt/ha)	l	240	320	264	20	180	17	100,000	75	575	1,280	720
Selling Price DR (Rs/qt)	m	200	150	1,500	2,000	200	800	1	1,000	300	31	33
Selling Price FL (Rs/qt)	n	200	150	1,450	2,000	200	800	1	750	300	30	33
Income from Produce DR (Rs)	o=km	116,000	72,000	487,500	58,000	56,000	25,600	111,000	109,000	262,500	52,700	32,500
Income from Produce FL (Rs)	p=ln	48,000	48,000	382,800	40,000	36,000	13,400	53,000	56,250	172,500	38,400	23,400
Net Seasonal Income DR (Rs)	q=o-g	93,459	58,010	430,650	41,048	34,150	9,990	103,600	86,460	219,500	32,855	14,250
Net Seasonal Income FL (Rs)	r=p-h	36,210	35,880	322,800	29,400	24,700	5,950	47,600	43,750	132,500	21,025	8,400
Additional Area Cultivated with Water Savings DR (ha)	s	0.7	0.4	0.9	1.5	0.7	0.5	1.5	0.8	0.8	2.0	0.9
Net Additional Income DR (Rs)	t=sq	65,421	23,204	387,585	61,573	23,905	4,995	155,400	69,168	175,600	65,710	13,395
Gross Benefit/Cost Ratio DR	u=o/g	5.15	5.15	8.58	3.42	2.56	1.64	15.00	4.84	6.10	2.66	1.78
Gross Cost/Benefit Ratio FL	v=p/h	4.07	3.96	6.38	3.77	3.19	1.80	9.81	4.50	4.31	2.21	1.56
Net Profit/mm Water Used DR	w=q/i	491.89	261.31	1,549.10	141.55	99.56	17.22	161.88	110.14	226.29	34.95	9.25
Net Profit/mm Water Used FL	x=r/j	109.73	110.74	606.77	37.69	41.17	6.61	28.67	30.38	75.28	9.78	2.80
Net extra Income from DRIP	y=q+t-r	122,670	45,334	495,435	73,221	33,355	9,035	211,400	111,878	262,600	77,540	19,245

Table 3.21 Crops Under Drip Irrigation (NCPA, 1990)

Crop	Number of Holdings (1,000)	Area of Holdings (1,000 Ha)	Average Holding Size (Ha)	Percent of Holdings Irrigated
TOTAL	97155	164562	1.69	24.6%
TEMPORARY CROPS				
Rice	43388	42226	0.97	41.2%
Sorghum (Jowar)	13841	17124	1.24	4.4%
Millet (Bajra)	7828	11412	1.46	6.5%
Maize	11395	5736	0.50	19.4%
Finger Millet (Ragi)	2492	2125	0.85	9.6%
Wheat	24020	23680	0.99	73.4%
Barley	3170	1381	0.44	50.8%
Tur	7313	3495	0.48	3.3%
Chickpeas (Grams)	7758	7232	0.93	18.7%
Sugarcane		2957		84.2%
Black Pepper	2292	174	0.08	4.6%
Chillies	1822	495	0.27	37.4%
Ginger	495	35	0.07	17.1%
Tumeric	310	12	0.04	50.0%
Potatoes	2244	668	0.30	49.6%
Sweet Potatoes	205	45	0.22	4.4%
Cassave	1655	120	0.07	4.2%
Onions	332	107	0.32	64.5%
Groundnuts	5637	6675	1.18	12.4%
Castorbeans	290	261	0.90	23.0%
Sesameseed	2437	1553	0.64	7.7%
Rapeseed/Mustard	4147	2904	0.70	55.1%
Linseed	1513	1033	0.68	1.9%
Cotton	4251	7414	1.74	27.8%
Jute	2201	879	0.40	20.5%
Opium	48	8	0.17	100.0%
Tobacco	361	228	0.63	53.5%
Tea	31	403	13.00	1.7%
PERMANENT CROPS				
Citrus Fruits	396	10	0.03	50.0%
Mangoes	3968	256	0.06	6.3%
Bananas	3551	236	0.07	41.9%
Grapes	22	10	0.45	100.0%

Table 3.22 Cropwise Number and Area of Holdings (Agricultural Census, 1986)

pomegranate and banana. These crops had the highest water requirements of those tested in Table 3.21 and are not considered suitable for PV irrigation. None of the remaining crops cover more than 5% of the total land area under drip irrigation. Table 3.23 indicates that a substantial proportion of farmers are willing to invest in a capital intensive drip irrigation system for growing grapes, another indication that grapes are a highly valued crop.

Crop	Area (ha)	Percent
Grape	8,617	27.8
Sugarcane	4,650	15.0
Orang/Lemon Citrus	4,495	14.5
Pomegranate	3,565	11.5
Banana	2,790	9.0
Sapota	1,395	4.5
Vegetables	1,085	3.5
Mango	775	2.5
Coconut	775	2.5
Guava	558	1.8
Betelvine	403	1.3
Others (Fig Ber, Apple, etc.)	1,891	6.1
Total	30,999	100.0

Table 3.23 Area Covered by Various Crops Under Drip Irrigation in Maharashtra State (Magar, 1995)

Referring back to Table 3.21, grapes show the highest net profit per mm of water used whether grown under drip or flood irrigation. Expected profits for grapes are 1,549 Rs/mm of water under drip irrigation and 607 Rs/mm under flood irrigation. The nearest competitors are watermelon at 492 Rs/mm and tomato at 261 Rs/mm (both under drip irrigation). The lowest is groundnut at 17 Rs/mm under drip irrigation.

Grapes also show the highest net seasonal income at 430,650 Rs, almost twice that of the nearest competitor (bananas at 219,500 Rs), and the highest net extra income from the use of drip irrigation over surface irrigation. If profits from extra land cultivated with the water savings are included the annual net extra income from drip irrigation over surface irrigation is 495,435 Rs (followed by bananas at 262,600 Rs). If this additional cultivated area is not included the annual net extra income is 107,850 Rs (followed by bananas at 87,000 Rs).

3.12 CASE STUDY: GRAPES

Of all crops tested under drip irrigation in India, grapes were considered the most suitable for irrigation with a PV water supply. The reasons for focusing on grapes for PV drip irrigation are listed below.

- A number of studies have been done on the use of drip irrigation for grapes in India and data on cultivation costs, crop coefficients, and crop yields are available from the literature.
- Because grapes are a widely spaced crop, water savings resulting from the use of drip irrigation are high.
- Average farm sizes for grape cultivation are in the range generally considered viable for PV irrigation. India wide, average grape farm size is approximate 0.5 ha (Table 3.8). Ravi Babu et al. (1995) report grape farm sizes between 1.1 and 2.2 ha in Maharashtra state.
- Chauhan (1995) reported that the maximum scope for drip irrigation in India was in fruit crops covering approximately 2.5 million ha. Worldwide, grapes occupy more land area than any other single fruit and account for nearly half of all fruit production (Ravi Babu et al, 1995).
- Grapes are considered a major crop in India. Ten years ago there were approximately 22,000 grape farms occupying 10,000 ha of land India wide (Indian Agricultural Census, 1986).
- There is now 8,617 ha of land on which grapes are grown using drip irrigation in Maharashtra state alone. In Maharashtra grapes occupy 27.8% of all land under drip irrigation (Magar, 1995).
- Grape growing regions tend to be clustered together, making it easier to set up servicing networks for PV systems. (Of the 8,617 ha of drip irrigated grape farms in Maharashtra, 7,000 ha are located in the Nasik district (Magar, 1995).)

- Many grape growers are already familiar with drip irrigation systems and do not have to start from scratch on the learning curve. (Most grape growers in the Nasik district adopted drip irrigation systems in 1987 after facing 7 water shortages due to lowering of the ground water table (Magar, 1995).)
- Grapes are a perennial crop and irrigation water requirements are therefore spread out over the entire year minimizing the unit cost of water for a solar pumping system.
- Grapes are a high value cash crop and therefore likely to generate sufficient returns for timely repayment of loans.

The first step in determining the economic viability of PV drip irrigation systems for grape cultivation is calculation of crop water requirements (ET_{grape}). This was done in Section 3.12.1 by multiplying the reference crop evapotranspiration rate (ET_o) by the appropriate crop coefficient (kc). Irrigation water requirements (calculated in Section 3.12.2) are equal to crop water requirements minus effective precipitation. The critical design month for different remote pumping options is determined in Section 3.12.3. In Section 3.12.4 critical month water pumping requirements for a drip irrigation system are calculated. Water pumping requirements for a drip irrigation system are considerably lower than irrigation water requirements for other methods of irrigation. Critical month water pumping requirements are calculated for all 42 stations where relevant climatic data was available.

Detailed pump sizings are done only for stations considered suitable for grape cultivation. This is determined in Section 3.12.5 on the basis of temperature, relative humidity, precipitation and soils. Detailed pump sizings are done in Section 3.12.6 for PV, diesel, animal and human powered pumps using both drip and surface irrigation. A life cycle cost comparison is done in Section 3.12.7 to determine the least cost pumping option for farms between 0.5 and 2.0 ha. In Section 3.12.8 a full cost-benefit analysis is

preformed for farms growing grapes under PV drip irrigation. The cost-benefit analysis shows whether long term income from grape cultivation justifies the expense of the pump and irrigation system. In Section 3.12.9 the pump sizings and cost-benefit analysis are repeated for systems using a ground water source.

3.12.1 Crop Water Requirements for Grapes

Tables used for the calculation of crop water requirements from reference crop evapotranspiration are attached in Appendix X. Crop water requirements for grapes (ET_{grape}) were found by multiplying the reference crop evapotranspiration rate (ET_o) by the crop coefficient (kc). The resulting daily crop water requirements for grapes (ET_{grape}) in mm/day are listed in Table 3.24.

Crop coefficients for grapes were taken from Doorenbos and Pruitt (1977). This source gives different coefficients for different climatic regions. Climates are categorized according to temperature (hot areas versus areas with light frosts), humidity and average winds. To determine which stations fit into each category, stations were sorted on the basis of minimum temperature, wind speed, and combined average annual relative humidity and precipitation. Areas with minimum temperature below 0°C were categorized as "light frost". Areas with average annual wind speeds in excess of 10 m/s were considered to have "strong winds". To determine whether a station was humid or dry, stations were sorted and ranked individually on the basis of average annual relative humidity and precipitation. The rankings were then added and the stations resorted. Stations with the lowest combined ranking were considered dry. In general, these stations had average annual relative humidity less than 50% and average annual precipitation less than 800 mm/year. Appendix W contains the sorted tables for identification of various climatic regions and the crop coefficients for each region.

GRAPES - Crop Evapotranspiration, ETcrop, (mm/day)

Max 7 49
Min 0 00

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	5	0.00	0.00	0.90	2.71	4.32	5.20	3.73	2.75	2.50	1.74	0.88	0.00
2	5	Ahmadabad Airport	23.1	72.6	55	5	0.00	0.00	0.99	2.79	4.64	4.63	2.92	2.35	2.28	2.01	1.20	0.00
3	9	Akola Airport	20.7	77.1	309	5	0.00	0.00	1.01	2.86	4.78	4.86	2.82	2.42	2.21	1.98	1.26	0.00
4	13	Allahabad Airport	25.5	81.7	98	5	0.00	0.00	0.92	2.67	4.20	4.62	3.22	2.50	2.30	1.69	0.89	0.00
5	19	Amini Divi	11.1	72.7	4	6	0.00	0.00	1.03	2.40	3.34	3.06	2.93	2.83	2.49	1.73	1.19	0.00
6	21	Amritsar Airport	31.6	74.9	234	5	0.00	0.00	0.68	2.40	4.31	5.20	4.01	3.20	2.39	1.55	0.70	0.00
7	37	Bangalore Airport	13.0	77.6	897	5	0.00	0.00	1.02	2.45	3.31	2.95	2.50	2.41	1.94	1.48	1.01	0.00
8	59	Bhopal Airport	23.3	77.4	523	5	0.00	0.00	1.03	2.90	5.28	5.32	2.75	2.09	2.16	1.99	1.14	0.00
9	64	Bikaner	28.0	73.3	224	7	0.00	0.00	1.45	3.48	5.73	7.49	5.94	4.71	3.84	2.52	1.25	0.00
10	69	Bombay-Colaba	18.9	72.8	11	5	0.00	0.00	0.99	2.49	3.65	3.16	2.20	2.03	1.94	1.87	1.29	0.00
11	70	Bombay-Santacruz	19.1	72.9	14	5	0.00	0.00	1.04	2.75	4.05	3.32	2.29	2.07	1.97	1.89	1.31	0.00
12	75	Calcutta-Alipore	22.5	88.3	6	5	0.00	0.00	0.93	2.48	3.58	2.87	2.59	2.28	1.82	1.47	0.94	0.00
13	76	Calcutta-Dum Dum	22.7	88.5	6	5	0.00	0.00	0.88	2.50	3.63	2.91	2.64	2.29	1.84	1.48	0.96	0.00
14	97	Cuttack	20.5	85.9	27	5	0.00	0.00	0.92	2.44	3.83	3.25	2.45	2.29	1.93	1.56	1.00	0.00
15	48	Belgaum Airport	15.9	74.6	747	5	0.00	0.00	0.96	2.32	3.29	2.85	2.08	2.08	1.89	1.62	1.23	0.00
16	112	Dibrugarh Airport	27.5	95.0	111	5	0.00	0.00	0.63	1.48	2.20	2.45	2.51	2.45	1.70	1.26	0.71	0.00
17	126	Gannavaram Airport	16.5	80.8	24	5	0.00	0.00	1.02	2.61	4.20	4.08	3.19	2.92	2.26	1.76	1.21	0.00
18	127	Gauhati Airport	26.1	91.6	54	5	0.00	0.00	0.75	1.96	2.71	2.67	2.76	2.53	1.91	1.45	0.78	0.00
19	131	Gao-Panjim	15.5	73.8	60	5	0.00	0.00	1.01	2.55	3.63	2.72	2.27	2.34	2.04	1.81	1.41	0.00
20	153	Hyderabad-Begumpet	17.5	78.5	545	5	0.00	0.00	1.09	2.87	4.66	4.59	3.24	2.87	2.26	1.90	1.20	0.00
21	156	Indore Airport	22.7	75.8	567	6	0.00	0.00	1.05	3.05	6.16	5.89	3.15	2.37	2.36	2.01	1.12	0.00
22	158	Jagdalpur	19.1	82.0	553	5	0.00	0.00	0.97	2.50	3.67	3.23	2.23	2.00	1.79	1.59	1.04	0.00
23	159	Jaipur Airport	26.8	75.8	390	7	0.00	0.00	1.46	3.25	4.98	5.62	3.78	3.02	3.03	2.36	1.34	0.00
24	172	Jodhpur	26.3	73.0	217	7	0.00	0.00	1.58	3.57	6.09	7.03	4.93	3.95	3.57	2.65	1.61	0.00
25	194	Kodaikanal	10.2	77.5	2343	6	0.00	0.00	0.75	1.58	2.17	2.17	1.82	1.84	1.41	0.99	0.70	0.00
26	200	Kota Airport	25.2	75.9	274	7	0.00	0.00	1.60	3.93	6.26	6.86	4.36	3.18	3.13	2.59	1.56	0.00
27	209	Madras- Minambakkam	13.0	80.2	16	5	0.00	0.00	1.06	2.65	3.83	4.20	3.59	3.15	2.51	1.72	1.10	0.00
28	231	Minicoy	8.3	73.0	2	5	0.00	0.00	0.93	2.17	2.85	2.82	2.81	2.92	2.35	1.79	1.25	0.00
29	239	Nagpur Airport	21.1	79.1	310	5	0.00	0.00	1.05	2.88	4.96	4.55	2.80	2.28	2.14	1.92	1.17	0.00
30	250	New Dehli - Safdarjung	28.6	77.2	216	5	0.00	0.00	0.88	2.75	4.39	5.14	3.65	2.86	2.46	1.75	0.92	0.00
31	256	Okha	22.5	69.1	7	6	0.00	0.00	0.91	2.28	4.11	4.00	3.10	2.68	2.51	1.86	1.33	0.00
32	122	Fort Cochin	10.0	76.2	3	5	0.00	0.00	0.99	2.14	2.39	2.15	1.91	1.93	1.81	1.49	1.16	0.00
33	271	Patna Airport	25.6	85.1	60	5	0.00	0.00	0.94	2.92	4.45	4.40	3.26	2.77	2.26	1.67	0.98	0.00
34	278	Port Blair	11.7	92.7	79	5	0.00	0.00	0.93	2.21	2.34	2.38	2.31	2.15	1.73	1.51	1.13	0.00
35	281	Pune Airport	18.6	73.9	593	6	0.00	0.00	1.17	3.15	5.32	4.50	2.81	2.58	2.19	2.00	1.26	0.00
36	314	Shillong	25.6	91.9	1600	5	0.00	0.00	0.60	1.68	2.30	2.05	2.02	1.79	1.38	1.01	0.56	0.00
37	320	Silchar - Khumbhigram	24.9	93.0	97	5	0.00	0.00	0.81	1.97	2.64	2.56	2.64	2.37	1.92	1.39	0.86	0.00
38	325	Srinagar Airport	34.0	74.8	1668	5	0.00	0.00	0.36	1.23	2.40	3.56	3.48	2.86	1.88	0.98	0.38	0.00
39	340	Trivandrum Airport	8.5	77.0	8	5	0.00	0.00	0.90	1.90	2.50	2.28	2.29	2.49	2.15	1.50	1.03	0.00
40	342	Tuticorin	8.8	78.2	4	6	0.00	0.00	1.04	2.51	3.91	4.78	4.87	4.51	3.27	2.10	1.30	0.00
41	352	Veraval	20.9	70.4	8	6	0.00	0.00	1.02	2.46	4.01	4.29	2.88	2.55	2.50	2.11	1.40	0.00
42	353	Vishakhapatnam	17.7	83.2	3	5	0.00	0.00	1.09	2.84	4.16	3.65	3.02	3.00	2.27	1.85	1.31	0.00

Table 3.24 Crop Water Requirements for Grapes, ETgrape (mm/day)

3.12.2 Irrigation Water Requirements for Grapes

To find average monthly irrigation requirements the daily crop water requirements were multiplied by the number of days in the month and total effective precipitation (found in Section 3.4) was subtracted off. Tables used for the calculation of irrigation water requirements can be found in Appendix X. The results are shown in Table 3.25.

Note from Table 3.21 that the annual irrigation water requirement for grapes under flood irrigation in Jalgaon is reported as 532 mm (NCPA,1990). The nearest station to Jalgaon is Akola (Station 3). The annual irrigation water requirement calculated in Table 3.25 for Akola is 530 mm.

3.12.3 Critical Month

The critical month for a diesel, hand or animal powered irrigation system is the month with the highest irrigation water requirement. The maximum daily water requirement in m^3/day for a 1 ha plot and the critical month in which they occur are listed in Table 3.26 for each station. Table 3.26 also lists total annual irrigation water requirements in m^3. Total annual irrigation water requirements are used for calculation of annual fuel costs for a diesel system or annual operating costs for a hand or animal powered pump.

The critical month for design of a PV irrigation system is the month with the highest ratio of water required to sunlight available. It was found by dividing the monthly average of daily irrigation water requirements for a 1 ha plot by the average monthly solar energy availability on an optimally tilted array. The month with the maximum value is the critical month for a PV irrigation system. The results for a PV system are listed in Table 3.27.

GRAPES - Average Monthly Irrigation Requirement (mm/month)

Max 220.5
Min 0.0

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	3	Agra Airport	27.2	78.0	169	5	0.0	0.0	28.0	81.2	133.9	149.2	0.0	0.0	39.4	54.0	26.3	0.0	512.1
2	5	Ahmadabad Airport	23.1	72.6	55	5	0.0	0.0	30.7	83.6	143.9	137.1	0.0	7.3	67.2	62.2	35.9	0.0	568.0
3	9	Akola Airport	20.7	77.1	309	5	0.0	0.0	31.3	85.9	148.1	69.1	0.0	0.0	10.2	61.3	37.7	0.0	443.5
4	13	Allahabad Airport	25.5	81.7	98	5	0.0	0.0	28.5	80.1	130.1	124.7	0.0	0.0	0.0	52.4	26.7	0.0	442.4
5	19	Amini Divi	11.1	72.7	4	6	0.0	0.0	31.9	71.9	84.7	0.0	0.0	0.0	14.4	0.0	19.2	0.0	222.1
6	21	Amritsar Airport	31.6	74.9	234	5	0.0	0.0	14.4	72.0	131.6	150.5	7.3	10.0	63.3	48.0	21.1	0.0	518.2
7	37	Bangalore Airport	13.0	77.6	897	5	0.0	0.0	31.5	66.6	40.1	46.3	27.0	5.4	0.0	0.0	30.3	0.0	247.2
8	59	Bhopal Airport	23.3	77.4	523	5	0.0	0.0	31.9	87.1	163.7	109.2	0.0	0.0	0.0	61.6	34.1	0.0	487.7
9	64	Bikaner	28.0	73.3	224	7	0.0	0.0	44.8	104.3	177.6	220.5	159.7	121.8	115.3	78.1	37.4	0.0	1059.6
10	69	Bombay-Colaba	18.9	72.8	11	5	0.0	0.0	30.6	74.6	113.3	0.0	0.0	0.0	0.0	57.9	38.8	0.0	315.1
11	70	Bombay-Santacruz	19.1	72.9	14	5	0.0	0.0	32.2	82.4	125.6	0.0	0.0	0.0	0.0	41.3	39.2	0.0	320.7
12	75	Calcutta-Alipore	22.5	88.3	6	5	0.0	0.0	28.3	58.5	53.5	0.0	0.0	0.0	0.0	0.0	28.2	0.0	168.4
13	76	Calcutta-Dum Dum	22.7	88.5	6	5	0.0	0.0	21.4	70.0	73.8	0.0	0.0	0.0	0.0	0.0	28.7	0.0	193.8
14	97	Cuttack	20.5	85.9	27	5	0.0	0.0	28.6	71.9	88.7	0.0	0.0	0.0	0.0	0.0	30.1	0.0	219.3
15	48	Belgaum Airport	15.9	74.6	747	5	0.0	0.0	29.7	59.1	67.5	0.0	0.0	0.0	0.0	18.9	19.7	0.0	194.9
16	112	Dibrugarh Airport	27.5	95.0	111	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	18.2
17	126	Gannavaram Airport	16.5	80.8	24	5	0.0	0.0	31.7	78.4	130.3	71.8	3.6	4.3	0.0	0.0	25.6	0.0	345.7
18	127	Gauhati Airport	26.1	91.6	54	5	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	16.7	22.7	0.0	45.9
19	131	Gao-Panjim	15.5	73.8	60	5	0.0	0.0	31.3	76.4	112.4	0.0	0.0	0.0	0.0	33.4	42.4	0.0	295.9
20	153	Hyderabad-Begumpet	17.5	78.5	545	5	0.0	0.0	33.7	86.1	140.6	82.5	0.0	5.6	0.0	34.3	36.0	0.0	418.8
21	156	Indore Airport	22.7	75.8	567	6	0.0	0.0	32.5	91.5	191.0	117.0	0.0	0.0	1.8	62.5	33.6	0.0	529.8
22	158	Jagdalpur	19.1	82.0	553	5	0.0	0.0	29.9	51.8	85.7	0.0	0.0	0.0	0.0	13.1	31.2	0.0	211.6
23	159	Jaipur Airport	26.8	75.8	390	7	0.0	0.0	45.2	97.6	154.5	164.5	8.4	12.5	77.7	73.2	40.1	0.0	673.6
24	172	Jodhpur	26.3	73.0	217	7	0.0	0.0	49.1	107.1	188.7	210.5	114.2	88.9	107.1	82.2	48.3	0.0	996.1
25	194	Kodaikanal	10.2	77.5	2343	6	0.0	0.0	17.2	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	19.6
26	200	Kota Airport	25.2	75.9	274	7	0.0	0.0	49.5	118.0	194.2	186.6	0.0	0.0	60.1	80.2	46.8	0.0	735.3
27	209	Madras- Minambakkam	13.0	80.2	16	5	0.0	0.0	32.8	79.4	118.7	106.3	60.7	33.1	15.1	0.0	0.0	0.0	446.1
28	231	Minicoy	8.3	73.0	2	5	0.0	0.0	28.7	51.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	79.8
29	239	Nagpur Airport	21.1	79.1	310	5	0.0	0.0	32.5	86.4	153.9	23.3	0.0	0.0	0.0	59.5	35.0	0.0	390.6
30	250	New Dehli - Safdarjung	28.6	77.2	216	5	0.0	0.0	27.4	82.5	136.0	145.3	7.4	3.9	43.3	54.1	27.6	0.0	527.5
31	256	Okha	22.5	69.1	7	6	0.0	0.0	28.2	68.5	127.4	120.0	61.8	75.8	75.2	57.6	39.9	0.0	654.5
32	122	Fort Cochin	10.0	76.2	3	5	0.0	0.0	21.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.5
33	271	Patna Airport	25.6	85.1	60	5	0.0	0.0	29.2	87.6	137.7	65.2	0.0	0.0	0.0	48.7	29.3	0.0	397.7
34	278	Port Blair	11.7	92.7	79	5	0.0	0.0	28.9	56.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85.2
35	281	Pune Airport	18.6	73.9	593	6	0.0	0.0	36.2	94.5	162.8	88.6	0.0	29.3	7.3	41.4	37.8	0.0	497.9
36	314	Shillong	25.6	91.9	1600	5	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.9	0.0	20.4
37	320	Silchar - Khumbhigram	24.9	93.0	97	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.7	0.0	25.7
38	325	Srinagar Airport	34.0	74.8	1668	5	0.0	0.0	0.0	0.0	41.8	92.8	89.2	61.6	49.2	27.9	11.4	0.0	373.8
39	340	Trivandrum Airport	8.5	77.0	8	5	0.0	0.0	21.2	0.0	12.4	0.0	0.0	17.1	22.3	0.0	0.0	0.0	73.0
40	342	Tuticorin	8.8	78.2	4	6	0.0	0.0	32.3	70.1	121.2	143.4	151.1	139.9	98.0	0.0	0.0	0.0	755.9
41	352	Veraval	20.9	70.4	8	6	0.0	0.0	31.5	73.8	124.5	118.8	0.0	65.6	74.9	65.4	41.9	0.0	596.3
42	353	Vishakhapatnam	17.7	83.2	3	5	0.0	0.0	33.8	85.1	129.0	65.5	24.7	25.2	0.0	0.0	33.8	0.0	397.0

Table 3.25 Irrigation Water Requirements for Grapes (mm/month)

Max 73.5
Min 0.0

GRAPES - Water Required for a 1 ha plot (m3/day)

Sta Eto	Sta Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Water Required for a 1 ha plot (m3/day) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max (m3/day)	Total (m3/yr)	Critical Month
1	3	Agra Airport	27.2	78.0	169	5	0.0	0.0	9.0	27.1	43.2	49.7	0.0	0.0	13.1	17.4	8.6	0.0	49.7	5,120.6	Jun
2	5	Ahmadabad Airport	23.1	72.6	55	5	0.0	0.0	9.9	27.9	46.4	45.7	0.0	2.4	22.4	20.1	12.0	0.0	46.4	5,679.8	May
3	9	Akola Airport	20.7	77.1	309	5	0.0	0.0	10.1	28.6	47.8	23.0	0.0	0.0	3.4	19.8	12.6	0.0	47.8	4,435.3	May
4	13	Allahabad Airport	25.5	81.7	98	5	0.0	0.0	9.2	26.7	42.0	41.6	0.0	0.0	0.0	16.9	8.9	0.0	42.0	4,424.4	May
5	19	Amini Divi	11.1	72.7	4	6	0.0	0.0	10.3	24.0	27.3	0.0	0.0	0.0	4.8	0.0	6.4	0.0	27.3	2,221.5	May
6	21	Amritsar Airport	31.6	74.9	234	5	0.0	0.0	4.6	24.0	42.5	50.2	2.4	3.2	21.1	15.5	7.0	0.0	50.2	5,182.2	Jun
7	37	Bangalore Airport	13.0	77.6	897	5	0.0	0.0	10.2	22.2	12.9	15.4	8.7	1.8	0.0	0.0	10.1	0.0	22.2	2,472.4	Apr
8	59	Bhopal Airport	23.3	77.4	523	5	0.0	0.0	10.3	29.0	52.8	36.4	0.0	0.0	0.0	19.9	11.4	0.0	52.8	4,876.9	May
9	64	Bikaner	28.0	73.3	224	7	0.0	0.0	14.5	34.8	57.3	73.5	51.5	39.3	38.4	25.2	12.5	0.0	73.5	10,595.7	Jun
10	69	Bombay-Colaba	18.9	72.8	11	5	0.0	0.0	9.9	24.9	36.5	0.0	0.0	0.0	0.0	18.7	12.9	0.0	36.5	3,151.2	May
11	70	Bombay-Santacruz	19.1	72.9	14	5	0.0	0.0	10.4	27.5	40.5	0.0	0.0	0.0	0.0	13.3	13.1	0.0	40.5	3,206.6	May
12	75	Calcutta-Alipore	22.5	88.3	6	5	0.0	0.0	9.1	19.5	17.3	0.0	0.0	0.0	0.0	0.0	9.4	0.0	19.5	1,684.4	Apr
13	76	Calcutta-Dum Dum	22.7	88.5	6	5	0.0	0.0	6.9	23.3	23.8	0.0	0.0	0.0	0.0	0.0	9.6	0.0	23.8	1,938.3	May
14	97	Cuttack	20.5	85.9	27	5	0.0	0.0	9.2	24.0	28.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	28.6	2,192.6	May
15	48	Belgaum Airport	15.9	74.6	747	5	0.0	0.0	9.6	19.7	21.8	0.0	0.0	0.0	0.0	6.1	6.6	0.0	21.8	1,948.6	May
16	112	Dibrugarh Airport	27.5	95.0	111	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	6.1	182.0	Nov
17	126	Gannavaram Airport	16.5	80.8	24	5	0.0	0.0	10.2	26.1	42.0	23.9	1.2	1.4	0.0	0.0	8.5	0.0	42.0	3,457.4	May
18	127	Gauhati Airport	26.1	91.6	54	5	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	5.4	7.6	0.0	7.6	458.9	Nov
19	131	Goa-Panjim	15.5	73.8	60	5	0.0	0.0	10.1	25.5	36.3	0.0	0.0	0.0	0.0	10.8	14.1	0.0	36.3	2,958.9	May
20	153	Hyderabad-Begumpet	17.5	78.5	545	5	0.0	0.0	10.9	28.7	45.3	27.5	0.0	1.8	0.0	11.1	12.0	0.0	45.3	4,188.4	May
21	156	Indore Airport	22.7	75.8	567	6	0.0	0.0	10.5	30.5	61.6	39.0	0.0	0.0	0.6	20.1	11.2	0.0	61.6	5,297.7	May
22	158	Jagdalpur	19.1	82.0	553	5	0.0	0.0	9.6	17.3	27.6	0.0	0.0	0.0	0.0	4.2	10.4	0.0	27.6	2,116.2	May
23	159	Jaipur Airport	26.8	75.8	390	7	0.0	0.0	14.6	32.5	49.8	54.8	2.7	4.0	25.9	23.6	13.4	0.0	54.8	6,735.7	Jun
24	172	Jodhpur	26.3	73.0	217	7	0.0	0.0	15.8	35.7	60.9	70.2	36.8	28.7	35.7	26.5	16.1	0.0	70.2	9,960.8	Jun
25	194	Kodaikanal	10.2	77.5	2343	6	0.0	0.0	5.5	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	5.5	196.4	Mar
26	200	Kota Airport	25.2	75.9	274	7	0.0	0.0	16.0	39.3	62.6	62.2	0.0	0.0	20.0	25.9	15.6	0.0	62.6	7,352.9	May
27	209	Madras- Minambakkam	13.0	80.2	16	5	0.0	0.0	10.6	26.5	38.3	35.4	19.6	10.7	5.0	0.0	0.0	0.0	38.3	4,460.7	May
28	231	Minicoy	8.3	73.0	2	5	0.0	0.0	9.3	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0	797.5	Apr
29	239	Nagpur Airport	21.1	79.1	310	5	0.0	0.0	10.5	28.8	49.6	7.8	0.0	0.0	0.0	19.2	11.7	0.0	49.6	3,905.7	May
30	250	New Delhi - Safdarjung	28.6	77.2	216	5	0.0	0.0	8.6	27.5	43.9	48.4	2.4	1.3	14.4	17.5	9.2	0.0	48.4	5,275.1	Jun
31	256	Okha	22.5	69.1	7	6	0.0	0.0	9.1	22.8	41.1	40.0	19.9	24.4	25.1	18.6	13.3	0.0	41.1	6,545.0	May
32	122	Fort Cochin	10.0	76.2	3	5	0.0	0.0	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	215.1	Mar
33	271	Patna Airport	25.6	85.1	60	5	0.0	0.0	9.4	29.2	44.4	21.7	0.0	0.0	0.0	15.7	9.8	0.0	44.4	3,976.9	May
34	278	Port Blair	11.7	92.7	79	5	0.0	0.0	9.3	18.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.8	852.1	Apr
35	281	Pune Airport	18.6	73.9	593	6	0.0	0.0	11.7	31.5	52.5	29.5	0.0	9.5	2.4	13.3	12.6	0.0	52.5	4,979.1	May
36	314	Shillong	25.6	91.9	1600	5	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.0	5.6	203.7	Nov
37	320	Silchar - Khumbhigram	24.9	93.0	97	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	0.0	8.6	257.3	Nov
38	325	Srinagar Airport	34.0	74.8	1666	5	0.0	0.0	0.0	0.0	13.5	30.9	26.8	19.9	16.4	9.0	3.8	0.0	30.9	3,738.4	Jun
39	340	Trivandrum Airport	8.5	77.0	8	5	0.0	0.0	6.8	0.0	4.0	0.0	0.0	5.5	7.4	0.0	0.0	0.0	7.4	730.4	Sep
40	342	Tuticorin	8.8	78.2	4	6	0.0	0.0	10.4	23.4	39.1	47.8	48.7	45.1	32.7	0.0	0.0	0.0	48.7	7,559.3	Jul
41	352	Veraval	20.9	70.4	8	6	0.0	0.0	10.2	24.6	40.1	39.6	0.0	21.2	25.0	21.1	14.0	0.0	40.1	5,983.0	May
42	353	Vishakhapatnam	17.7	83.2	3	5	0.0	0.0	10.9	28.4	41.6	21.8	8.0	8.1	0.0	0.0	11.3	0.0	41.6	3,970.1	May

Table 3.26 Critical Month for a Diesel, Hand or Animal Powered Irrigation System

Critical Month for PV = Maximum Irrigation Water Requirement for a 1 ha Plot / Solar Energy Availability on an Optimally Tilted Array (m3 / Peak Sun Hours)

St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Irrigation Water Requirement/Solar Energy Availability on an Optimally Tilted Array (m3/Peak Sun Hours)												Max	Critical Month
							Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1	3	Agra	27.2	78.1	169	5	0.00	0.00	1.31	3.91	6.39	8.32	0.00	0.00	2.19	2.50	1.20	0.00	8.32	Jun
2	4	Ahmadabad	23.1	72.6	55	5	0.00	0.00	1.46	3.96	6.36	7.15	0.00	0.51	3.94	2.81	1.58	0.00	7.15	Jun
3	5	Akola	20.7	77.0	282	5	0.00	0.00	1.46	4.11	6.90	3.90	0.00	0.00	0.66	3.04	1.74	0.00	6.90	May
4	7	Allahabad	25.5	81.7	98	5	0.00	0.00	1.37	3.82	5.95	7.08	0.00	0.00	0.00	2.45	1.22	0.00	7.08	Jun
5	8	Amini Divi	11.1	72.7	4	6	0.00	0.00	1.61	3.97	5.43	0.00	0.00	0.00	0.97	0.00	1.19	0.00	5.43	May
6	9	Amritsar	31.6	74.9	234	5	0.00	0.00	0.75	3.52	5.87	7.41	0.37	0.51	3.32	2.24	1.03	0.00	7.41	Jun
7	14	Bangalor	13.0	77.6	897	5	0.00	0.00	1.51	3.38	2.12	3.12	2.07	0.38	0.00	0.00	1.70	0.00	3.38	Apr
8	21	Bhopal	23.3	77.4	503	5	0.00	0.00	1.49	4.16	7.36	6.11	0.00	0.00	0.00	2.84	1.48	0.00	7.36	May
9	24	Bikaner	28.0	73.3	224	7	0.00	0.00	1.97	4.55	7.27	9.49	7.36	5.75	5.24	3.25	1.67	0.00	9.49	Jun
10	26	Bombay	19.1	72.9	14	5	0.00	0.00	1.46	3.65	5.34	0.00	0.00	0.00	0.00	2.89	1.81	0.00	5.34	May
11	26	Bombay	19.1	72.9	14	5	0.00	0.00	1.54	4.03	5.92	0.00	0.00	0.00	0.00	2.06	1.83	0.00	5.92	May
12	27	Calcutta	22.7	88.5	6	5	0.00	0.00	1.51	3.11	2.83	0.00	0.00	0.00	0.00	0.00	1.53	0.00	3.11	Apr
13	27	Calcutta	22.7	88.5	6	5	0.00	0.00	1.14	3.72	3.90	0.00	0.00	0.00	0.00	0.00	1.56	0.00	3.90	May
14	34	Cuttack	20.5	85.9	24	5	0.00	0.00	1.40	3.66	4.21	0.00	0.00	0.00	0.00	0.00	1.44	0.00	4.21	May
15	36	Dharwar	15.4	75.1	679	5	0.00	0.00	1.40	3.07	3.57	0.00	0.00	0.00	0.00	1.09	1.01	0.00	3.57	May
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	1.02	Nov
17	39	Gannavaram	16.5	80.8	24	5	0.00	0.00	1.58	3.93	6.44	4.72	0.24	0.27	0.00	0.00	1.34	0.00	6.44	May
18	40	Gauhati	26.1	91.6	54	5	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.91	1.16	0.00	1.16	Nov
19	41	Goa	15.5	73.8	55	5	0.00	0.00	1.48	3.69	5.39	0.00	0.00	0.00	0.00	1.73	1.96	0.00	5.39	May
20	56	Hyderabad	17.5	78.5	545	5	0.00	0.00	1.60	4.19	6.61	4.96	0.00	0.36	0.00	1.76	1.74	0.00	6.61	May
21	59	Indore	22.7	75.8	567	6	0.00	0.00	1.50	4.25	8.38	6.50	0.00	0.00	0.11	2.86	1.48	0.00	8.38	May
22	61	Jagadalpur	19.1	82.0	553	5	0.00	0.00	1.37	2.53	4.29	0.00	0.00	0.00	0.00	0.72	1.57	0.00	4.29	May
23	62	Jaipur	26.8	75.8	390	7	0.00	0.00	2.09	4.60	7.12	9.02	0.52	0.78	4.10	3.14	1.68	0.00	9.02	Jun
24	69	Jodhpur	26.3	73.0	224	7	0.00	0.00	2.28	4.93	8.26	10.17	6.08	4.74	5.40	3.54	2.05	0.00	10.17	Jun
25	76	Kodaikanal	10.2	77.5	2345	6	0.00	0.00	0.78	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.78	Mar
26	79	Kota	25.2	75.5	257	7	0.00	0.00	2.23	5.43	8.40	9.26	0.00	0.00	3.25	3.54	2.02	0.00	9.26	Jun
27	86	Madras	13.0	80.2	16	5	0.00	0.00	1.56	3.94	6.00	6.36	3.84	2.02	0.93	0.00	0.00	0.00	6.36	Jun
28	89	Minicoy	8.3	73.0	2	5	0.00	0.00	1.55	2.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.98	Apr
29	92	Nagpur	21.2	79.1	311	5	0.00	0.00	1.57	4.30	7.35	1.44	0.00	0.00	0.00	2.94	1.59	0.00	7.35	May
30	97	New Dehli	28.6	77.2	216	5	0.00	0.00	1.40	4.15	6.77	8.67	0.44	0.23	2.44	2.51	1.25	0.00	8.67	Jun
31	99	Okha	22.5	69.1	7	6	0.00	0.00	1.36	3.36	6.03	6.97	4.14	5.05	4.15	2.62	1.79	0.00	6.97	Jun
32	100	Olukara	10.5	76.3	22	5	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	Mar
33	105	Patna	25.5	85.3	52	5	0.00	0.00	1.42	4.32	6.30	3.59	0.00	0.00	0.00	2.44	1.39	0.00	6.30	May
34	107	Port Blair	11.7	92.7	79	5	0.00	0.00	1.55	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.23	Apr
35	108	Pune	18.5	73.9	563	6	0.00	0.00	1.69	4.55	7.59	5.20	0.00	2.02	0.46	2.13	1.80	0.00	7.59	May
36	123	Shillong	25.6	91.9	1596	5	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.00	1.09	Nov
37	124	Silicuri	24.8	92.9	40	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.39	0.00	1.39	Nov
38	127	Srinagar	34.1	74.8	1587	5	0.00	0.00	0.00	0.00	2.15	4.72	4.51	3.17	2.68	1.44	0.65	0.00	4.72	Jun
39	134	Trivandrum	8.5	77.0	64	5	0.00	0.00	1.00	0.00	0.68	0.00	0.00	0.97	1.27	0.00	0.00	0.00	1.27	Sep
40	135	Tuticorin	8.8	78.2	4	6	0.00	0.00	1.50	3.39	5.93	7.66	7.85	7.02	5.24	0.00	0.00	0.00	7.85	Jul
41	142	Veraval	20.9	70.4	8	6	0.00	0.00	1.38	3.57	5.60	6.27	0.00	4.33	4.07	2.99	1.88	0.00	6.27	Jun
42	144	Vishakhapatnam	17.7	83.2	3	5	0.00	0.00	1.66	4.29	6.34	4.37	1.75	1.58	0.00	0.00	1.67	0.00	6.34	May

Table 3.27 Critical Month for a PV Irrigation System

3.12.4 Water Pumping Requirements

Doorenbos and Pruitt (1977) suggest that ET_{crop} can be reduced by up to 60% for widely spaced crops and young orchards with 30% ground cover on light, sandy soils under high evaporation conditions and frequent irrigation. All of the criteria which Doorenbos and Pruitt suggest cause reductions in ET_{crop} are satisfied by grapes under PV drip irrigation in India. First, grapes are a widely spaced crop. Typical spacing is about 3 m by 3 m (Khanha, 1993) depending on the type of grape. Second, soils used for grape cultivation are generally course loamy soils, light clay soils, or deep sandy or loamy soils (Indian Horticultural Guide, 1993; Ravi Babu et al., 1995). Third, evapotranspiration losses in India are relatively high. ET_{crop} accounts for evapotranspiration losses over the whole field, but with drip irrigation only the soil in the direct vicinity of the plant root zone is wetted, the area between plants remains dry and evapotranspiration losses are therefore significantly reduced. The higher the evapotranspiration rate, the greater the percent reduction in ET_{crop}. Finally, a PV irrigation system (without storage) is by necessity a system designed for frequent (daily) irrigation. Water is applied all day long at low flow rates which closely match evapotranspiration rates. All of these factors suggest that a significant reduction in ET_{crop} can be expected for grapes under drip irrigation in India.

Table 3.21 showed ET_{grape} reduced from 532 mm under flood irrigation to 278 mm under drip irrigation, a reduction of approximately 48%, based on farm from Jalgaon. These figures are referenced often in literature on drip irrigation and are quoted by Guyen and Ravishanker (1993), Sivanappan (1994, 1995), Surywanshi (1995) and Saskena (1995). ET_{grape} has therefore been lowered by 48% for calculation of water pumping requirements for grapes under drip irrigation

Pumping requirements were then increased to allow for losses and inefficiencies in the distribution and field application of water. Losses in the distribution system are often

assumed to be zero for drip irrigation as the water is conveyed directly to the plant root zone by a piped distribution system. For this study an application efficiency (EA_{drip}) of 95% was assumed to allow for possible cracks and leaks in the pipes due to less than adequate maintenance.

At least two studies have been done recently checking actual field emission uniformity (EU_{drip}) for drip systems operated by local farmers in India. Holsambre (1995) tested 12 systems in Maharashtra state and found emission uniformities ranging between 35 and 95%. Low emission uniformities (from 35 to 54%) were due to the wrong choice of pump, lack of screen filters, poor maintenance, or improper design on undulating topography. For systems on flat topography system design was not critical. Properly designed and maintained systems had emission uniformities ranging from 88 to 95%.

Dalvi, et al. (1995) surveyed 42 farmers in Maharashtra and found similar results. Of the farmers surveys 17% had emission uniformities greater than 90%, 55% had emission uniformities greater than 80%, and 91% had emissions uniformities over 70%. Low uniformity values were due to improper maintenance and filter problems rather than poor design. Dalvi, et al. noted that newer systems generally had lower efficiencies and farmers who were familiar with system operation and maintenance had better performance. This suggests that emission uniformity can be expected to increase over time as farmers learn proper maintenance.

For this study EU_{drip} was assumed to be 90%. This value is on the conservative end of typical ranges given for drip irrigation systems but appears to be representative of field conditions for a well designed and maintained systems in India. Lower emission uniformity in newer systems is not critical as the pumping systems are sized for mature plants and water requirements in the first few years are much lower. The overall irrigation efficiency ($E = EA_{drip} * EU_{drip}$) is therefore 0.86%.

Equation 3.32 was used to calculated water pumping requirements (Q_{crit}) in m^3/day for drip systems from irrigation water requirements (ET_{grape}) in m^3/day for the critical month. EA_{drip} is assumed to be 0.95 and EU_{drip} is assumed to be 0.90.

$$Q_{crit} = \frac{0.48 ET_{grape}}{EA_{drip} EU_{drip}} \quad (3.32)$$

Field application efficiency for a surface irrigation system ($EA_{surface}$) is assumed to be equal to 60%. This is considered representative of field conditions for a well run surface irrigation system in India. Reports of surface irrigation efficiencies below 50% are common in India. For a surface irrigation system Q_{crit} is calculated using Equation 3.33, where $EA_{surface}$ is assumed to be 0.60.

$$Q_{crit} = \frac{ET_{grape}}{EA_{surface}} \quad (3.33)$$

Table 3.28 shows critical month water pumping requirements in m^3/ha/day for PV, diesel, hand and animal powered pumps. Critical month water pumping requirements were calculated for both drip and surface irrigation methods. These values are used for pump sizings. Total annual water pumping requirements in m^3/ha/year were calculated for diesel, hand and animal powered pumps. These values are used to calculate annual operating costs.

Drip Irrigation		Surface Irrigation			PV Systems				Diesel, Hand and Animal Powered Pumps						
Water Savings =	48%	EAsurface =		0.60						Crop Water Requirement		Drip Irrigation Water Requirement		Surface Irrigation Water Requirement	
EAdrip =	0.95														
EUdrip =	0.90														
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Critical Month	Crop Water Req'ment (m3/ha/day)	Drip Irrigation Pumping Req'ment (m3/ha/day)	Surface Irrigation Pumping Req'ment (m3/ha/day)	Critical Month	Max Daily (m3/ha/day)	Total Annual (m3/ha/yr)	Max Daily (m3/ha/day)	Total Annual (m3/ha/yr)	Max Daily (m3/ha/day)	Total Annual (m3/ha/yr)
1	Agra	27.2	78.1	169	Jun	49.7	30.3	82.9	Jun	49.7	5,120.6	30.3	3,114.3	82.9	8,534.4
2	Ahmadabad	23.1	72.6	55	Jun	45.7	27.8	76.2	May	46.4	5,679.8	28.2	3,454.4	77.4	9,466.4
3	Akola	20.7	77.0	282	May	47.8	29.1	79.6	May	47.8	4,435.3	29.1	2,697.5	79.6	7,392.2
4	Allahabad	25.5	81.7	98	Jun	41.6	25.3	69.3	May	42.0	4,424.4	25.5	2,690.9	70.0	7,374.0
5	Amini Divi	11.1	72.7	4	May	27.3	16.6	45.5	May	27.3	2,221.5	16.6	1,351.1	45.5	3,702.4
6	Amritsar	31.6	74.9	234	Jun	50.2	30.5	83.6	Jun	50.2	5,182.2	30.5	3,151.7	83.6	8,637.0
7	Bangalor	13.0	77.6	897	Apr	22.2	13.5	37.0	Apr	22.2	2,472.4	13.5	1,503.7	37.0	4,120.7
8	Bhopal	23.3	77.4	503	May	52.8	32.1	88.0	May	52.8	4,876.9	32.1	2,966.1	88.0	8,128.2
9	Bikaner	28.0	73.3	224	Jun	73.5	44.7	122.5	Jun	73.5	10,595.7	44.7	6,444.2	122.5	17,659.5
10	Bombay	19.1	72.9	14	May	36.5	22.2	60.9	May	36.5	3,151.2	22.2	1,916.5	60.9	5,252.0
11	Bombay	19.1	72.9	14	May	40.5	24.6	67.5	May	40.5	3,206.6	24.6	1,950.2	67.5	5,344.4
12	Calcutta	22.7	88.5	6	Apr	19.5	11.9	32.5	Apr	19.5	1,684.4	11.9	1,024.4	32.5	2,807.4
13	Calcutta	22.7	88.5	6	May	23.8	14.5	39.7	May	23.8	1,938.3	14.5	1,178.9	39.7	3,230.5
14	Cuttack	20.5	85.9	24	May	28.6	17.4	47.7	May	28.6	2,192.6	17.4	1,333.5	47.7	3,654.4
15	Dharwar	15.4	75.1	679	May	21.8	13.3	36.3	May	21.8	1,948.8	13.3	1,185.2	36.3	3,248.0
16	Dibrugarh (Mohanbari)	27.5	95.0	111	Nov	6.1	3.7	10.1	Nov	6.1	182.0	3.7	110.7	10.1	303.4
17	Gannavaram	16.5	80.8	24	May	42.0	25.6	70.0	May	42.0	3,457.4	25.6	2,102.7	70.0	5,762.3
18	Gauhati	26.1	91.6	54	Nov	7.6	4.6	12.6	Nov	7.6	458.9	4.6	279.1	12.6	764.8
19	Goa	15.5	73.8	55	May	36.3	22.0	60.4	May	36.3	2,958.9	22.0	1,799.6	60.4	4,931.5
20	Hyderabad	17.5	78.5	545	May	45.3	27.6	75.6	May	45.3	4,188.4	27.6	2,547.3	75.6	6,980.7
21	Indore	22.7	75.8	567	May	61.6	37.5	102.7	May	61.6	5,297.7	37.5	3,222.0	102.7	8,829.5
22	Jagadalpur	19.1	82.0	553	May	27.6	16.8	46.1	May	27.6	2,116.2	16.8	1,287.1	46.1	3,527.0
23	Jaipur	26.8	75.8	390	Jun	54.8	33.3	91.4	Jun	54.8	6,735.7	33.3	4,096.6	91.4	11,226.1
24	Jodhpur	26.3	73.0	224	Jun	70.2	42.7	117.0	Jun	70.2	9,960.8	42.7	6,058.0	117.0	16,601.3
25	Kodaikanal	10.2	77.5	2345	Mar	5.5	3.4	9.2	Mar	5.5	196.4	3.4	119.5	9.2	327.4
26	Kota	25.2	75.5	257	Jun	62.2	37.8	103.7	May	62.6	7,352.9	38.1	4,471.9	104.4	12,254.8
27	Madras	13.0	80.2	16	Jun	35.4	21.6	59.1	May	38.3	4,460.7	23.3	2,712.9	63.8	7,434.4
28	Minicoy	8.3	73.0	2	Apr	17.0	10.3	28.4	Apr	17.0	797.5	10.3	485.0	28.4	1,329.2
29	Nagpur	21.2	79.1	311	May	49.6	30.2	82.7	May	49.6	3,905.7	30.2	2,375.4	82.7	6,509.4
30	New Dehli	28.6	77.2	216	Jun	48.4	29.5	80.7	Jun	48.4	5,275.1	29.5	3,208.3	80.7	8,791.9
31	Okha	22.5	69.1	7	Jun	40.0	24.3	66.7	May	41.1	6,545.0	25.0	3,980.6	68.5	10,908.3
32	Oltukara	10.5	76.3	22	Mar	6.9	4.2	11.6	Mar	6.9	215.1	4.2	130.8	11.6	358.5
33	Patna	25.5	85.3	52	May	44.4	27.0	74.0	May	44.4	3,976.9	27.0	2,418.7	74.0	6,628.1
34	Port Blair	11.7	92.7	79	Apr	18.8	11.4	31.3	Apr	18.8	852.1	11.4	518.2	31.3	1,420.2
35	Pune	18.5	73.9	563	May	52.5	31.9	87.5	May	52.5	4,979.1	31.9	3,028.2	87.5	8,298.5
36	Shillong	25.6	91.9	1598	Nov	5.6	3.4	9.4	Nov	5.6	203.7	3.4	123.9	9.4	339.5
37	Silicuri	24.8	92.9	40	Nov	8.6	5.2	14.3	Nov	8.6	257.3	5.2	156.5	14.3	428.8
38	Srinagar	34.1	74.8	1587	Jun	30.9	18.8	51.6	Jun	30.9	3,738.4	18.8	2,273.6	51.6	6,230.6
39	Trivandrum	8.5	77.0	64	Sep	7.4	4.5	12.4	Sep	7.4	730.4	4.5	444.2	12.4	1,217.4
40	Tuticorin	8.8	78.2	4	Jul	48.7	29.6	81.2	Jul	48.7	7,559.3	29.6	4,597.5	81.2	12,598.9
41	Veraval	20.9	70.4	8	Jun	39.6	24.1	66.0	May	40.1	5,963.0	24.4	3,626.6	66.9	9,938.4
42	Vishakhapatnam	17.7	83.2	3	May	41.6	25.3	69.4	May	41.6	3,970.1	25.3	2,414.5	69.4	6,616.8

Table 3.28 Critical Month Water Pumping Requirements for PV, Diesel, Hand and Animal Powered Pumps

3.12.5 Grape Growing Areas of India

Before detailed pump sizings were done, an effort was made to narrow the stations down so that only those considered well suited to grape production were considered. Stations considered potentially suitable for grape cultivation are shown in blue on the map in Figure 3.19. The location of grape cultivating areas was inferred from references made by various authors. Magar (1995) discussed grape cultivation in the state of Maharashtra but did not specify the exact location, Ravi Babu et al. (1995) discussed grape cultivation around the city of Hyderabad, and Khanha (1993) reported on studies in the Jalgaon area. This corresponds approximately to Stations 3, 20, 21, 29, 10, 11 and 35. All of these stations are located in the west central and coastal regions.

Further guidance was obtained from The Indian Horticultural Guide (1993) which states than grapes are grown in areas with cool, dry summers and mild winters, and do best in areas with low precipitation and relative humidity less than 40%. Ravi Babu et al. (1995) wrote that grapes require warm dry summers and cool rainy winters, further suggesting that the highest temperature should be 40.6°C and lowest temperature should be 4.4°C.

In Appendix Y stations are sorted by average annual relative humidity, precipitation, and maximum and minimum temperature. Stations considered potentially suitable for grape production are marked with an asterisk . Annual average relative humidity was over 40% for all stations. Relative Humidity was less than or approximately equal to 60% for stations 24, 26, 9, 23, 21, 3, 8, 2, 1, 30, 29, 4, 20, and 35 (from least to most humid). These stations were considered adequate for grape cultivation on the basis of relative humidity. Stations 10 and 11 (on the coast of Maharashtra state) were eliminated because they had an average annual relative humidity in excess of 70% and average annual rainfall totals in excess of 2,000 mm.

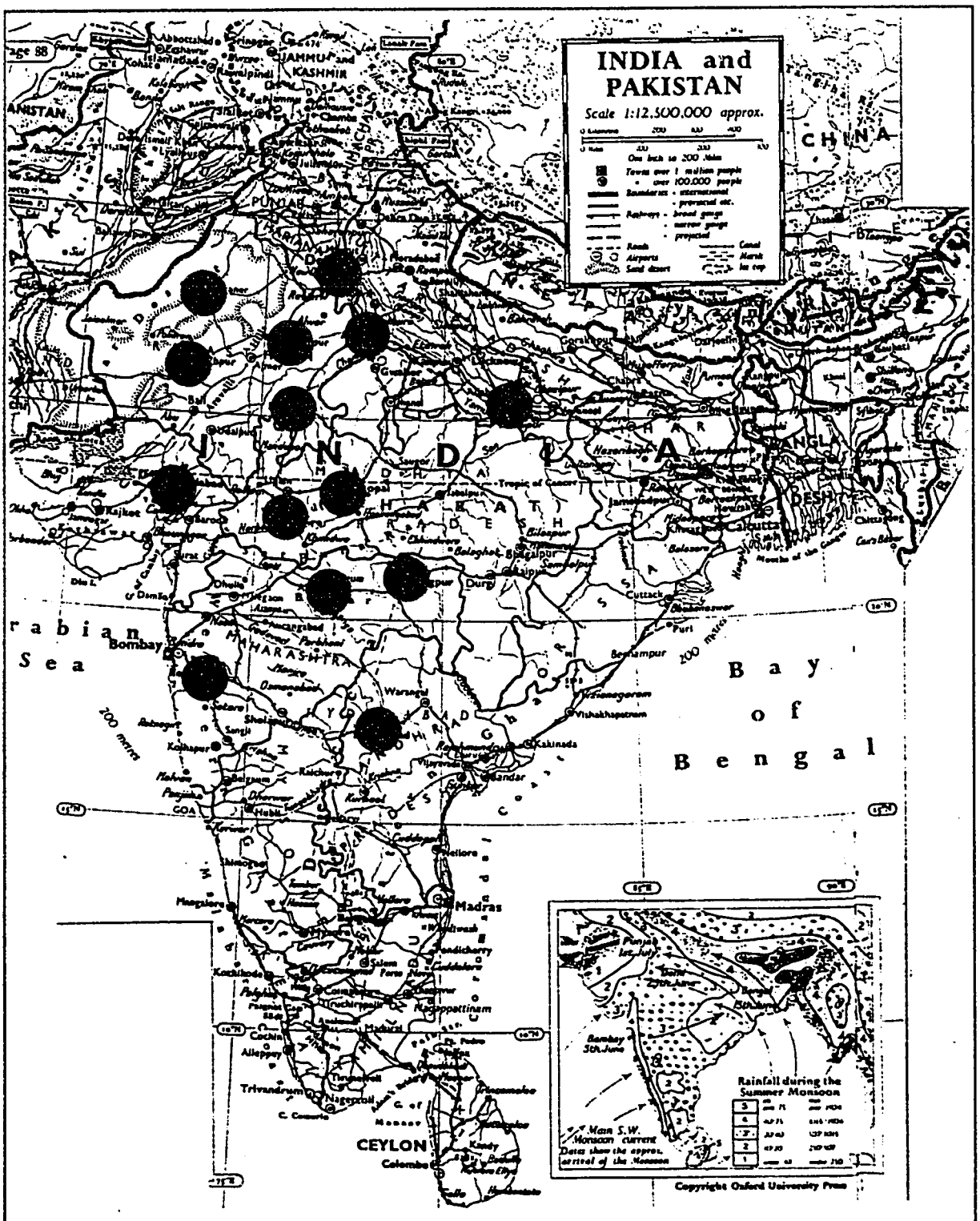


Figure 3.19 Stations Considered Suitable for Grape Cultivation

Temperature restrictions were considered next. The maximum temperature recorded over the 10 year period from 1958 to 1967 for all stations considered in this study was 42.4°C for Agra. This is slightly higher than the recommended 40.6°C, but the maximum temperature recorded for Jalgaon was 42.7°C and grapes are known to grow in Jalgaon. Maximum temperatures of 42.4°C were therefore considered suitable and no stations were eliminated using this criteria. Minimum temperature drops below 4.4°C only in Srinagar, which had already been eliminated on the basis of relative humidity and rainfall.

Looking at soil types, Ravi Babu et al. (1995) suggested grapes grow best on coarse textured loamy soils with free drainage. The Indian Horticultural Guide (1993) states that grapes are best suited to well drained loams, though light clay soils or deep sandy or loamy soils are acceptable. Stations 3, 20, 29 and 35 (taken from the references) are all located in the west central region where black or red soils predominate, as are Stations 2, 4, 8, 21, and 26 (found suitable based on climate). Black soils have a texture ranging from clay loam to clayey, with clay contents varying between 30 and 80% (Louis Berger International Inc., 1988). Red soils, such as those around Hyderabad (Station 20), are particularly well suited to grape production. These soil are generally well drained and range from loam to clay loam in texture (Louis Berger International Inc., 1988). Stations 1 and 30 are located in regions of alluvial soils which are generally rich in plant nutrients and well suited to most agricultural crops including fruit crops. Station 30 is located in Haryana, where soils are mostly loams or sandy loams and are thus well suited to grape production. Station 23 borders on the area between red/yellow soils, alluvial soils and desert soils and was also considered potentially suited to grape production. Stations 9 and 24 are located in the desert area of Rajastan. Soils in this region range from sandy to loamy fine sand and occasional sandy loam. Although marginal, these soils can be used for agriculture with careful application of fertilizers.

3.12.6 Pump Sizing (Surface Water Source)

Appendix Z contains pump sizings for PV, diesel, hand and animal powered pumps using both drip and surface irrigation. Table 3.29 shows a sample sizing for a PV pump using drip irrigation. Sizings were done for 0.5, 1.0, 1.5, and 2.0 ha farms. All pump sizings are based on water pumping requirements in the critical month. Only stations suitable for grape cultivation were considered. The results of the pump sizings are compared in Table 3.30. Pump sizings vary with location and are dependant on local evapotranspiration rates (and solar energy availability for PV pumps). Table 3.30 compares average capital costs for all stations where grape cultivation was considered viable.

Total water pumping head (H) for the drip irrigation system was assumed to be 16 m. This assumes a surface water source with minimal suction head and filter losses. Emitters for the drip irrigation systems are operated at pressure head of 1.25 kg/cm^2 or 12.5 m of water. Losses in the distribution system should be less than 15 to 20% (Melby, 1995) to ensure an even distribution of water. Total water pumping head for the surface irrigation system was assumed to be 2 m.

PV pump sizings depend on daily water requirements and insolation levels in the critical month. Pump outputs at various insolation levels were found by linear interpolation of manufacturer's data. The pump and array with the closest daily water output (that matched or exceeded the daily water pumping requirement) was chosen for each station. Costs for PV pumps were obtained from tables in Appendix U. Costs were calculated for DC surface pumping systems only since these are the least cost option with a surface water source. This is illustrated by the graph included in Appendix U which shows costs (in 1994 US$) for DC surface, DC submersible, and AC submersible pumps at various flow rates for a 15 m head.

Pump Sizing for Grapes, Drip Irrigation					0.5 ha Plot							Nearest Pump Size		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Crop Water Req'ment (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	DC Surface Pump Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	24.9	15.1	16	21.6	530	162,668
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	22.9	13.9	16	23.6	530	162,668
3	5	Akola	20.7	77.0	282	5	May	6.93	23.9	14.5	16	15.2	424	143,104
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	20.8	12.6	16	21.1	530	162,668
8	21	Bhopal	23.3	77.4	503	5	May	7.17	26.4	16.1	16	27.2	530	162,668
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	36.7	22.4	16	32.4	530	162,668
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	22.7	13.8	16	15.0	424	143,104
21	59	Indore	22.7	75.8	567	6	May	7.35	30.8	18.7	16	28.1	530	162,668
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	27.4	16.7	16	22.1	530	162,668
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	35.1	21.3	16	26.0	530	162,668
26	79	Kota	25.2	75.5	257	7	Jun	6.72	31.1	18.9	16	25.1	530	162,668
29	92	Nagpur	21.2	79.1	311	5	May	6.75	24.8	15.1	16	25.2	530	162,668
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	24.2	14.7	16	14.7	530	162,668
35	108	Pune	18.5	73.9	563	6	May	6.92	26.3	16.0	16	26.0	530	162,668
AVERAGE								6.66	27.0	16.4	16	23.1	515	159,673

Pump Sizing for Grapes, Drip Irrigation					1.0 ha Plot							Nearest Pump Size		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Crop Water Req'ment (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	DC Surface Pump Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	49.7	30.3	16	34.1	742	213,993
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	45.7	27.8	16	29.9	636	188,331
3	5	Akola	20.7	77.0	282	5	May	6.93	47.8	29.1	16	32.9	636	188,331
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	41.6	25.3	16	27.0	636	188,331
8	21	Bhopal	23.3	77.4	503	5	May	7.17	52.8	32.1	16	34.3	636	188,331
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	73.5	44.7	16	48.9	742	213,993
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	45.3	27.6	16	32.5	636	188,331
21	59	Indore	22.7	75.8	567	6	May	7.35	61.6	37.5	16	42.7	742	213,993
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	54.8	33.3	16	34.7	742	213,993
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	70.2	42.7	16	46.3	848	188,331
26	79	Kota	25.2	75.5	257	7	Jun	6.72	62.2	37.8	16	38.7	742	213,993
29	92	Nagpur	21.2	79.1	311	5	May	6.75	49.6	30.2	16	31.9	636	188,331
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	48.4	29.5	16	31.6	742	213,993
35	108	Pune	18.5	73.9	563	6	May	6.92	52.5	31.9	16	32.9	636	188,331
AVERAGE								6.66	54.0	32.8	16	35.6	697	199,329

Pump Sizing for Grapes, Drip Irrigation					1.5 ha Plot							Nearest Pump Size		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Crop Water Req'ment (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	DC Surface Pump Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	74.6	45.4	16	49.4	1,060	282,008
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	68.6	41.7	16	42.9	848	239,656
3	5	Akola	20.7	77.0	282	5	May	6.93	71.7	43.6	16	46.5	848	239,656
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	62.4	37.9	16	39.4	848	239,656
8	21	Bhopal	23.3	77.4	503	5	May	7.17	79.2	48.2	16	59.7	1,060	282,008
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	110.2	67.1	16	72.0	1,060	282,008
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	68.0	41.4	16	46.0	848	239,656
21	59	Indore	22.7	75.8	567	6	May	7.35	92.4	56.2	16	61.2	1,060	282,008
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	82.2	50.0	16	50.2	1,060	282,008
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	105.3	64.0	16	65.7	1,272	331,539
26	79	Kota	25.2	75.5	257	7	Jun	6.72	93.3	56.7	16	63.9	1,272	331,539
29	92	Nagpur	21.2	79.1	311	5	May	6.75	74.5	45.3	16	45.3	848	239,656
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	72.6	44.2	16	46.0	1,060	282,008
35	108	Pune	18.5	73.9	563	6	May	6.92	78.8	47.9	16	57.5	1,060	282,008
AVERAGE								6.66	81.0	49.3	16	53.3	1,015	273,958

Pump Sizing for Grapes, Drip Irrigation					2.0 ha Plot							Nearest Pump Size		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Crop Water Req'ment (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	DC Surface Pump Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	99.5	60.5	16	63.3	1,484	381,070
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	91.4	55.6	16	60.7	1,272	331,539
3	5	Akola	20.7	77.0	282	5	May	6.93	95.6	58.1	16	66.0	1,272	331,539
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	83.2	50.6	16	55.6	1,272	331,539
8	21	Bhopal	23.3	77.4	503	5	May	7.17	105.6	64.2	16	68.3	1,272	331,539
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	147.0	89.4	16	93.0	1,484	381,070
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	90.7	55.2	16	57.0	1,060	282,008
21	59	Indore	22.7	75.8	567	6	May	7.35	123.2	74.9	16	78.0	1,484	381,070
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	109.6	66.7	16			
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	140.4	85.4	16			
26	79	Kota	25.2	75.5	257	7	Jun	6.72	124.4	75.7	16			
29	92	Nagpur	21.2	79.1	311	5	May	6.75	99.3	60.4	16	64.2	1,272	331,539
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	96.9	58.9	16	59.1	1,484	381,070
35	108	Pune	18.5	73.9	563	6	May	6.92	105.0	63.9	16	65.9	1,272	331,539
AVERAGE								6.66	108.0	65.7	16	66.5	1,330	345,047

Table 3.29 Sample Pump Sizing: PV Pump with Drip Irrigation

	PV PUMP	DIESEL PUMP		PERSIAN WHEEL*		PERSIAN WHEEL**		HAND PUMP	
	Capital Cost (Rs)	Capital Cost (Rs)	Annual Fuel Cost (Rs)	Capital Cost (Rs)	Annual Fodder Cost (Rs)	Capital Cost (Rs)	Annual Fodder Cost (Rs)	Capital Cost (Rs)	Annual Labour Cost (Rs)
0.5 ha Farm									
Surface Irrigation	112,213	10,000	128	16,875	0	36,875	33,200	4,149	731
Drip Irrigation	159,873	10,000	373	16,875	0	36,875	33,200	11,149	5,845
1.0 ha Farm									
Surface Irrigation	175,252	10,000	255	16,875	0	36,875	33,200	7,779	1,461
Drip Irrigation	199,329	10,000	745	22,143	4,734	42,143	37,943	19,706	11,691
1.5 ha Farm									
Surface Irrigation	237,817	10,000	383	16,875	0	36,875	33,200	11,149	2,192
Drip Irrigation	273,953	10,000	1,118	51,116	30,829	61,116	64,029	28,781	17,536
2.0 ha Farm									
Surface Irrigation		10,000	511	16,875	0	36,875	33,200	14,001	2,923
Drip Irrigation	345,047	10,000	1,490	59,018	37,943	79,018	71,143	37,856	23,382

* Assumes Farmer already owns 4 animals
** Asumes Farmer must purchase animals

Table 3.30 Results of Pump Sizing

Spaces in the tables used for sizing PV pumps are left blank where manufacturers data is not available for pumps large enough to supply the required amount of water under the given conditions of total head and insolation. No data was available on PV pumps large enough to supply water to a 2.0 ha farm using surface irrigation. Capital costs for PV pumps were found to increase gradually with increases in farm size. PV pumps sized for use with surface irrigation were slightly less expensive than PV pumps sized for drip irrigation in all cases where data was available.

The smallest diesel engine available was assumed to be 3.7 kW and to cost approximately 10,000 Rs. Fuel consumption (F_c) was estimated at 0.34 *l*/kWhr and fuel costs (C_f) at 7 Rs/*l*. These assumptions were based on literature reviews of recent studies done specifically for India (See Section 3.10). Pump efficiency (ε_p) was assumed to be 50% and maximum run time per day (τ_d) 8 hours. From Table 3.30, the capital cost for a diesel pump is the same for all farm sizes. The smallest available diesel pump is considerably oversized for all farms considered, and one pump was sufficient in all cases. Annual fuel costs increase gradually with farm size, and are slightly higher for drip irrigation

Annual fuel costs increase gradually with farm size, and are slightly higher for drip irrigation than for surface irrigation. Capital costs for diesel pumps were found to be much lower than for all other options (except hand pumps for farms under 1 ha).

No recent data was available on the cost of either hand or animal powered pumps. Thomas (1988) estimated hand and animal powered pumps cost 280 US$ (3,630 Rs) and 1,302 US$ (16,875 Rs) respectively in 1987. At 1994 exchange rates (with no allowance for inflation) the same pumps would cost 8,785 Rs and 40,850 Rs. It seemed unlikely that pump costs would have risen this much since this would make a hand pump almost as expensive as a diesel pump and a Persian wheel over four times as expensive. Prices of hand and animal powered pumps in India were therefore assumed to be similar to prices estimated by Thomas in 1987 and converted to equivalent Indian prices using 1987 exchange rates.

Capital costs for the Persian wheel include the cost of the pumps and animals. The cost of one animal was estimated at 5,000 Rs and the cost of fodder for one year at 8,300 Rs per animal based on a study from Pakistan (World Bank, 1989). It was assumed that four animals are required to operate one Persian wheel. Two cases were considered, the first assumes that the farmer already owns four animals and includes only the cost of purchasing and feeding extra animals if they are required. The second includes the cost of purchasing and feeding all required animals. The average run time per day (τ_d) was assumed to be 8 hours.

From Table 3.30, one Persian wheel was found to be sufficient for all farm sizes considered when surface irrigation was used. If the cost of purchasing and feeding four animals was excluded from the irrigation costs (Case One), capital costs were quite low and annual fodder costs were zero. Both capital and annual fodder costs increased significantly when the cost associated with the animals was factored in (Case Two). When

drip irrigation is used most farms over 1.0 ha require more than one pump and extra animals must be purchased, this increases costs significantly.

Labour costs for operating a hand pump were assumed to be 23.3 Rs/day according to the latest UN estimate (United Nations, 1995). Average run time per day was assumed to be 8 hours. Table 3.30 show that capital costs for hand pumps are fairly reasonable in most cases especially for surface irrigation. With drip irrigation it requires approximately 10 pumps to irrigate the average 2.0 ha field. At this point both capital and annual labour costs become unreasonable.

The relative merits of different remote pumping options for farms using drip irrigation are compared on the basis of life cycle costs in Section 3.12.7. A comparison of costs incurred over the life of the equipment is much more relevant than a simple comparison of capital costs, since high annual recurring costs for one option may balance the effects of high capital costs for another option.

Capital costs for all remote pumping systems were consistently higher when the pumps were sized for use with drip irrigation. The benefits of using drip irrigation will be seen in the cost-benefit analysis of Section 3.12.8 when increased yields from crops irrigated by the drip method are factored in.

3.12.7 Life Cycle Cost Comparison of Remote Pumping Options

Table 3.31 show the assumptions used for a life cycle cost comparison of PV, diesel, hand and animal powered pumping systems supplying water to 0.5 ha, 1.0 ha, 1.5 ha and 2.0 ha vineyards under drip irrigation. Table 3.32 shows a sample life cycle cost comparison for a 1.0 ha farm. Pump sizings, capital expenses and operating costs are based on average values from Table 3.30 and Appendix Z. A discount rate of 4.1% was assumed to be appropriate for India based on the literature review of Section 3.10.

Installation costs for PV systems were assumed to be 5% of capital equipment costs, approximately half the value allowed for by Thomas (1988). This reduction is due

Assumptions: Life Cycle Cost Comparison for Remote Pumping Systems using Drip Irrigation		0.5 ha	1.0 ha	1.5 ha	2.0 ha
Period of Analysis (yrs) =		20	20	20	20
Net Discount Rate =		4%	4%	4%	4%
PV Surface					
Capital Cost for Pump & Array (Rs) =		159,873	199,329	273,958	345,047
Pump Replacement Cost (Rs) =		34,355	34,355	34,355	34,355
Installation (Rs) =	5.0%	7,994	9,966	13,698	17,252
Annual Maintenance (Rs/yr) =	0.3%	480	598	822	1,035
Pump Life (yrs) =		10	10	10	10
Diesel Systems					
Capital Cost for Pump (Rs) =		10,000	10,000	10,000	10,000
Installation (Rs) =	0.5%	50	50	50	50
Annual Fuel Costs (Rs/yr) =		373	745	1,118	1,490
Annual Maintenance Costs (Rs/yr) =	10.0%	1,000	1,000	1,000	1,000
System Life (yrs) =		10	10	10	10
Animal Powered Pumps					
Capital Cost for Pump (Rs) =		16,875	19,286	32,545	36,161
Capital Cost of Animals 1 (Rs) =		0	2,857	18,571	22,857
Capital Cost of Animals 2 (Rs) =		20,000	22,857	38,571	42,857
Annual Fodder Costs 1 (Rs/yr) =		0	4,743	30,829	37,943
Annual Fodder Costs 2 (Rs/yr) =		33,200	37,943	64,029	71,143
Annual Maintenance Costs (Rs/yr) =		130	143	246	272
Pump Life (yrs) =		10	10	10	10
Hand Pumps					
Capital Cost for Pumps (Rs) =		11,149	19,706	28,781	37,856
Annual Labour Costs (Rs/yr) =		5,845	11,691	17,536	23,382
Annual Maintenance Costs (Rs/yr) =		2,009	3,499	5,120	6,740
Pump Life (yrs) =		7	7	7	7

Table 3.31 Assumptions for Life Cycle Cost Comparison of Remote Pumping Options for Drip Irrigation

	1.0 ha Plot				
	PV	Diesel	Animal 1	Animal 2	Hand
PW (Rs)	240,308	40,256	100,789	567,625	250,230
Year 0	209,295	10,050	22,143	42,143	19,706
1	598	1,745	4,886	38,086	15,190
2	598	1,745	4,886	38,086	15,190
3	598	1,745	4,886	38,086	15,190
4	598	1,745	4,886	38,086	15,190
5	598	1,745	4,886	38,086	15,190
6	598	1,745	4,886	38,086	15,190
7	598	1,745	4,886	38,086	34,896
8	598	1,745	4,886	38,086	15,190
9	598	1,745	4,886	38,086	15,190
10	34,953	11,795	24,172	57,372	15,190
11	598	1,745	4,886	38,086	15,190
12	598	1,745	4,886	38,086	15,190
13	598	1,745	4,886	38,086	15,190
14	598	1,745	4,886	38,086	34,896
15	598	1,745	4,886	38,086	15,190
16	598	1,745	4,886	38,086	15,190
17	598	1,745	4,886	38,086	15,190
18	598	1,745	4,886	38,086	15,190
19	598	1,745	4,886	38,086	15,190
20	598	1,745	4,886	38,086	15,190

Table 3.32 Sample Life Cycle Cost Comparison of Remote Pumping Options: 1.0 ha Farm

to the significantly lower labour costs in India. Annual maintenance costs are assumed to be 0.3% as calculated in Table 3.11 based on Thomas (1988). The PV array lasts the full 20 years, the pump is replaced in year 10. Installation and maintenance costs for diesel systems were estimated at 0.5% and 10.0% of capital equipment costs based on a review of literature from India (Section 3.10). The entire diesel system is replaced in year 10.

Maintenance costs for hand and animal powered pumps were taken from Thomas (1988). Hand pumps are replaced every 7 years, animal powered pumps every 10. Animals are assumed to live for 20 years. As in the previous sub-section, two cases were considered for animal-powered pumps. The first case assumes the farmer already owns

four animal and includes only the costs associated with additional animals. The second case includes the cost of purchasing and feeding all animals.

Table 3.33 shows the results of the life cycle cost comparison, detailed tables can be found in Appendix AA. Comparing the present worth of all costs incurred over a 20 year period, diesel pumps are the least cost option for all farms over 0.5 ha in size. A Persian wheel is the least expensive option for a small 0.5 ha farm if the cost of purchasing and feeding animals is excluded from the total cost of irrigation (Case One). A Persian wheel is less expensive than a PV system for farms 1.0 ha and smaller if the cost of the animals is excluded (Case One). If the cost of the animals is included in the total irrigation cost, however, (Case Two) a Persian wheel is the most expensive option in all cases. PV pumps are less expensive than hand pumps for mid-range farm sizes.

Cost estimates for hand and animal pumps are not considered reliable because of the lack of data (recent or otherwise) specific to India. The exclusion of these pumping systems from Indian irrigation studies suggests that they are not considered a significant force in the irrigation sector. Data used in this study is relatively old and likely under-estimates current costs. In spite of this, PV pumps were found to be less expensive than both hand or animal powered pumps for most farm sizes considered. Diesel pumping systems are therefore considered the main competitor to PV pumps in the irrigation sector.

	Present Worth of Costs (Rs)				
Farm Size	PV	Diesel	Animal 1	Animal 2	Hand
0.5 ha	197,286	35,241	29,900	496,735	131,608
1.0 ha	240,308	40,256	100,789	567,625	250,230
1.5 ha	321,682	45,270	491,110	957,946	371,787
2.0 ha	399,196	50,285	597,525	1,064,360	351,479

Table 3.33 Results of Life Cycle Cost Comparison

Farm Size	Present Worth (Rs)	
	PV	Diesel
0.5 ha	197,286	364,322
I.0 ha	240,308	369,336
I.5 ha	321,682	374,351
2.0 ha	399,196	379,365

Table 3.34 Life Cycle Cost Comparison for PV and Diesel Pumping Systems Using the Equivalent North American Price for Diesel Pumps

Recall from Section 3.10 that a diesel pump in North America is approximately ten times more expensive than a similar pump on the Indian market. Figure 3.16 (Section 3.9) indicates that average critical month water pumping requirements for all farm sizes considered do indeed fall into the range generally considered viable for PV water pumping. Table 3.34 shows a life cycle cost comparison for PV and diesel pumps using the equivalent North American price of 32,127 Rs/kW for diesel pumps (see Section 3.10). Note that PV is the least cost option for all farm sizes smaller than 2.0 ha. This would include most grape farms in India. Unfortunately, in North America (where farm sizes are generally large) there is very little market for smaller PV systems and in India (where farm sizes are small) there is a large market but diesel pump prices are lower and small PV systems are less competitive. The price of a PV system will therefore have to drop significantly before PV becomes competitive with diesel for irrigation purposes in India.

3.12.8 Cost-Benefit Analysis for Grapes under PV Drip Irrigation

Table 3.35 shows total costs and benefits over a 20 year period for a 1 ha vineyard (Anab-e-Shahi grapes) under PV drip irrigation. Costs for the PV pumping system are identical to estimates used in the previous sub-sections. The capital cost of the pump and array is 199,329 Rs as calculated in Section 3.12.6. Installation costs of 5% (9,966 Rs) and annual maintenance costs of 0.3% (598 Rs) are the same as those used in Section 3.12.7. The pump is replaced in year 10.

GRAPES (Anib-e-Shahi) Overall Economics

Economics	Present Worth (1994 Rs)	Discount Rate = 4% Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pump System Cost	222,294	199,329										34,355										
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines	15,000	15,000																				
Yield (t/ha) Anab-e-Shahi Grapes			26.74	27.52	28.33	29.17	30.02	30.91	31.82	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561.3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60.8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24.8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75.6 Rs/t)	31,665		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	434,764	246,605	6,952	7,676	8,409	9,144	9,885	10,631	11,363	12,140	12,702	67,307	13,263	13,263	13,263	13,263	13,263	13,263	13,263	13,263	13,263	13,263
INCOME (5000 Rs/t of produce)	2,094,249		133,676	137,609	141,658	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLO* / (Rs)	1,659,485	-246,605	126,724	129,931	133,250	136,682	140,232	143,903	147,699	151,622	151,061	96,456	150,500	150,500	150,500	150,500	150,500	150,500	150,500	150,500	150,500	150,500

Table 3.35 Cost-Benefit Analysis for a 1.0 ha Grape Farm under PV Drip Irrigation

The costs of a drip irrigation system designed for use with grapes was obtained from the literature. Drip irrigation systems used with grapes normally use single point emitters rather than drip tape or tubing (which is more suitable for row crops). The cost of the irrigation system depends mainly on the plant spacing and the number of emitters per plant. Table 3.36 lists cost estimates from various sources for drip irrigation systems designed for use with grapes. Estimates over 25,000 Rs/ha were assumed to include the cost of the pump. Ravi Babu et al. (1995) was the only reference to give a detailed cost breakdown (Table 3.37). These estimates were designed specifically for Anab-e-Shahi and Thompson Seedless grapes.

The total capital cost for the drip irrigation system used in the cost-benefit analysis of Table 3.35 (19,689 Rs) is taken from Table 3.37 for Anib-e-Shahi grapes (Ravi Babu et al., 1995). The study by Ravi Babu et al. (1995) was based on industry information combined with surveys of farmers in the Hyderabad region. The drip system layouts described in the study consisted of buried PVC mains and submains with above ground laterals. Two emitters were used for each plant, one on each side at a distance of 0.6 m. The emitters operated at a pressure of 1.25 kg/cm^2 or 12.5 m of water. The life of a drip irrigation system was estimated at 10 years. Annual maintenance for the drip irrigation system was estimated at 1% of total system costs (197 Rs).

Plant Spacing	Cost (US$/ha)	Cost (Rs/ha)	Source
3.03 m x 1.80 m		44,000	Sivanappan (1995)
3.04 m x 3.04 m	628	19,148	Saskena (1995)
2.44 m x 2.44 m	785	23,935	Saskena (1995)
1.80 m x 1.20 m	964-1,708	29,395 - 52,082	Saskena (1995)
2.28 m x 2.28 m		41,997	Ravi Babu et al. (1995)*
4.57 m x 4.57 m		33,189	Ravi Babu et al. (1995)*
3.00 m x 3.00 m		20,000	Khanha (1993)
		32,500	Khanha (1993)*

Table 3.36 Cost Estimates for Drip Irrigation Systems for Grapes

Component	Anab-e-Shahi Grapes		Thompson Seedless	
	Length (m) or no. of Units per ha	Cost (Rs/ha)	Length (m) or no. of Units per ha	Cost (Rs/ha)
Pump Assembly (7.5 hp)	1	13,500.00	1	13,500.00
Screen Filter	1	1,800.00	1	1,800.00
Main Pipe (75 mm)	175.9	5,980.00	103.05	3,503.70
Submain (50 mm)	88.23	2,029.00	111.26	2,558.98
Laterals (12 mm)	2165.34	6,712.55	4463.25	13,836.00
Emitters (8 l/hr)	952	2,142.00		
Emitters (4 l/hr)			3720	5,580.00
Valve	2	750.00	2	750.00
Bend	6	122.10	9	183.15
Tee	2	17.90	3	26.85
GTO	37	51.80	120	168.00
End Cap	3	34.05	3	34.05
MTA	6	48.60	7	56.70
TOTAL (with pump)		33,188.00		41,997.43
TOTAL (excluding pump)		19,688.00		28,497.43

Table 3.37 Breakdown of Costs for Drip Irrigation of Grapes (Ravi Babu et al., 1995)

Other costs identified by Ravi Babu et at. (1995) include the cost of support pillars, seedlings, planting, fertilizer, inter culture (weeding and inter row cropping), harvesting, labour, packaging, and transport. Costs for support pillars and seedlings are estimated at 15,000 Rs and 706 Rs respectively. The other costs are annual costs which depend on the yield or age of the crop.

Table 3.21 (Section 3.11) gives the yield of grapes under drip irrigation as 325 qt/ha (32.5 t/ha). This figure is repeated in Guyen (1993), Sivanappan (1994, 1995), and Surywanshi (1995). Ravi Babu et al. (1995) calculated the yields of Anab-e-Shahi (Y_{AS}) and Thompson seedless (Y_{TS}) grapes in t/ha as a function of the age of the crop (t) in years. Y_{AS} and Y_{TS} were given by Equations 3.34 and 3.35 respectively.

$$Y_{AS}=25.971e^{0.0290t} \qquad (3.34)$$

$$Y_{TS}=15.613e^{0.1516t} \quad (3.35)$$

Y_{AS} and Y_{TS} correspond reasonably to yields given by other sources. Y_{AS} and Y_{TS} reach 32.5 t/ha in the eighth and fifth years respectively. Ravi Babu et al. (1995) obtained data for crops up to eight years old for Anab-e-Shahi grapes and four years old for Thompson seedless grapes. Yields for eight year old Anab-e-Shahi grapes were slightly higher than 32.5 t/ha and yields for four year old Thompson seedless grapes slightly lower. Y_{AS} is therefore assumed to level off at the calculated value in year eight and Y_{TS} to level of at 32.5 t/ha in year five. In Table 3.35, the annual yield of Anib-e-Shahi grapes is calculated using Equation 3.34 up to year 8, after this point yield levels off at 32.75 t/ha.

Annual costs associated with fertilizer, harvesting, labour, packaging and transport are dependant on the annual crop yield. These costs were derived from tables in Ravi Babu et al. (1995). For the purposes of Table 3.35, the annual cost of fertilizing was estimated at 47.08 Rs/t yield of grapes. The cost of harvesting was estimated at 60.80 Rs/t. Labour is approximately 24.81 Rs/t and packaging and transport at about 75.63 Rs/t. The cost of inter culture increases with the age of the crop at approximately 561 Rs/year. Inter culture costs were assumed to level out in year 10 at 5,613 Rs.

The selling price for any crop can vary dramatically from year to year and consistent data on harvest prices is difficult to obtain. The selling price for grapes was estimated 1,500 Rs/qt (15,000 Rs/t) under drip irrigation and 1,450 Rs/qt (14,500 Rs/t) under surface irrigation in Table 3.21 (NCPA, 1990). The difference is presumably due to the higher quality of produce under drip irrigation. Ravi Babu et al. (1995) found farmers surveyed in the Hyderabad area obtained returns of 5,000 Rs/t for Anab-e-Shahi grapes and 4,500 Rs/t for Thompson seedless grapes (both under drip irrigation). Data used in Table 3.35 was taken from Ravi Babu et al. (1995), as it is the most recent and most conservative.

Using a value of 5,000 Rs/t yield and a discount rate of 4.1% (as was used in the previous subsection), the present worth of all income over the 20 year period is 2,094,249 Rs. The present worth of all costs incurred over the 20 year period, including the cost of the PV pump and irrigation system, is approximately 434,764 Rs. The present worth of the net cash inflow (benefits minus costs) over the 20 year period is therefore 1,659,485 Rs.

Some concern arises over water usage reported in the study by Ravi Babu et al. (1995), which was considerably higher than water requirements calculated for Hyderabad in Section 3.12.4. The total annual water pumping requirements for mature grapes under drip irrigation in Hyderabad was calculated as 2,547 m^3/ha (Table 3.28). Total water applied by farmers in Hyderabad ranged from 6,042 to 7,775 m^3 for 2 to 8 year old Anab-e-Shahi grapes and 11,830 to 15,222 m^3 for 2 to 4 year old Thompson seedless grapes. Water usage was approximately 3 times the calculated water requirements for mature Anab-e-Shahi grapes and 6 times the calculated water requirements for mature Thompson seedless grapes. Since crop coefficients specific to Anab-e-Shahi and Thompson seedless grapes were not available from the literature, it is difficult to tell if farmers were simply over watering, if these varieties of grapes have a much higher water demand than most other grapes, or if the years considered in the study by Ravi Babu et al. (1995) were particularly dry.

Table 3.38a shows the incremental net benefits for PV drip irrigation over PV surface irrigation. This table assumes that grape yields increase 23% under drip irrigation as reported in Table 3.23. This figure is also reported in Guyen and Ravishankar (1993), Sivanappan (1994, 1995), Surywanshi (1995), and Saskena (1995). Using this assumption, the increase in yield for a drip system over a surface system is approximately 0.187 times the overall yield for the drip system. The present worth of additional income accrued over a 20 year period from using drip irrigation over surface irrigation is approximately 393,091 Rs. Differences in the quality of produce and expected returns per

GRAPES (Anib-e-Shahi) Incremental Economics of PV Drip Irrigation over PV Surface Irrigation

Economics	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	222,294	199,329										34,355										
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Subtract PV Surface Irrig. Pump Cost*	-191,925	-175,252										-24,942										
Subtract PV Surface Pump Install. (5%)	-8,763	-8,763																				
Subtract PV Surface Maintenance (0.3%)	-7,076		-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526
Drip System Cost	32,650	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Inc. Yield (t/ha) Anab-e-Shahi Grapes			5.02	5.17	5.32	5.47	5.64	5.80	5.97	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15
Inc. Fertilizer Cost (47.1 Rs/t of produce)	3,703		236	243	250	258	265	273	281	290	290	290	290	290	290	290	290	290	290	290	290	290
Inc. Harvesting Cost (60.8 Rs/t of produce)	4,780		305	314	323	333	343	353	363	374	374	374	374	374	374	374	374	374	374	374	374	374
Inc. Labour Cost (24.8 Rs/t of produce)	1,950		124	128	132	136	140	144	148	152	152	152	152	152	152	152	152	152	152	152	152	152
Inc. Packaging/Transport Cost (75.6 Rs/t)	5,944		379	391	402	414	426	439	451	465	465	465	465	465	465	465	465	465	465	465	465	465
ADDITIONAL COST (Rs)	85,125	45,595	1,319	1,350	1,382	1,415	1,449	1,483	1,519	1,556	1,556	30,658	1,556	1,556	1,556	1,556	1,556	1,556	1,556	1,556	1,556	1,556
ADDITIONAL INCOME (5000 Rs/t yield)	393,091		25,091	25,829	26,589	27,372	28,177	29,006	29,860	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738
NET ADDITIONAL CASH INFLOW (Rs)	307,965	-45,595	23,772	24,479	25,207	25,957	26,728	27,523	28,341	29,182	29,182	81	29,182	29,182	29,182	29,182	29,182	29,182	29,182	29,182	29,182	29,182

*PV pump sized for drip irrigation replaces PV pump sized for surface irrigation. PV pumping system sized for surface irrigation costs Rs 175,252. Pump replacement cost is Rs 24,942.

GRAPES (Anib-e-Shahi) Incremental Economics of PV Drip Irrigation over Surface Irrigation with a Diesel Pump

Economics	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	222,294	199,329										34,355										
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Subtract Diesel System Cost*	-16,685	-10,000										-10,000										
Subtract Diesel System Installation (.5%)	-83	-50										-50										
Subtract Annual Fuel Costs	-3,435		-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255
Subtract Annual Maintenance Costs (10%)	-13,459		-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000
Drip System Cost	32,650	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Inc. Yield (t/ha) Anab-e-Shahi Grapes			5.02	5.17	5.32	5.47	5.64	5.80	5.97	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15
Inc. Fertilizer Cost (47.1 Rs/t of produce)	3,703		236	243	250	258	265	273	281	290	290	290	290	290	290	290	290	290	290	290	290	290
Inc. Harvesting Cost (60.8 Rs/t of produce)	4,780		305	314	323	333	343	353	363	374	374	374	374	374	374	374	374	374	374	374	374	374
Inc. Labour Cost (24.8 Rs/t of produce)	1,950		124	128	132	136	140	144	148	152	152	152	152	152	152	152	152	152	152	152	152	152
Inc. Packaging/Transport Cost (75.6 Rs/t)	5,944		379	391	402	414	426	439	451	465	465	465	465	465	465	465	465	465	465	465	465	465
ADDITIONAL COST (Rs)	259,226	219,559	590	621	653	685	719	754	790	826	826	44,820	826	826	826	826	826	826	826	826	826	826
ADDITIONAL INCOME (5000 Rs/t yield)	393,091		25,091	25,829	26,589	27,372	28,177	29,006	29,860	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738
NET ADDITIONAL CASH INFLOW (Rs)	133,864	-219,559	24,501	25,208	25,937	26,686	27,458	28,252	29,070	29,912	29,912	-14,082	29,912	29,912	29,912	29,912	29,912	29,912	29,912	29,912	29,912	29,912

*PV pump sized for drip irrigation replaces diesel pump sized for surface irrigation.

Table 3.38 Incremental Economic Benefits for Anab-e-Shahi Grapes under PV Drip Irrigation

unit yield under drip and surface irrigation were not be considered, but could be expected to increase the viability of drip irrigation even more.

Incremental costs include the full cost of a PV pumping system sized for drip irrigation (199,329 Rs) minus the cost of a PV pumping system sized for surface irrigation (175,252 Rs) These figures were calculated in Appendix AA (PV pump sizings for a 1.0 ha grape farm). Differences in installation and maintenance costs for the two systems are also considered. The full cost of the drip irrigation system, including system design and maintenance is considered an incremental cost. Figures used are the same as those in Table 3.38. Incremental costs for fertilizer, harvesting, labour, packaging and transport are calculated based on increased yields with drip irrigation. The cost of seedlings, planting and support pillars are independent of the yield and method of irrigation and are not considered an incremental cost. Inter culture costs are slightly lower for drip irrigation systems because the area between plants does not receive as much water. This factor was not considered but could be expected to raise incremental benefits for drip systems slightly. The present worth of all incremental costs for a PV drip irrigation system over a PV surface irrigation system was found to be 85,125 Rs.

The present worth of incremental net benefits accruing over a 20 year period is approximately 307,965 Rs. The fact that incremental net benefits are positive indicates that overall returns from a PV drip irrigation system exceed returns from a PV surface irrigation system even though equipment costs for the drip irrigation system are higher (See Section 3.12.6). The compatibility of drip irrigation and PV pumping systems in terms of flow rates and labour savings was discussed in the study background. Table 3.38a shows that PV drip irrigation is also more economical than PV surface irrigation, at least for grapes, because additional income from the higher yields associated with drip irrigation outweighs additional equipment costs.

Table 3.38b shows the incremental net benefits for PV drip irrigation over surface irrigation with a diesel pump. The methodology used for Table 3.38b is the same as that used for Table 3.38a. Incremental costs include the full cost of the PV pumping system and the drip irrigation system minus the cost of a diesel pumping system sized for surface irrigation (10,000 Rs as per Table 3.30). Differences in maintenance and installation are also considered. The present worth of incremental net benefits accrued over a 20 year period is approximately 133,864 Rs showing that PV drip irrigation is even more profitable than surface irrigation with a diesel pump in spite of the considerably lower costs associated with diesel pumps in India.

The financial analysis for cultivation of Anab-e-Shahi grapes under PV drip irrigation is shown in Table 3.39. The fact that grape cultivation with a PV drip irrigation system is profitable means little if the farmer cannot afford the initial capital cost. The financial analysis shows actual costs for the farmer considering all available subsidies and soft loans. For the farmer to consider a PV drip irrigation system, initial capital costs must be relatively low and annual net cash inflow must be sufficient to keep the family alive until the next year's harvest.

A subsidy of 170 Rs/W_p is available for the PV pumping systems through the MNES program (discussed in the study background). The average pump cost for a 1 ha grape farm under drip irrigation was 199,329 Rs. The average array size required was 697 W_p (as calculated in Table 3.29, Section 3.12.6), giving a subsidy of 118,490 Rs. The remaining pump cost (80,839 Rs) can be paid off over a ten year period through a soft loan with an interest rate of 5% (considerably lower than the average lending rate over the last 20 years of 16.4%). The loan is assumed to be paid in ten equal installments of 10,469 Rs. Annual installments (A) are given by Equation 3.36 (Riggs et al., 1986), where PW is the present worth of the loan, t is the number of years required to pay the loan off and i is the interest rate.

GRAPES (Anib-e-Shahi) Overall Finances Considering Subsidies and Soft Loans for Pumping System and Drip Irrigation Equipment

Financial	Present Worth (1994 Rs)	Discount Rate = 4% Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pump System Cost*	112,724		10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	9,530	9,530	9,530	9,530	9,530					
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Drip System Cost**	23,403				3,426	3,426	3,426	3,426	3,426						3,426	3,426	3,426	3,426	3,426			
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines***	18,468		4,161	4,161	4,161	4,161	4,161															
Yield (Vha) Anab-e-Shahi Grapes			26.74	27.52	28.33	29.17	30.02	30.91	31.82	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561.3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60.8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24.8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75 6 Rs/t)	31,665		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	319,215	12,587	21,582	22,308	26,464	27,200	27,941	24,526	25,278	22,609	23,171	23,732	22,793	22,793	26,219	26,219	26,219	16,689	16,689	13,263	13,263	13,263
INCOME (5000 Rs/t of produce)	2,094,249		133,678	137,609	141,658	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLOW (Rs)	1,775,034	-12,587	112,094	115,301	115,194	118,626	122,176	130,008	133,804	141,153	140,592	140,031	140,969	140,969	137,544	137,544	137,544	147,074	147,074	150,500	150,500	150,500

*Assumes pump cost is Rs 199,329 with subsidy of Rs 118,490. Remaining portion of cost (Rs 80,839) paid off over 10 years at 5% interest as per MNES program. Pump is replaced in year 10 with a loan at 12% interest paid off over 5 years

**Assumes drip system cost is Rs 19,689 with subsidy of 50%. Remaining portion of cost is Rs 9,844 paid off over 5 years at 12% interest after a 2 year moratorium. Entire drip system is replaced in year 10 under the same loan conditions.

***Assumes the full cost of the support pillars are covered by a loan at 12% interest, paid over 5 years after a 2 year moratorium

Table 3.39 Net Financial Benefits for Anab-e-Shahi Grapes under Drip Irrigation

$$A = PW\frac{i(1+i)^t}{(1+i)^t - 1} \qquad (3.36)$$

The PV pump is replaced in year 10, using a loan at 12% interest paid off over 5 years (annual installments of 9,530 Rs). The drip irrigation system was assumed to cost 19,689 Rs. A 50% subsidy is available. The remaining cost is 9,844 Rs, paid using a loan at 12% interest over five years after a two year moratorium. Interest accumulates over the two year moratorium so the loan is worth 12,349 Rs by the end of this period. This is paid off in 5 equal installments of 3,426 Rs. The entire drip irrigation system is replaced after 10 years under the same subsidy and loan conditions. Pillars used to support the vines cost 15,000 Rs. It is assumed that these will be paid for over a 5 year period with a loan at 12% interest (annual installments of 4,161 Rs). The pillars are assumed to last the full 20 year period.

Initial start up costs (Year 0) are reduced to 12,587 Rs once available subsidies and loans are considered. These costs could be further reduced by including the PV pump installation cost (9,966 Rs) and the drip system design cost (625 Rs) in with the relevant loans. Income at the end of the first year is 112,094 Rs. This increases to 150,500 Rs by the end of the 20 year period. The present worth of the net cash inflow over the 20 year period is 1,775,034 Rs. A survey of farmers in India done by Ingle and Sagne (1992) considered respondents with an annual income of 100,000 Rs. or more (the highest income bracket considered in the study) to have "high economic status".

Incremental financial benefits for PV drip irrigation over PV surface irrigation and PV drip irrigation over surface irrigation with a diesel pump are calculated in Appendix AB. Incremental financial benefits were calculated in the same manner as incremental economic benefits but with all available subsidies and loans considered. It is assumed that the PV surface irrigation pumping system would have been financed under the same loan

conditions as the PV drip irrigation pumping system. The subsidy for the PV surface irrigation pumping system is slightly lower because the required array is slightly smaller. It was assumed that the diesel pumping system would have been paid for over a 5 year period with a loan at 12% interest. The present worth of incremental net benefits accrued over a 20 year period for the financial study is 328,379 Rs for PV drip irrigation over PV surface irrigation and 256,738 Rs for PV drip irrigation over surface irrigation with a diesel pump.

Appendix AB also contains a financial study for Thompson seedless grapes. These table were calculated using the same assumptions as were used for Anab-e-Shahi grapes. The cost of the drip irrigation system is slightly higher for Thompson seedless grapes, the yield is calculated using Equation 3.35 instead of Equation 3.34, and the net income per unit of produce is lower (4,500 Rs/t). The present worth of net financial benefits is 1,485,000 Rs, slightly lower than that calculated for Anab-e-Shahi grapes. The present worth of incremental financial benefits for PV drip irrigation over surface irrigation with a PV or diesel pump are also slightly lower (264,553 Rs and 192,912 Rs respectively). Figures for Thompson seedless grapes should be held suspect since water requirements for these grapes appear to be considerably higher than calculated water requirements and the PV pumping system is likely undersized for this application.

3.12.9 Pump Sizing and Cost-Benefit Analysis (Ground Water Source)

Tables 3.40 and 3.41 shows PV pump sizings for drip and surface irrigation respectively using a ground water source. Sizings were done for 0.5 ha, 1.0 ha, 1.5 ha, and 2.0 ha farms. Approximate depths to the ground water table were obtained from Section 3.6. The tables have been left blank where manufacturer's data was not available, presumably because costs are prohibitively high.

Pump Sizing for Grapes, Drip Irr			0.8		Crop Water	Water Pumping	Depth to		Assumed	Nearest Pump Size								
										DC Surface Pump*			DC Submersible Pump			AC Submersible Pump		
Stn ETo	Stn Sun	Station Name	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Water Table	Pressure Required	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)
2	4	Ahmedabad	Jun	6.39	22.9	13.9	2	15	17	24.2	636	188,331	14.6	318	201,725	15.0	448	202,788
23	62	Jaipur	Jun	6.08	27.4	16.7	5	15	20	17.1	530	162,668	18.1	477	241,565	28.3	840	294,178
35	106	Pune	May	6.92	26.3	16.0	5	15	20	20.5	530	162,668	17.5	424	228,285	32.8	840	294,178
AVERAGE										20.6	565	171,222	16.7	406	223,658	25.4	709	263,715
3	5	Akola	May	6.93	23.9	14.5	10	15	25				14.6	424	228,285	26.3	840	294,178
4	7	Allahabad	Jun	5.87	20.8	12.6	10	15	25				13.4	530	250,358	21.3	840	294,178
8	21	Bhopal	May	7.17	26.4	16.1	10	15	25				16.5	450	234,566	27.4	840	294,178
20	56	Hyderabad	May	6.86	22.7	13.8	10	15	25				14.3	424	228,285	25.9	840	294,178
21	59	Indore	May	7.35	30.8	18.7	10	15	25				19.3	530	250,358	28.2	840	294,178
26	79	Kota	Jun	6.72	31.1	18.9	10	15	25				20.5	600	272,073	25.3	840	294,178
29	92	Nagpur	May	6.75	24.8	15.1	10	15	25				15.6	477	241,565	25.4	840	294,178
AVERAGE													16.3	491	243,641	25.7	840	294,178
1	3	Agra	Jun	5.98	24.9	15.1	15	15	30				18.3	750	303,747	16.2	840	292,452
30	97	New Delhi	Jun	5.59	24.2	14.7	15	15	30				16.7	750	303,747	14.9	840	292,452
AVERAGE													17.5	750	303,747	15.6	840	292,452
9	24	Bikaner	Jun	7.74	36.7	22.4	50	15	65				22.8	1,500	471,990	26.3	1,920	536,876
24	69	Jodhpur	Jun	6.90	35.1	21.3	50	15	65				22.5	1,590	493,526	23.0	1,920	536,876
AVERAGE													22.7	1,545	482,758	24.7	1,920	536,876

Pump Sizing for Grapes, Drip Irr			1.0		Crop Water	Water Pumping	Depth to		Assumed	Nearest Pump Size								
										DC Surface Pump*			DC Submersible Pump			AC Submersible Pump		
Stn ETo	Stn Sun	Station Name	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Water Table	Pressure Required	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)
2	4	Ahmedabad	Jun	6.39	45.7	27.8	2	15	17	29.1	742	213,993	28.8	530	250,358	34.8	840	294,178
23	62	Jaipur	Jun	6.08	54.8	33.3	5	15	20	35.9	1,272	331,539	35.3	795	314,515	36.0	1,024	338,325
35	106	Pune	May	6.92	52.5	31.9	5	15	20	32.3	742	213,993	33.7	675	290,826	32.8	840	294,178
AVERAGE										32.4	919	253,175	32.6	667	285,233	34.5	901	308,894
3	5	Akola	May	6.93	47.8	29.1	10	15	25				30.0	750	303,747	29.1	896	307,368
4	7	Allahabad	Jun	5.87	41.6	25.3	10	15	25				26.2	795	314,515	25.9	960	323,250
8	21	Bhopal	May	7.17	52.8	32.1	10	15	25				34.1	795	314,515	32.7	960	323,250
20	56	Hyderabad	May	6.86	45.3	27.6	10	15	25				29.6	750	303,747	28.7	896	307,368
21	59	Indore	May	7.35	61.6	37.5	10	15	25				38.5	848	327,346	52.2	1,440	426,619
26	79	Kota	Jun	6.72	62.2	37.8	10	15	25				44.0	1,060	369,699	47.8	1,440	426,619
29	92	Nagpur	May	6.75	49.6	30.2	10	15	25				31.5	795	314,515	30.5	960	323,250
AVERAGE													33.4	828	321,155	35.3	1,079	348,246
1	3	Agra	Jun	5.98	49.7	30.3	15	15	30				32.1	1,125	394,599	33.5	1,440	426,619
30	97	New Delhi	Jun	5.59	48.4	29.5	15	15	30				29.7	1,060	369,699	31.1	1,440	426,619
AVERAGE													30.9	1,093	382,149	32.3	1,440	426,619
9	24	Bikaner	Jun	7.74	73.5	44.7	50	15	65									
24	69	Jodhpur	Jun	6.90	70.2	42.7	50	15	65									
AVERAGE																		

Pump Sizing for Grapes, Drip Irr			1.5		Crop Water	Water Pumping	Depth to		Assumed	Nearest Pump Size								
										DC Surface Pump*			DC Submersible Pump			AC Submersible Pump		
Stn ETo	Stn Sun	Station Name	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Water Table	Pressure Required	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)
2	4	Ahmedabad	Jun	6.39	68.6	41.7	2	15	17	41.9	1,272	331,539	43.5	795	314,515	44.0	1,024	338,325
23	62	Jaipur	Jun	6.08	82.2	50.0	5	15	20				52.5	1,200	412,769	51.0	1,440	426,619
35	106	Pune	May	6.92	78.8	47.9	5	15	20	50.0	1,484	381,070	54.1	1,060	369,699	58.2	1,440	426,619
AVERAGE										46.0	1,378	356,305	50.0	1,018	365,661	51.1	1,301	397,188
3	5	Akola	May	6.93	71.7	43.6	10	15	25				45.5	1,060	369,699	49.2	1,440	426,619
4	7	Allahabad	Jun	5.87	62.4	37.9	10	15	25				40.0	1,125	394,599	41.7	1,440	426,619
8	21	Bhopal	May	7.17	79.2	48.2	10	15	25				49.8	1,125	394,599	50.9	1,440	426,619
20	56	Hyderabad	May	6.86	68.0	41.4	10	15	25				45.0	1,060	369,699	48.7	1,440	426,619
21	59	Indore	May	7.35	92.4	56.2	10	15	25				59.8	1,325	431,612	59.9	1,680	482,610
26	79	Kota	Jun	6.72	93.3	56.7	10	15	25				61.6	1,500	471,990	62.9	1,920	536,601
29	92	Nagpur	May	6.75	74.5	45.3	10	15	25				46.6	1,125	394,599	48.0	1,440	426,619
AVERAGE													49.8	1,189	403,826	51.6	1,543	450,615
1	3	Agra	Jun	5.98	74.6	45.4	15	15	30				47.0	1,500	471,990	46.0	1,920	536,601
30	97	New Delhi	Jun	5.59	72.6	44.2	15	15	30				46.9	1,590	493,526	43.0	1,920	536,601
AVERAGE													47.0	1,545	482,758	44.5	1,920	536,601
9	24	Bikaner	Jun	7.74	110.2	67.1	50	15	65									
24	69	Jodhpur	Jun	6.90	105.3	64.0	50	15	65									
AVERAGE																		

Pump Sizing for Grapes, Drip Irr			2.0		Crop Water	Water Pumping	Depth to		Assumed	Nearest Pump Size								
										DC Surface Pump*			DC Submersible Pump			AC Submersible Pump		
Stn ETo	Stn Sun	Station Name	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Water Table	Pressure Required	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)
2	4	Ahmedabad	Jun	6.39	91.4	55.6	2	15	17				58.0	1,200	412,769	63.1	1,440	430,384
23	62	Jaipur	Jun	6.08	109.6	66.7	5	15	20							69.5	1,920	542,366
35	106	Pune	May	6.92	105.0	63.9	5	15	20				64.9	1,325	431,612	68.8	1,680	486,375
AVERAGE													61.5	1,263	422,191	67.1	1,680	486,375
3	5	Akola	May	6.93	95.6	58.1	10	15	25				63.5	1,500	471,990	64.9	1,920	536,601
4	7	Allahabad	Jun	5.87	83.2	50.6	10	15	25				53.9	1,500	471,990	55.0	1,920	536,601
8	21	Bhopal	May	7.17	105.6	64.2	10	15	25				65.7	1,500	471,990	67.1	1,920	536,601
20	56	Hyderabad	May	6.86	90.7	55.2	10	15	25				55.7	1,325	431,612	56.0	1,680	482,610
21	59	Indore	May	7.35	123.2	74.9	10	15	25									
26	79	Kota	Jun	6.72	124.4	75.7	10	15	25									
29	92	Nagpur	May	6.75	99.3	60.4	10	15	25				61.9	1,500	471,990	63.2	1,920	536,601
AVERAGE													60.1	1,465	463,914	61.2	1,872	527,403
1	3	Agra	Jun	5.98	99.5	60.5	15	15	30									
30	97	New Delhi	Jun	5.59	98.9	58.9	15	15	30									
AVERAGE																		
9	24	Bikaner	Jun	7.74	147.0	89.4	50	15	65									
24	69	Jodhpur	Jun	6.90	140.4	85.4	50	15	65									
AVERAGE																		

Table 3.40 PV Pump Sizing for Drip Irrigation with a Ground Water Source

Pump Sizing for Grapes, Surf			0.8								Nearest Pump Size									
					Crop	Water	Depth			Assumed	DC Surface Pump*			DC Submersible Pump			AC Submersible Pump		
Stn ETo	Stn Sun	Station Name	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	to Water Table	Lift Required		Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)
2	4	Ahmedabad	Jun	6.39	22.9	38.1	2	1	3	41.4	318	104,622							
23	62	Jaipur	Jun	6.08	27.4	45.7	5	1	6	52.4	530	153,256	49.6	477	252,659	87.7	840	299,511	
35	108	Pune	May	6.92	26.3	43.8	5	1	6	46.7	424	131,182	46.9	375	215,812	52.6	512	222,570	
AVERAGE										46.8	424	129,687	48.3	426	234,336	70.2	676	261,041	
3	5	Akola	May	6.93	23.9	39.8	10	1	11				40.1	450	234,566	52.8	840	297,943	
4	7	Allahabad	Jun	5.87	20.8	34.6	10	1	11				37.1	530	250,358	44.3	840	297,943	
8	21	Bhopal	May	7.17	26.4	44.0	10	1	11				44.0	477	241,565	54.7	840	297,943	
20	56	Hyderabad	May	6.86	22.7	37.8	10	1	11				39.6	450	234,566	52.2	840	297,943	
21	59	Indore	May	7.35	30.8	51.3	10	1	11				53.3	600	272,073	56.1	840	297,943	
26	79	Kota	Jun	6.72	31.1	51.8	10	1	11				52.6	675	290,826	55.2	896	311,133	
29	92	Nagpur	May	6.75	24.8	41.4	10	1	11				44.2	530	250,385	51.3	840	297,943	
AVERAGE													44.4	530	253,477	52.4	848	299,827	
1	3	Agra	Jun	5.98	24.9	41.4	15	1	16				42.4	795	314,515	42.9	1,024	368,325	
30	97	New Delhi	Jun	5.59	24.2	40.4	15	1	16				42.2	848	327,346	57.8	1,440	430,384	
AVERAGE													42.3	822	320,931	50.4	1,232	409,355	
9	24	Bikaner	Jun	7.74	36.7	61.2	50	1	51										
24	69	Jodhpur	Jun	6.90	35.1	58.5	50	1	51										
AVERAGE																			

Pump Sizing for Grapes, Surf			1.0								Nearest Pump Size									
					Crop	Water	Depth			Assumed	DC Surface Pump*			DC Submersible Pump			AC Submersible Pump		
Stn ETo	Stn Sun	Station Name	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	to Water Table	Lift Required		Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)
2	4	Ahmedabad	Jun	6.39	45.7	76.2	2	1	3	78.0	530	153,256							
23	62	Jaipur	Jun	6.08	54.8	91.4	5	1	6	101.6	1,060	272,596	99.4	848	346,014	95.1	896	312,702	
35	108	Pune	May	6.92	52.5	87.5	5	1	6	88.9	742	204,581	87.6	675	302,121	100.8	840	299,511	
AVERAGE										89.5	777	210,144	93.5	762	324,068	98.0	868	306,107	
3	5	Akola	May	6.93	47.8	79.6	10	1	11				88.2	1,060	369,699	101.0	1,440	431,952	
4	7	Allahabad	Jun	5.87	41.6	69.3	10	1	11				74.4	1,060	369,699	83.6	1,440	431,952	
8	21	Bhopal	May	7.17	52.8	88.0	10	1	11				91.4	1,060	369,699	105.0	1,440	431,952	
20	56	Hyderabad	May	6.86	45.3	75.6	10	1	11				87.3	1,060	369,699	99.9	1,440	431,952	
21	59	Indore	May	7.35	61.6	102.7	10	1	11				117.2	1,325	442,907	107.9	1,440	431,952	
26	79	Kota	Jun	6.72	62.2	103.7	10	1	11				108.3	1,325	442,907	106.1	1,536	454,564	
29	92	Nagpur	May	6.75	49.6	82.7	10	1	11				85.9	1,060	369,699	98.1	1,440	431,952	
AVERAGE													93.0	1,136	390,616	100.2	1,454	435,182	
1	3	Agra	Jun	5.98	49.7	82.9	15	1	16				85.9	1,590	493,526	83.9	1,920	543,935	
30	97	New Delhi	Jun	5.59	48.4	80.7	15	1	16										
AVERAGE													85.9	1,590	493,526	83.9	1,920	543,935	
9	24	Bikaner	Jun	7.74	73.5	122.5	50	1	51										
24	69	Jodhpur	Jun	6.90	70.2	117.0	50	1	51										
AVERAGE																			

Pump Sizing for Grapes, Surf			1.6								Nearest Pump Size									
					Crop	Water	Depth			Assumed	DC Surface Pump*			DC Submersible Pump			AC Submersible Pump		
Stn ETo	Stn Sun	Station Name	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	to Water Table	Lift Required		Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)
2	4	Ahmedabad	Jun	6.39	68.6	114.3	2	1	3	118.2	848	230,244							
23	62	Jaipur	Jun	6.08	82.2	137.0	5	1	6				139.2	1,500	483,285	144.3	1,440	431,952	
35	108	Pune	May	6.92	78.8	131.3	5	1	6				131.7	1,200	424,064	162.0	1,440	431,952	
AVERAGE										118.2	848	230,244	135.5	1,350	453,675	153.2	1,440	431,952	
3	5	Akola	May	6.93	71.7	119.5	10	1	11				131.8	1,590	504,820	135.9	1,920	543,935	
4	7	Allahabad	Jun	5.87	62.4	103.9	10	1	11				110.4	1,590	504,820	115.2	1,920	543,935	
8	21	Bhopal	May	7.17	79.2	132.0	10	1	11				136.7	1,590	504,820	140.6	1,920	543,935	
20	56	Hyderabad	May	6.86	68.0	113.4	10	1	11				130.4	1,590	504,820	118.0	1,680	487,944	
21	59	Indore	May	7.35	92.4	154.0	10	1	11										
26	79	Kota	Jun	6.72	93.3	155.5	10	1	11										
29	92	Nagpur	May	6.75	74.5	124.1	10	1	11				126.2	1,590	504,820	132.4	1,920	543,935	
AVERAGE													127.5	1,590	504,820	126.4	1,872	532,737	
1	3	Agra	Jun	5.98	74.6	124.3	15	1	16										
30	97	New Delhi	Jun	5.59	72.6	121.1	15	1	16										
AVERAGE																			
9	24	Bikaner	Jun	7.74	110.2	183.7	50	1	51										
24	69	Jodhpur	Jun	6.90	105.3	175.4	50	1	51										
AVERAGE																			

Pump Sizing for Grapes, Surf			2.0								Nearest Pump Size									
					Crop	Water	Depth			Assumed	DC Surface Pump*			DC Submersible Pump			AC Submersible Pump		
Stn ETo	Stn Sun	Station Name	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	to Water Table	Lift Required		Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)	Output (m3/day)	Array (Wp)	Cost (Rs)
2	4	Ahmedabad	Jun	6.39	91.4	152.4	2	1	3										
23	62	Jaipur	Jun	6.08	109.6	182.7	5	1	6										
35	108	Pune	May	6.92	105.0	175.0	5	1	6							180.9	1,680	487,944	
AVERAGE																180.9	1,680	487,944	
3	5	Akola	May	6.93	95.6	159.3	10	1	11										
4	7	Allahabad	Jun	5.87	83.2	138.6	10	1	11										
8	21	Bhopal	May	7.17	105.6	176.0	10	1	11										
20	56	Hyderabad	May	6.86	90.7	151.1	10	1	11										
21	59	Indore	May	7.35	123.2	205.4	10	1	11										
26	79	Kota	Jun	6.72	124.4	207.3	10	1	11										
29	92	Nagpur	May	6.75	99.3	165.5	10	1	11										
AVERAGE																			
1	3	Agra	Jun	5.98	99.5	165.8	15	1	16										
30	97	New Delhi	Jun	5.59	96.9	161.4	15	1	16										
AVERAGE																			
9	24	Bikaner	Jun	7.74	147.0	245.0	50	1	51										
24	69	Jodhpur	Jun	6.90	140.4	233.9	50	1	51										
AVERAGE																			

Table 3.41 PV Pump Sizing for Surface Irrigation using a Ground Water Source

As depth to the ground water table increases PV drip irrigation pumping systems become less expensive than PV surface irrigation pumping systems for all farm sizes. When the depth to the ground water table is less than 5 m, DC surface pumping systems are slightly less expensive for surface irrigation. When the depth to water table is greater than 5 m drip irrigation pumping systems are less expensive in all cases. When the depth to water table increased to 50 m no PV pumps were available with sufficient capacity to supply a surface irrigation system but PV pumps were available which could supply water to small farms up to 0.5 ha if drip irrigation was used. For farms over 2.0 ha PV pumps were not available with sufficient capacity for a surface irrigation systems at any depth but PV pumps were available for most drip irrigation systems when the depth to water table was less than 5 m.

Table 3.42 shows net economic benefits for a 1 ha grape farm under drip irrigation using a ground water source. Depths to water table of 5 m, 10 m, and 15 m were considered. Net economic benefits of 1,374,008 Rs over a 20 year period were calculated even with a depth to water table of 15 m. Net economic benefits increased as the depth to water table decreased. Net financial benefits (after subsidies and loans are considered) would be even higher.

GRAPES (Anib-e-Shahi) Overall Economics for a PV Drip Irrigation System using a Ground Water Source (Depth to Water Table = 5 m)

Economics	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	276,140	253,175										34,355										
Pump System Installation (5%)	12,659	12,659																				
Maintenance for Pump System (0 3%)	10,222		760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines	15,000	15,000																				
Yield (t/ha) Anab-e-Shahi Grapes			26 74	27 52	28 33	29 17	30 02	30 91	31 82	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561 3 Rs/yr)	53,919	250	561	1,123	-1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60 8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24 8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75 6 Rs/t)	31,665		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	493,477	303,144	7,113	7,839	8,570	9,306	10,047	10,793	11,545	12,302	12,863	67,468	13,425	13,425	13,425	13,425	13,425	13,425	13,425	13,425	13,425	13,425
INCOME (5000 Rs/t of produce)	2,094,249		133,676	137,609	141,658	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLOW (Rs)	1,600,772	-303,144	126,563	129,770	133,088	136,521	140,071	143,742	147,537	151,461	150,899	96,294	150,338	150,338	150,338	150,338	150,338	150,338	150,338	150,338	150,338	150,338

GRAPES (Anib-e-Shahi) Overall Economics for a PV Drip Irrigation System using a Ground Water Source (Depth to Water Table = 10 m)

Economics	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	406,856	348,246										90,671										
Pump System Installation (5%)	17,412	17,412																				
Maintenance for Pump System (0 3%)	14,061		1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines	15,000	15,000																				
Yield (t/ha) Anab-e-Shahi Grapes			26 74	27 52	28 33	29 17	30 02	30 91	31 82	32.75	32 75	32.75	32 75	32 75	32.75	32 75	32 75	32 75	32 75	32.75	32 75	32 75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561 3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60 8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24 8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75 6 Rs/t)	31,665		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	634,785	402,968	7,399	8,125	8,855	9,591	10,332	11,078	11,830	12,587	13,148	124,059	13,710	13,710	13,710	13,710	13,710	13,710	13,710	13,710	13,710	13,710
INCOME (5000 Rs/t of produce)	2,094,249		133,676	137,609	141,658	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLOW (Rs)	1,459,464	-402,968	126,277	129,485	132,803	136,235	139,785	143,456	147,252	151,176	150,614	39,693	150,053	150,053	150,053	150,053	150,053	150,053	150,053	150,053	150,053	150,053

GRAPES (Anib-e-Shahi) Overall Economics for a PV Drip Irrigation System using a Ground Water Source (Depth to Water Table = 15 m)

Economics	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	487,229	426,619										90,671										
Pump System Installation (5%)	21,331	21,331																				
Maintenance for Pump System (0 3%)	17,225		1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines	15,000	15,000																				
Yield (t/ha) Anab-e-Shahi Grapes			26 74	27.52	28 33	29 17	30 02	30 91	31 82	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32 75	32.75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561 3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60 8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24 8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75 6 Rs/t)	31,665		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	720,241	485,260	7,634	8,360	9,090	9,826	10,567	11,313	12,065	12,822	13,384	124,305	13,945	13,945	13,945	13,945	13,945	13,945	13,945	13,945	13,945	13,945
INCOME (5000 Rs/t of produce)	2,094,249		133,676	137,609	141,658	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLOW (Rs)	1,374,008	-485,260	126,042	129,250	132,568	136,000	139,550	143,221	147,017	150,940	150,379	39,458	149,818	149,818	149,818	149,818	149,818	149,818	149,818	149,818	149,818	149,818

Table 3.42 Economic Analysis for PV Drip Irrigation using a Ground Water Source

3.13 SUMMARY

Section 3 began with a brief look at past studies on the use of photovoltaics for irrigation. Reference crop evapotranspiration rates, effective precipitation, and solar energy availability were determined for a number of stations across India. This was followed by a discussion of methods used for sizing a remote pumping system and comparing costs over the life of the pumping system. Grapes were chosen for detailed study because they are a widely spaced, perennial crop with a high return and low water requirement. Crop evapotranspiration rates, irrigation water requirements, and water pumping requirements were then calculated for grapes. Different options for remote irrigation pumping for grapes were then compared. For surface water sources, the capital costs for PV pumps using drip irrigation were slightly higher than costs for PV pumps using surface irrigation. This trend reversed for ground water sources when the depth to ground water table was more than 5 m. Diesel pumping systems were found to be considerably less expensive than PV pumping systems, even for small irrigation water requirements because of reduced prices on the Indian market.

An economic and financial analysis of net benefits from PV drip irrigation systems for small grape farms showed that returns from increased yields more than covered the cost of the irrigation system. Net benefits from a PV drip irrigation system exceeded net benefits from either a PV or diesel system using surface irrigation in spite of higher capital costs. This is due to higher yields and increased returns from grapes grown with drip irrigation. The relative benefits of using drip irrigation increased when a ground water source was considered.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

This study examined the use of PV water pumps for irrigation in India, focusing on drip irrigation methods, and considering grapes for detailed economic study. The advantages of PV pumping systems for remote irrigation are summarized below along with the advantages of drip irrigation for use with PV pumping systems, and the reasons for focusing on grapes. The study conclusions are summarized in Section 4.1 and recommendations for future work are made in Section 4.2.

The advantages of PV irrigation systems compared to other remote irrigation systems are listed below.

- *The energy source (sunlight) is free.*
- *Maintenance for a PV water pumping system is simple, relatively inexpensive and easily handled by the owner.*
- *PV modules have an expected useful life span of over 30 years.*
- *PV systems are modular and can be easily sized to meet individual water demands and budgets, with room allowed for future expansion.*
- *Electricity is generated on site, eliminating costly power distribution networks.*
- *Time consuming trips into town to collect diesel or gas are eliminated.*
- *Solar powered pumps are is more reliable than both diesel and wind systems. Long term maintenance and repair costs are generally lower for solar systems and user satisfaction is higher.*
- *Wind energy levels tend to drop when evapotranspiration demands are highest.*

- *Diesel shortages and electric power blackouts tend to occur during critical periods when irrigation demands are highest and crops are most suceptable to damage from a water shortage.*
- *Shared water supply systems also tend to fail during critical periods. Large canal irrigation schedules do not allow everyone to irrigate during critical periods.*
- *Farmers dependant on purchase of water from other farmers with large diesel pumps may be forced to give up large shares or their crop, preform free labour or pay exorbitant fees if desperate to purchase water during critical periods.*
- *The correlation between water supply and irrigation water demand for a PV pumping system is excellent, far better than other remote pumping options. Evapotranspiration levels drop in the winter and in cloudy, rainy weather when PV pumps are delivering the least water. and rise on sunny, summer days*
- *PV systems do not contribute to either noise or air pollution.*

Benefits of using drip irrigation with PV water pumps:

- *Water delivery rates from a PV pump are well matched to those of a drip irrigation system. Both are designed to deliver a low flow over a long period of time.*
- *Pressure requirements for a drip irrigation system are much lower than for a sprinkler system. This is important because the cost of water delivery increases rapidly with increasing pressure head.*
- *Labour costs are considerably reduced: Since the low flow from a PV pump is typically much lower than that of a diesel pump the length of time required to irrigate the same area increases. This means a significant increase in labour requirements when surface irrigation is used. Using drip irrigation eliminates this problem completely, as the system basically runs itself.*
- *Irrigation water requirements are minimized with a drip irrigation system because water is applied directly to the crop root zone, virtually eliminating deep percolation losses, surface run-off, and evaporation losses.*

- *Application efficiency can be as high as 95% compared to typical efficiencies below 60% for surface irrigation.*
- *Additional water savings of up to 60% over surface irrigation methods can be achieved for widely spaced crops in areas with high evapotranspiration rates since the area between plants remains dry.*
- *Plant yield and vigour generally increases through maintenance of optimal air-soil-water ratios. Record yields have been obtained even under adverse conditions of high land and water source salinity, high temperature, and low relative humidity.*
- *Increases in yield and quality of the crop can be used to offset the high cost of the PV system.*

Reasons why grapes were considered an ideal crop for irrigation with a PV drip system:

- *Grapes are a widely spaced crop and water savings resulting from the use of drip irrigation are high.*
- *Grapes are a perennial crop and irrigation water requirements are therefore spread out over the entire year minimizing the unit cost of water for a solar pumping system.*
- *Average farm sizes for grape cultivation are in the range generally considered viable for PV irrigation. The average farm size for grape cultivation in India is approximately 0.5 ha. Studies from Maharashtra report farms used for grape cultivation vary between 1 and 2 ha.*
- *Grape growing regions tend to be clustered together, making it easier to set up servicing networks for PV and drip equipment.*
- *Grapes require irrigation in India and drip irrigation systems are already recommended.*
- *Grape growers are already familiar with drip irrigation practices.*
- *Grapes are a high value cash crop and therefore likely to generate sufficient returns for timely repayment of loans.*

4.1 CONCLUSIONS

PV pumpsets cannot compete with diesel pumps in the Indian context even with the current subsidies. Irrigation water requirements for small grape farms using drip irrigation did fall into the range generally considered viable for a photovoltaic (PV) pump when North American costs were used. Prices for PV pumps in India were not found to be significantly different from North American prices. However, a review of relevant literature from India suggests that diesel pumpsets are considerably less expensive than in North America. This reduces the scope for PV irrigation systems in India.

In spite of the relative economic advantage of diesel systems, PV drip irrigation system are profitable when used for high value crops with low water requirements. The present worth of net benefits over a 20 year period for a 1 ha grape farm using PV drip irrigation are estimated at 1,660,000 Rs. When financing and equipment subsidies are considered net benefits increase to 1,775,000 Rs.

Returns from increased yields from a drip irrigation system more than compensate for the cost of the PV pumping and irrigation equipment for high value, widely spaced crops with low water requirements, such as grapes. Grape farms using PV drip irrigation systems are more profitable over the long run than farms using considerably lower priced diesel systems with surface irrigation.

The relative benefits of using drip irrigation increase with the depth to the water source. Costs for PV pumps sized for drip irrigation of grapes drop below costs for similar pumps using surface irrigation when the depth to water table is greater than 5 m.

4.2 RECOMMENDATIONS

PV drip irrigation systems are recommended for for small-scale demonstration grape farms in India. The reduced labour requirements with a drip irrigation system and low maintenance requirements with a PV pumping system should combine to guarantee high user satisfaction and create a positive image of PV irrigation systems in general. High economic returns expected from increased grape yields will likely ensure that these demonstration farms are profitable.

PV drip irrigation should be considered for high value, widely spaced, perennial crops with low water requirements in other countries with high solar energy availability and average farm sizes smaller than 2 ha. The economic merit of a PV drip irrigation system depends on the relative cost of other remote pumping options and the returns expected from increased crop yields. These costs and benefits may vary from one location to another.

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APPENDIX A

Review of the Study by

Sir William Halcrow and Partners
in association with
Intermediate Technology Power Ltd

SMALL-SCALE SOLAR-POWERED PUMPING SYSTEMS:

THE TECHNOLOGY, ITS ECONOMICS AND ADVANCEMENT

June 1983

Small-Scale Solar-Powered Pumping Systems: The Technology, its Economics and Advancement

A Review

Introduction

The study done by Sir William Halcrow and Partners in association with Intermediate Technology Power Ltd. was the first comprehensive study of the economics of solar thermal and photovoltaic (PV) powered water pumping systems for irrigation and drinking water supply. This review focuses on the economics of PV powered pumps for irrigation.

Phase I

Phase I laboratory tests and field trials were completed in 1981. From the results of these tests solar powered pumps were considered to have potential for irrigating small areas between 0.5 and 1.0 ha with pumping heads of no more than 5 m. Further development was required to make the systems more robust, reliable, efficient and cost-effective. To this end a mathematical model was created to aid in photovoltaic systems design and prepare performance specifications for improved pumping systems.

Phase II - Technical Evaluation of Solar Water Pumps

Further laboratory testing was done in Phase II. Table B.1 show the results of these tests. The technical design of the pumps had improved considerably, though room remained for improvements in efficiencies of the pump and motor subsystems.

Cat	System Supplier	Projected ($) Capital Cost $	Vol (2) del at design hd m³	Daily Efficiency (DE)s (1) at low hd (3) (75 % DH)	at Design hd (DH)	high head (3) (150% DH)	Max Subsystem Effic at Design Hd %	Projected Specific Capital Cost $/kJ	Results @ 4 kWh/m²/d at Design Hd Daily Efficiency %	Vol (4) Del m³	Remarks
A	Monegon	2124									Failed to work, needs further development
	SEI	4415	90	25	21	06*	33	25	18	63	Good system concept but could have lower SCC with better matching System best at 5 m head
	Solomat	2150	48*	20	19	20	34	23	14	30*	Performance not as good as expected Flap valve in self priming tank could be unreliable and causes energy losses
	IPA	3231	16*	05	06	07	12	71	05	15	Interesting system but performance poor due to many losses PV array deteriorated rapidly Good scope for low cost manufacture
B	ALG	4614	73		28	19	57	09	25	55	Good concept and very efficient sub system but several minor features need to be modified to improve reliability Very low SCC Performance generally met or exceeded specification
	Helmdynamics	5276	62	13	15	14	33	12	13	44	Good surface mounted pumpset with self priming tank Needs more efficient pump & motor to bring SCC down to $1.0/kJ/day
	KSB	4822	48*	35	34	20*	53	15	22	27*	Very efficient subsystem but output below specification More suited to 5m head than 7m Good system concept
	Solarforce	9544	64	20	22	20	30	22	18	44*	Good system for permanent installation in borehole Pump efficiency poor Robust design, but complicated to install
C	Grundfos	7812	33	34	38	33	44	1.2	3.2	24	Very good concept, easy to install and operate Performance met or exceeded specification in all respects Very good daily efficiency Low SCC
	Wm Lamb	4445	16(6)	26	25	23	41	15	16	8*	Good system provided head remains constant and daily insolation is >5kWh/m² since high threshold irradiance
	Solartec	11239	23	16	18	16	30	24	13	15*	Good concept and performance met specification, but efficiency poor, hence high SCC
	Tensolar Corp	10770	19*	21	23	25	38	29	19	13	Performance just below specification MPC ensures low threshold to start Unsuitable for situations where head changes every day Fine filter cannot be back-flushed if it becomes blocked

NOTES

(1) Based on gross array area

(2) Spec required 60m³ for A & B and 20 m³ for C for 5kWh/m² day

(3) Spec required DE at end of head ranges to be ≥ 75% of DE at DH

(4) Spec required vol under 4 kWh/m².d to be ≥ 70% of design volume under 5kWh/m² d

(5) Based on array $5/Wp plus estimate for system in quantity production Equivalent to FOB costs, installation costs not included

(6) System accepted on basis of 15m³/day output

(7) * indicates below specified performance

Table B.1 Summary of Test Results on PV Pumping Systems

Phase II - Economic Evaluation of PV Pumps for Irrigation

The Phase II study included a detailed comparative evaluation of solar, wind, diesel, kerosene, animal and human powered pumps for irrigation of small farms. This study was done using representative technical data and international cost data drawn from the world market scenario and considered to be free from the influence of subsidies.

The baseline study compared the cost of irrigating a 2 ha farm with a peak crop water requirement of 6 mm/day for each of the six water pumping methods. Most farms in developing countries are between 0.5 and 2 ha. Crop water requirements vary from month to month due to variations in evapotranspiration rates and rainfall. Two cases of static lift were considered: a 2 m lift from an open water source and a 7 m lift from a borehole. Both furrow and trickle irrigation methods were considered for each pumping systems. With furrow irrigation channels could be either unlined or concrete lined. The optimal irrigation and conveyance method was determined for each system prior to comparison. The area to be irrigated was then varied between 0.25 to 4 ha to find the optimal area for each type of pump and thus the number of pumps required to irrigate the base case 2 ha farm.

Two cases were considered for both diesel and kerosene pumps. The high case represented realistic performance of small engine pumps under most field conditions in developing countries (diesel/pump efficiencies = 6%). The low case represented the best that could be expected under good conditions in developing countries (diesel/pump efficiency = 9%). Water storage (0.5 to 1.0 days worth at peak water demand) was considered for both solar and wind systems.

Baseline Study Methodology

The methodology used in the baseline study is outlined below.

1) Input technical, cost, meteorological, water use and economic parameters.
2) Determine the critical month for solar and wind pumps (minimum ratio of energy available to that required).
3) Calculate the optimal irrigated area and pump size for each type of pump (an iterative process since total dynamic head depends on flow). Only the critical month is considered for solar and wind systems.
4) Determine total system costs from the size dependant cost functions. Capital cost, $C= C_0 + C_1S^b$, where C_0 is the fixed cost, C_1 is the size dependant cost, S is the size of the component and b an exponent.
5) Calculate yearly maintenance, repairs and replacements.
6) Find present worth of total system costs assuming a 30 year period of analysis and a discount rate. Differential inflation rates of -7% per annum for PV modules and +3.5% per annum for diesel fuel were used.
7) Calculate the unit cost of water.

Two criteria were used to determine economic viability: first the pumping system must provided water at costs similar to or lower than other systems and second the cost must be low enough to be recovered through increased crop production. The true cut off point for economic viability depends on the crop, the crop water requirements and the market prices. Ten cents/m^3 (1982 $US) was assumed to be an acceptable cost for water delivered to the crop. Assuming a 60% application efficiency (furrow irrigation), water must be delivered to the field at 6 cents/m^3. For trickle irrigation (application efficiency = 85%), water must be delivered to the field at 8.5 cents/m^3.

Table B.2 shows the technical characteristics of all the pumping systems considered. Capital costs (C) for each component of each system were calculated from a size dependant cost function. For a solar pumping system capital costs were determined separately for the array, pump and balance of system components. For the array: C=\$10/W_p. For the pump: C= \$530+ \$1.5 S. For miscellaneous costs of pipe work, foundations, array support structure, shipping, transport and labour: C= \$6/W_p. Table B.3 gives examples of pumping system costs at different hydraulic outputs and Table B.4 gives examples of infrastructural costs. Riser pipe costs for the 7 m lift were added to the borehole cost and affected all alternatives equally.

Results

The critical month for solar energy was found to be May with insolation levels of 20.8 MJ/m^2. The critical month for wind was February with average wind speeds of 2.5 m/s (typical of inland tropical regions with moderate winds).

Figure B.1 shows the variation in the unit cost of water with irrigated area for a solar pump working against a 7 m static lift. Unit water costs are a minimum for areas of 0.75 to 1.5 ha. Two solar pumps were therefore used to irrigate a 2 ha plot. Tables B.5 and B.6 show the optimal supply area and method of irrigation for each of the six pump types at 2 and 7 m static lifts respectively. The number of pumps required to irrigate the 2 ha baseline study area and the cost to do so are also shown in these tables.

At 2 m lift all the systems except solar with storage, high case kerosene, and hand pumps delivered water at the required 10 cents/m^3. Low case diesel was the least expensive options at 4.3 cents/m^3, though high case diesel, the more realistic case, delivered water for about 9.0 cents/m^3. The least expensive solar irrigation system used

Solar pump	
Tilt	20 degrees
Critical Radiation level(daily ave)	250 W/m^2
PV array efficiency	11% (4)
Array lifetime	15 years
Motor/pump efficiency(ave)	40% (3)
Motor/pump lifetime	20,000 operating hours or 10 years maximum (1)
Windpump	
Cut in wind speed	Mean wind speed of least windy month
Rated wind speed	10 m s^{-1}
Furling wind speed	12 m s^{-1}
Efficiency at rated wind speed	9%
Pump lifetime	40,000 operating hours or 10 years maximum (1)
Tower/Rotor lifetime	30 years
Diesel pump (high case)	
Size (Rated shaft power)	2.5 kW
Engine efficiency	10%
Engine lifetime	3700 operating hours or 7.5 years maximum (1)
Pump efficiency	60%
Pump lifetime	40,000 operating hours or 10 years maximum (1)
Diesel pump (low case)	
Size (rated shaft power)	2.5 kW
Engine efficiency	15%
Engine lifetime	5000 operating hours or 10 years maximum (1)
Pump efficiency	60%
Pump lifetime	40,000 operating hours or 10 years maximum (1)
Kerosene pump (high case)	
Size (rated shaft power)	1.1 kW
Engine efficiency	3%
Engine lifetime	2700 operating hours or 5 years maximum (1)
Pump efficiency	60%
Pump Lifetime	40,000 operating hours or 10 years maximum (1)
Kerosene pump (low case)	
Size (rated shaft power)	1.1 kW
Lifetime	3700 operating hours or 5 years maximum (1)
Engine efficiency	5%
Pump efficiency	60%
Pump Lifetime	40,000 operating hours or 10 years maximum
Animal pump	
Mean animal power rating	350 W
Length of working day per animal	5 hours
Pump efficiency	60%
Pump lifetime	15 years maximum
Animal lifetime	10 years
Hand pump	
human power rating	60W
Length of working day	8 hours social) irrigation only 5 hours actual)
Pump efficiency	60%
Pump lifetime	20,000 operating hours or 10 years maximum (1)
Peak flow rate (2)	(at 2m static head) = 1.83 lit/s (at 7m static head) =0.52 lit/s (at 20m static head) = 0.18 lit/s

NOTES:

(1) : Unit replaced at whichever limit is reached first.
(2) : Extrapolated from data from 'Performance Index for Man Powered Pumps' by A R O'Hea, Appropriate Technology Vol 9 No. 4, March 1983 assuming 36 watt output maintained for duration of 10h.
(3) : Based on ratio of hydraulic energy output to energy input when pump is working
(4) : Based on gross cell area (not array)

Table B.2 Technical Characteristics of Irrigations Pumps

System	Hydraulic Rating of Pump (watts)	Capital Cost of Pumping Systems	Maintenance Cost $ per yr	Maintenance Cost $ per 1000 operating hours	Operating Cost
Solar	100-400	$17.1-18.7 Wp of array output(3)	50(2)	12	0(4)
Wind	N/A	$300 per m² of rotor (for 1m <dia <10m)	50(2)	6	0(4)
Diesel - low	1.5 kW	$850 per kW engine shaft output	-	200	40¢ per litre(5)
Diesel - high	1.5 kW	$850 per kW engine shaft output	-	400	80¢ per litre(5)
Kerosene - low	550	$400 per kW engine shaft output	-	200	40¢ per litre(5)
Kerosene - high	550	$400 per kW engine shaft output	-	400	80¢ per litre(5)
Animal	210	$5.2 per hydraulic Watt output(1)	10(2)	-	$2.25 per animal day
Handpump	36	$6-$8 per hydraulic Watt	50(2)	-	$1 per man day

NOTES:

(1) On the basis that one animal generates 350 watts
(2) Probably low for one pump alone, but when groups of pumps are involved total cost is reasonable
(3) See Table 8.4 for details
(4) Values will be small and in absence of firm data costs have been set to zero
(5) Costs of attendance on engine not included

Table B.3 Pump Costs at Various Hydraulic Outputs

Component	Size	Capital Cost	Maintenance Cost ($ per year)
Well	2m	$ 3 per metre	) deemed to
Borehole	7m	$56 per metre	) be included) in pump maintenance costs
Pipework in borehole(1)	-	$25 per metre	0(2)
Storage Tank	30m³	$16.2 per m³	0
Earth Channel	100m²	$0.6 per m²	50
Lined Channel	100m²	$3 per m²	35
Furrow	-	0	0(2)
75mm O PVC pipe	N/A	$12 per metre	0(2)
12mm O PVC pipe	N/A	$0.4 per metre	0(2)

NOTES:

(1) Added to cover costs of riser pipe within borehole for all systems. In case of solar this is extra over the pipework provided as part of the pumping system under miscellaneous costs item - ref. Table 8.4

(2) Values have been small and in absence of firm data costs have been set to zero

Table B.4 Cost of Infrastructural Components

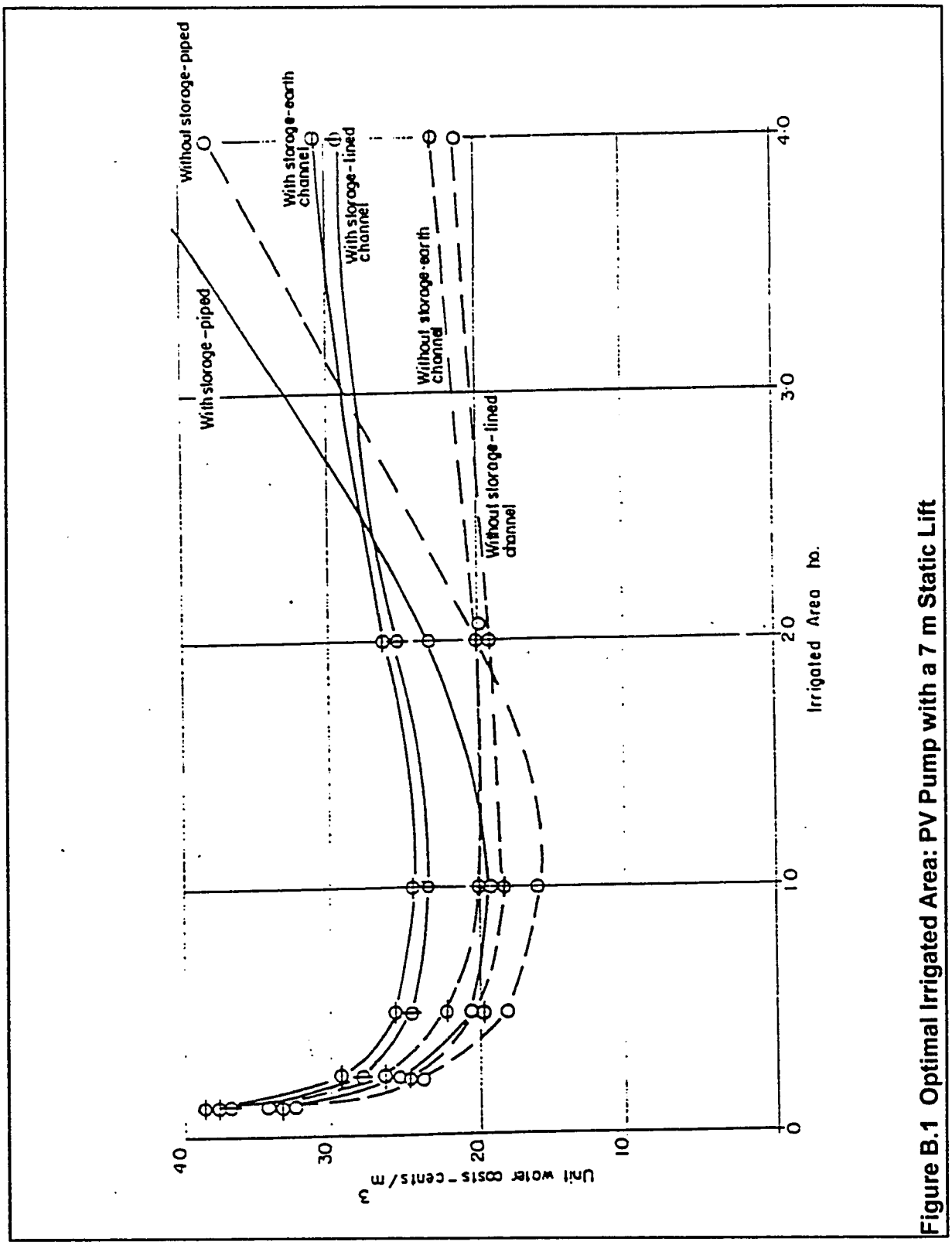


Figure B.1 Optimal Irrigated Area: PV Pump with a 7 m Static Lift

Pump	Optimum Supply Area	Optimum Distribution Method	Number of Pumps	Power Source Size per pump	Actual Lifetime		System Capital Cost	PW of replacements	Annual Running Costs	Annual Maint Costs	Life Cycle Costs (PW)	Unit Cost of water to crop
					Power Source	Pump						
	hectares				yrs	yrs	$	$	$	$	$	cents per m³
Solar	1	lined channel	2	425 Wp (2)	15	6.9(7)	17060	3074	0	245	22676	8.8
Solar + Store	1	lined channel	2	468 Wp (2)	15	6.9(7)	26106	7909	0	175	35831	13.9
Wind	1	lined channel	2	18.6 m²(3)	30	10	11071	730	0	187	13742	5.3
Wind + Store	1	lined channel	1	32.7 m²(3)	30	10	20958	1101	0	187	23998	9.3
Diesel - low	> 4	lined channel	1	2.5 kW(4)	9.1	10	2470	1525	451	241	11169	4.3
Diesel - high	> 4	lined channel	1	2.5 kW(4)	6.7	10	2470	2079	1352	441	23147	9.0
Kerosene - low	2	lined channel	1	1.1 kW(4)	3.6	10	715	1138	1097	142	14699	5.7
Kerosene - high	2	lined channel	1	1.1 kW(4)	3.6	10	715	1138	2193	243	27119	10.5
Animal	1	lined channel	2	350W/animal(5)	10	10	3632	1036	755	90	13427	5.2
Handpump	0.2(1)	lined channel	10	60W/person(6)	-	10	3756	1975	2048	650	33712	13.1

NOTES:
(1) Not optimum, but limited by pump output
(2) Array output
(3) Rotar area
(4) Shaft output
(5) Assumed output per animal
(6) Assumed input power maintained over 5 working hours
(7) Includes electric motor

Table B.5 Irrigation of 2 ha with a 2 m Static Lift

Pump	Optimum Supply Area	Optimum Distribution Method	Number of Pumps	Power Source Size per pump	Actual Lifetime		System Capital Cost	PW of replacements	Annual Running Costs	Annual Maint Costs	Life Cycle Costs (PW)	Unit Cost of water to crop
					Power Source	Pump						
	hectares				yrs	yrs	$	$	$	$	$	cents per m³
Solar	1	piped	2	636 Wp (2)	15	6.9(7)	33093	8707	0	175	43615	16.9
Solar : Store	1	piped	2	802 Wp (2)	15	6.9(7)	39734	9336	0	175	50885	19.8
Wind	1	lined channel	2	46.2 m²(3)	30	10	27892	1461	0	187	31295	12.2
Wind + Store	1	piped	2	31.2 m²(3)	30	10	29830	6063	0	117	37107	14.4
Diesel - low	> 4	lined channel	1	2.5 kW(4)	5.5	10	3014	2561	748	241	15828	6.1
Diesel - high	> 4	lined channel	1	2.5 kW(4)	4.0	10	3014	3537	2243	441	34384	13.4
Kerosene - low	1	lined channel	2	1.1 kW(4)	1.9	10	2450	1986	1982	282	27192	10.8
Kerosene - high	1	lined channel	2	1.1 kW(4)	1.9	10	2450	1986	3969	482	50537	19.6
Animal	1	piped	3	350W/animal(5)	10	10	14110	6036	971	20	30425	11.8
Handpump	0.12(1)	piped	16	60W/person(6)	-	10	26634	9425	3176	800	77337	30.0

NOTES:
(1) Not optimum but limited by pump output
(2) Array output
(3) Rotar area
(4) Shaft output
(5) Assumed output per animal
(6) Assumed input power maintained over 5 working hours
(7) Includes electric motor

Table B.6 Irrigation of 2 ha with a 7 m Static Lift

furrow irrigation with lined channels and no storage. This system delivered water for slightly less than high case diesel at 8.8 cents/m^3. Animal pumps and wind pumps without storage both delivered water for about 5.3 cents/m^3. Storage tanks for wind or solar systems increased water costs by 4 to 5 cents/m^3.

For a 7 m static head, only low case diesel delivered water for less than 10 cents/m^3, the rate required for economic viability. High case diesel pumps delivered water at 13.4 cents/m^3 and wind without storage at 12.2 cents/m^3. The cheapest solar system, with piped distribution and no storage, delivered water for 16.9 cents/m^3. Storage tanks for wind or solar systems increased water costs by 2 to 3 cents/m^3 at 7 m lift. Kerosene pumps were significantly more costly than diesel due to low efficiency, long working hours required and short life of the equipment. Hand pumps at 30 cents/m^3 were not at all viable because of the labour costs.

Figure B.2 shows the variation in unit water cost with static lift. The effect of static lift on unit water costs is most dramatic for human and animal powered pumps. The diesel systems used in the base case scenario were already oversized and increases in head did not have as great an effect.

The most appropriate method of irrigation for a PV system depended on the static lift. The cross-over point between solar irrigation with piped distribution and solar irrigation via furrows and lined channels occurred at approximately 4 m. As static lift increased, the cost of pumping increased along with the need to conserve water. For static lifts less than 4 m it was less expensive to remain with furrow irrigation. Lining the channels, a relatively inexpensive water conservation method, was justified but providing piped distribution was not. As lift increased beyond 4 m piped distribution became the less expensive option. Unfortunately, by the time static lift increased beyond 3 m neither system provided water for less than the 10 cent/m^3 cut-off limit for economic viability.

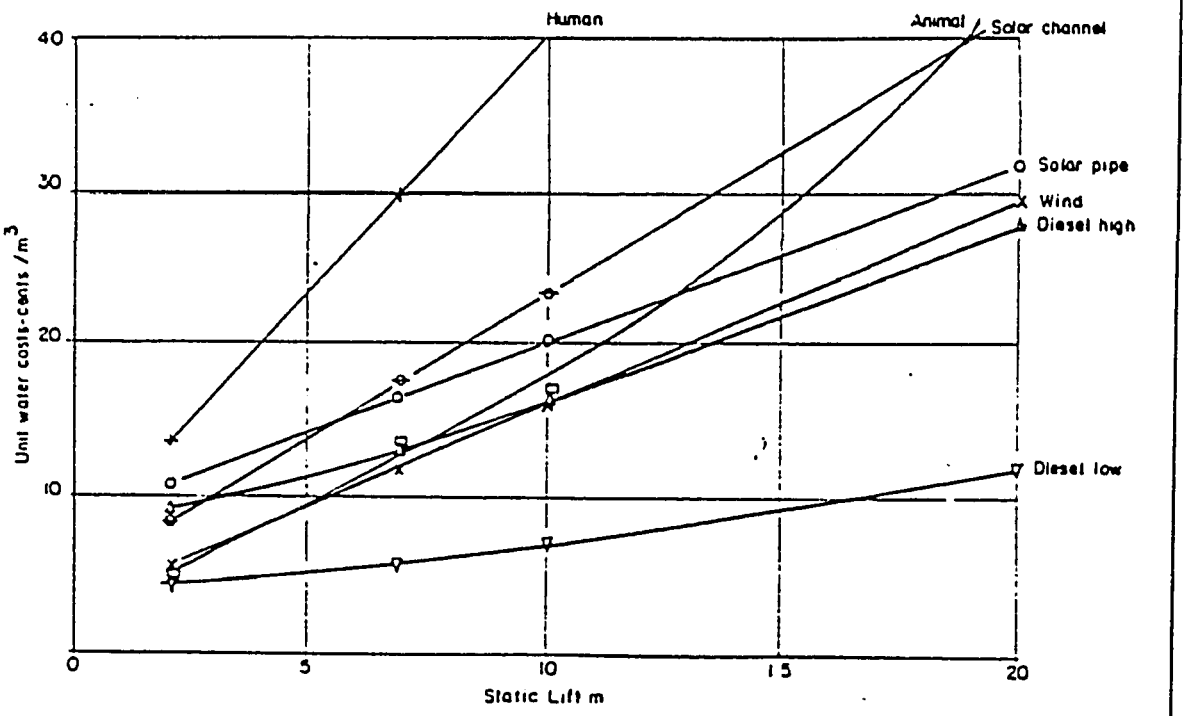


Figure B.2 Effect of Static Lift on Unit Water Cost

Target and Potential Cases

Because the cost of PV modules and pumps were expected to drop, two extra cases were considered for PV systems: target and potential. For present-case systems, module costs of \$10/W_p and total systems costs of approximately \$18/W_p (1982 \$US) had been assumed. Pump/motor subsystem efficiencies of 40% were used based on the best systems tested at the time. Significant cost reduction were expected for solar water pumps through improved manufacturing and increased production. By 1987, the target case, increased production was expected to bring module prices down to \$5/W_p and halve pump/motor and maintenance costs. Technological improvements in the pump/motor

subsystem would raise efficiencies to 50%, and total system costs would drop to about $\$9/W_p$. For the potential case, sometime between 1993 and 1998, technological improvements in solar modules were expected to bring module costs down to about $\$2/W_p$. Pump and maintenance costs would remain the same as for target conditions, and overall system costs would drop to $\$6/W_p$. Details of each case can be found in Table B.7.

Figure B.3 shows the variation in unit water cost with static head for the optimal present, target and potential case for solar systems. As the cost of the solar pumps dropped, the need to provide piped distribution also dropped. With reduced pricing, furrow irrigation was sufficient over the whole range of lifts studied. Target case solar systems (1987) with furrow irrigation and lined channels were expected to provide water for under 10 cents/m^3 to lifts of 9 m, and would be cheaper than all other systems with the exception of low case diesel. Potential case solar systems (1993-1998) with furrow irrigation and lined channels were found to be competitive with low case diesel over the whole range of lifts studied and could deliver water for less than 10 cents/m^3 at heads up to 14 m.

Case	Hydraulic rating of pump hydr. watts	Motor/Pump Costs (FOB) $ per peak hydr watt	Motor/Pump Costs (FOB) $ per peak watt array output	Module Costs FOB $ per peak watt	Miscellaneous Costs(5) $ per peak watt	Total installed solar pumping system cost $ per peak watt
Present (mid 1982)	100	6.80(1)	2.70(3)	10	6	18.7
	200	4.15	1.70			17.7
	400	2.82	1.10			17.1
Target (by 1987)	100	3.40(2)	1.70(4)	5	3	9.7
	200	2.80	1.40			9.0
	400	1.41	0.70			8.7
Potential (1993-1998)	100	3.40(2)	1.70(4)	2	3	6.7
	200	2.08	1.04			6.0
	400	1.41	0.70			5.7

NOTES:

(1) From equation C = 530 + 1.5P (Fig 8.3)
(2) From equation C = 0.5 (530 + 1.5P (Table 5.5)
(3) Assumes average subsystem efficiency of 40%
(4) Assumes average subsystem efficiency of 50%
(5) Covers pipework (excluding riser pipe in borehole) foundations, array support, shipping, transport and labour.

Table B.7 Present, Target and Potential Cost Assumptions

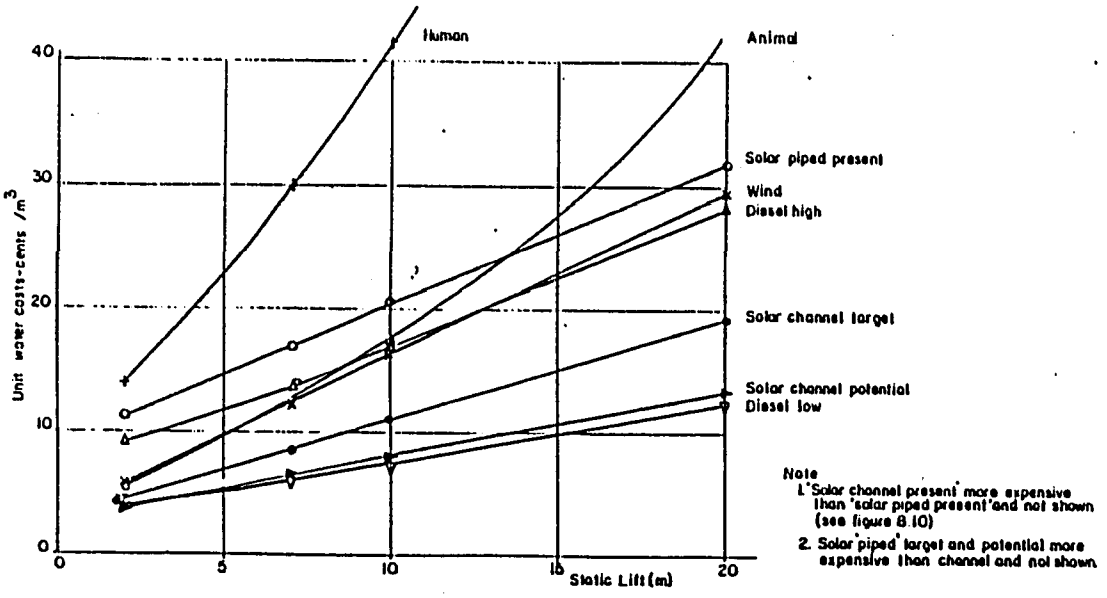


Figure B.3 Present, Target and Potential Unit Water Cost as Function of Lift

Sensitivity Analysis

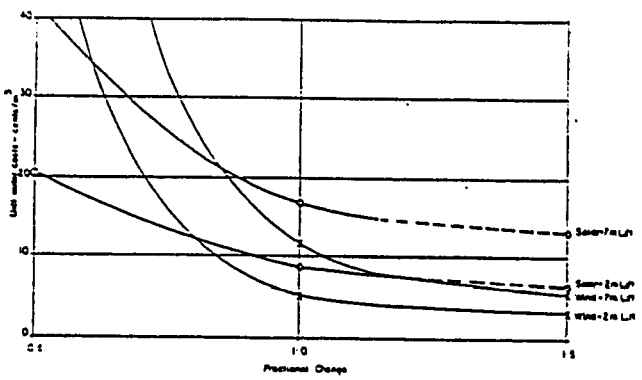
The major parameters thought to influence the study were varied (by +/- 50% in most cases) to determine their effect on the study conclusions. These parameters were divided into 4 groups: climate, agricultural and technical factors, cost and economic factors. The effect of variations in the cost of solar systems were discussed previously as target and potential cases.

Climate

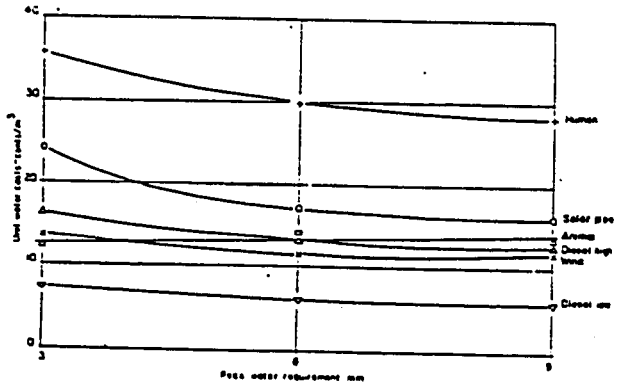
The effects of variations in climatic factors are shown in Figure B.4. The most significant effects are due to changes in the solar and wind resource, shown in B.4a. Total

system cost increases as solar energy decreases. The unit water cost at 4 kWh/m^2 is more than double the unit cost at 5 kWh/m^2. The cost of a wind pumping system increases even more dramatically with decreases in the wind resource. This is especially true for wind speeds less than 2.5 m/s.

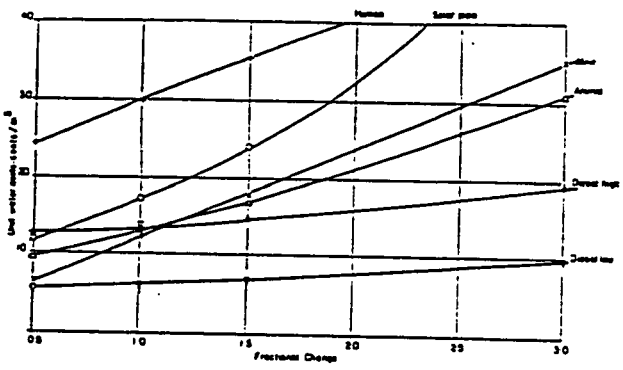
The effect of crop water requirements on systems designed for a 7 m static lift is shown in B.4b. In general unit water costs decrease slightly as total water demand increases. By contrast, increases in the peak demand factor (demand during the peak month relative to annual demand) caused significant increases in unit water cost as shown in B.4c. This is because systems sized for the worst case were significantly oversized for the rest of the year.



Effect of Climatic Conditions
(Baseline irrigation scenario - no storage)
Base Case: Mean wind speed 2.5m/s; critical month mean daily solar irradiation 5.5 kWh/m^2



Effect of Peak Crop Water Requirements - 7m static lift
(Baseline irrigation scenario - no storage)
Base Case: 6mm per day



Effect of Peak Monthly Demand Factor - 7m static lift
(Baseline irrigation scenario - no storage)
Base Case: Peak Monthly Demand Factor 1.76

Figure B.4 Sensitivity Analysis: Meteorological Factors

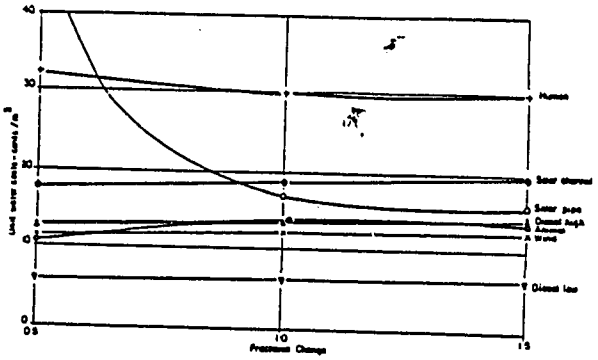
Agricultural and Technical Factors

The effects of variations in agricultural and technical factors are shown in Figure B.5. B.5a shows the effect of variation in pipe diameter or channel slope. Undersizing the pipe diameter in a trickle irrigation system has a significant effect on the unit cost of water. B.5b and B.5c respectively show the effect of changes in the field application efficiency and pump/motor subsystem efficiency.

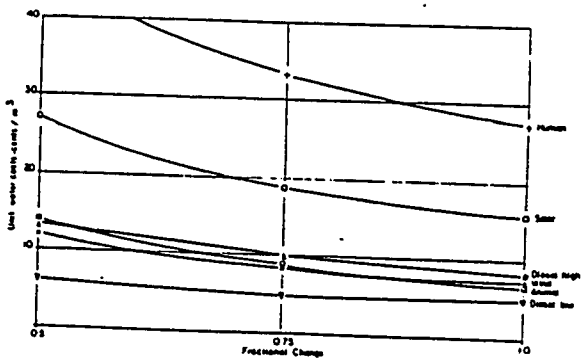
Economic Factors

Figure B.6 shows the effect of changes in economic factors. B.6a shows how the value of labour affects hand pumping costs. Handpumps are only acceptable for low lifts when labour is valued at less than 50 cents/day.

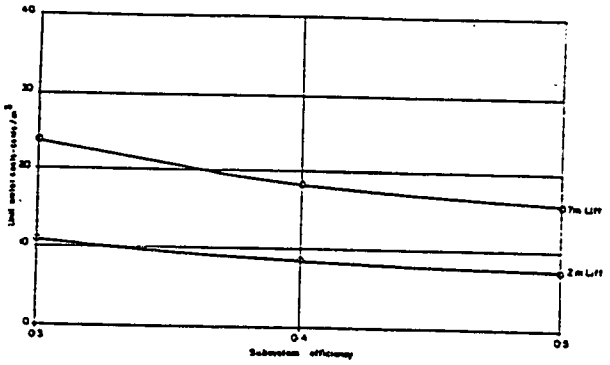
B.6b shows the effect of discount rate on unit water cost. High discount rates favour low



Sensitivity to Pipe Diameter or Channel Slope - 7m static lift
(Baseline irrigation scenario - no storage)
Base Case: Channel 1% slope; conveyance pipe 75mm; trickle pipe 12mm



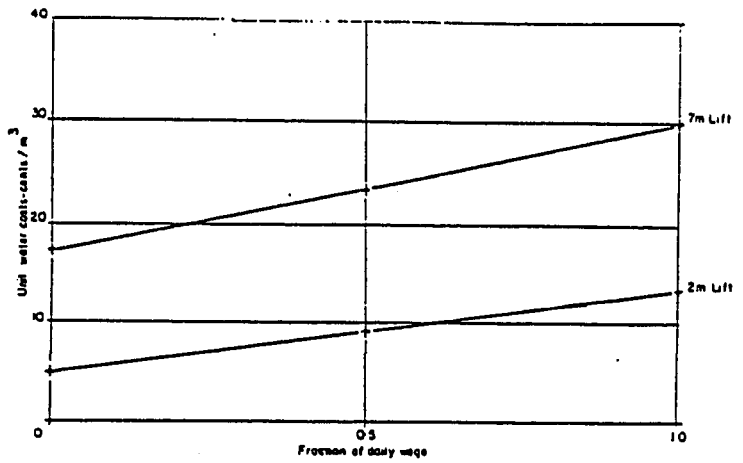
Sensitivity to Field Application Efficiency - 7m static lift
(Baseline irrigation scenario - no storage)
Base Case: Furrows 50%, pipes 55% efficiency



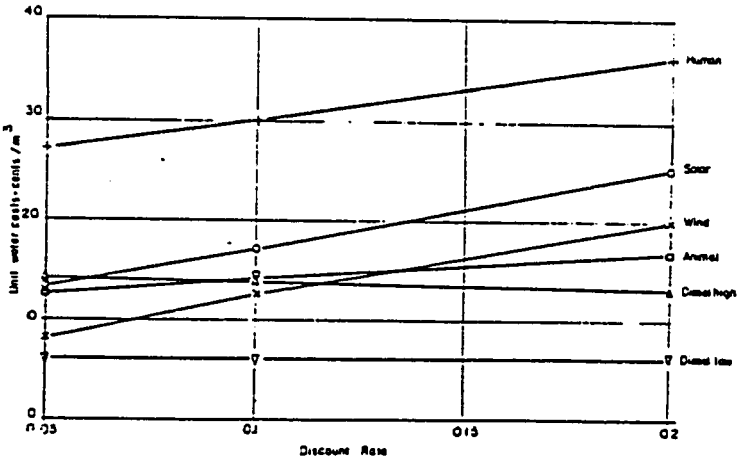
Sensitivity to PV Subsystem Efficiency
(Baseline irrigation scenario - no storage)
Base Case: Subsystem efficiency 40%

Figure B.5 Sensitivity Analysis: Technical and Agricultural Factors

capital cost, high recurrent costs systems, like diesel, as future costs are heavily discounted. Low discount rates favour capital intensive, low recurrent cost systems, like solar and wind. For a 7 m lift, present case solar is more economic than high case diesel at discount rates of about 6%. Target case solar systems are more economic than high case diesel for discount rates up to 15%. Discount rates of 2.5 to 3% are acceptable for low risk investments in settled economic times, but in many developing countries the opportunity cost of capital is much higher and it would be difficult to justify using a value lower than 10%.



Effect of the Value of Labour Costs on Cost of Irrigation Water Pumped by Hand (Baseline scenario)
Base Case: Wage $1 per day



Effect of Discount Rate on Irrigation Costs - 7m static head (Baseline irrigation scenario - no storage)
Base Case: Discount rate 10%

Figure B.6 Sensitivity Analysis: Economic Factors

At a discount rate of 10% the period of analysis could be shortened from 30 to 20 years with little difference in unit water costs. At lower discount rates the length of the period of analysis becomes more important.

Country Specific Studies

Country specific studies were done for Bangladesh, Kenya and Thailand. India was initially considered for a country specific study because of favourable solar and hydrological conditions, a large potential market, a government supported PV program and local manufacture of all components. Unfortunately resources were not available for data collection at the time and India was put on a reserve list for potential future study.

Summary

Unit water costs for solar systems were most sensitive to static lift, peak monthly demand factor, solar energy available in the critical month, capital cost, discount rate. irrigated area, subsystem efficiency and field application efficiency. Solar powered irrigation pumps were best suited to conditions of low static lift, high solar irradiation and steady water demand. Pump/motor subsystem efficiency and field application efficiency should be as high as possible. If trickle irrigation systems are used pipes must be adequately sized. Reductions in capital cost were expected to have a significant effect on the viability of solar systems. Target case solar pumps without storage were expected to have good prospects for lifts up to 9 m. Potential case solar pumps were expected to have good prospects over the entire range of lifts studied. Solar pumps were favoured by lower discount rates. A period of analysis of 20 years was sufficient.

The competitiveness of solar systems compared to other systems was dependant on the recurrent cost of diesel pumps, wind regime and the value of time spent hand pumping. Wind speeds around 2.5 m/s in the critical month represented an approximate break even point between wind and solar systems. The costs of hand pumping water did not become comparable to wind, low case diesel, or animal systems until the daily wage rate fell below 10 cents/day.

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APPENDIX B

PHOTOVOLTAICS FOR IRRIGATION

A
LITERATURE
REVIEW

LITERATURE REVIEW

This review is intended to show the historical development of the use of photovoltaics (PV) for irrigation. The review is divided into two sections. The first looks at the technical development of PV systems for irrigation and the second looks at economic studies. The papers are reviewed in chronological order. An attempt has been made to highlight information relevant to the current study. Particular attention was paid to work done in India.

1. Technical Aspects

The idea of using of solar energy to pump water for irrigation was born centuries ago. As far back as 1615, Solomon de Caux, a French engineer, described a machine to raise water through the expansion of air from solar heat. Between 1850 and 1880 a number of inventors began working on solar steam engines. Notable work was done by Gunter of Austria, Mouchot and Pifre of France and Ericsson, a Swedish immigrant to America. All of these people eventually used their machines to pump water. Research was also being conducted in India. Between 1876 and 1878, Adams, of Bombay, experimented with the use of small plane mirrors to approximate a spherical surface to concentrate radiation on a copper boiler. The 12.2 m diameter arrangement was used to power a 2.5 hp pump for 20 days (Pytlinski, 1978).

At approximately the same time that inventors were developing solar steam engines, scientists were developing a greater understanding of the nature of light. In 1873 James Clerk Maxwell presented a theory of light as high frequency electromagnetic waves. This theory was verified experimentally by Heinrich Hertz in 1887, though subsequent experiments demonstrated shortcomings in Maxwell's theory. Hertz showed that metals exposed to light emitted electrons, and further that the kinetic energy of these electrons

was independent of the light intensity. This discovery, labelled the photoelectric effect, was explained by Albert Einstein in 1905. Einstein's explanation was based on the theory of quantization developed by Max Plank. The energy of the emitted electrons is equal to Plank's constant (6.63×10^{-34} J·s) multiplied by the frequency of the light. If the frequency is below a certain threshold level (the value of which depends on the type of metal) no electrons will be emitted regardless of light intensity. (Serway, 1982)

The first photovoltaic (PV) cell was patented in the early 1940s and the first major breakthrough in the manufacture of PV cells came from Bell Laboratories in 1954. Interest declined with the onset of cheap fossil fuel pricing after World War I, but was revived in the late 50s and early 60s (Enochian, 1982). The first terrestrial PV application, for copper electrolysis, was developed in France in 1961 (Thigle and Gorantiwar, 1992). Interest in PV grew rapidly during the OPEC oil crises of the 70s. Increasing fuel prices and impending shortages, combined with a growing interest in food production prompted experimentation with PV water pumping systems designed for irrigation. The interest in providing irrigation to arid lands of developing countries was especially keen (Enochian, 1982).

The first use of photovoltaics to generate electricity for water pumping occurred in the Soviet Union. In September 1964 a system was installed and tested near Gelendzhik, a remote semiarid region in the south eastern part of the USSR. (Pytlinski, 1978; Thigle and Gorantiwar, 1992) Three panels with a total surface area of 3.6 m^2 were used. The panels rotated "equatorially" and were equipped with flat plate concentrating mirrors with a 2.5 concentration ratio. The maximum power output, 0.25 kW, occurred at a radiation level of $1.98(10^3)$ kJ/hm^2. The total energy conversion efficiency from solar energy to pumped water was 2.6%.

The first large scale use of photovoltaics for irrigation pumping was at Mead,

Nebraska (**Matlin, Romaine and Fishbach**, 1978) The installation consisted of 2212 Solarex and Sensor Technology modules arranged in 28 panels to form a 25 kWp array which could be tilted between 0° and 65°. Thirty-eight 6 V, 375 AH lead-acid batteries provided at total of 85 kWh of energy storage at 115 V. Extensive power conditioning and control equipment included 3 variable frequency, pulse width modulated inverters controlled by a single master circuit, digitally controlled maximum power point trackers, a 3-phase battery charger to supplement array power from the utility during cloudy periods, a 0.25 kW power dump, switch gear, meters and control panels, and an extensive data logging system. The system was used to test a DC and a 3-phase AC motor for irrigation pumping, as well as 3-phase AC fans for crop drying, and a number of single phase loads such as lighting, air conditioning, and utility outlets.

The irrigation system consisted of a 7.5 kW pump used to supply water to an automatic gated pipe system with reuse, chosen for its high efficiency of 85 to 92%. The system operated 12 hours a day, supplying water to 32 ha of corn. Water was lifted from a surface reservoir and pressurized at 25 to 40 kPa. Flow rates varied between 3,500 and 4,200 l/min, depending on the water level in the reservoir and the field being irrigated. Scheduling was preformed by a computer program which used crop and soil data, application efficiencies, and weekly updates from a water meter, minimum-maximum thermometer and electrical resistance blocks, to calculate the date of the next irrigation.

The experimental system was designed to test technical and economic feasibility and obtain detailed information for future applications. Data was collected on weather and insolation, subsystem performance, maintenance requirements, array/load matching, status and fault conditions, to determine the suitability of PV to the application.

The advantages propounded by the authors for using PV to power irrigation pumps included the ability of crops to withstand intermittent pumping, the availability of

inexpensive energy storage in the form of a water pond, the seasonal coincidence of water needs with periods of maximum insolation, and the decrease in evapotranspiration requirements during periods of low insolation. They judged large scale crop irrigation combined with off-season energy uses one of the most promising areas for development of PV in mid to late 80s.

Shortly after this the World Bank/ UNDP commissioned a large scale study on the use of solar energy for water supply and irrigation pumping (**Sir William Halcrow and Partners**, 1981 and 1983). A number of prototypes solar thermal and photovoltaic pumps were submitted from around the world and subjected to extensive laboratory and field testing. These studies are reviewed in detail in Appendix B. Solar thermal pumps were found to be in need of more work before large scale adoption could be considered but PV pumps showed promise for irrigation of small 2 ha farms. The pumps were found to be most suited to conditions of low head, high radiation levels and steady water demand. Computer modelling of the pumping systems was used to examine the system design and a number of recommendations were made for improvement,

By this time India had already begun manufacture of PV modules and components through the government owned Central Electronics Limited (CEL), and in 1982 **Basu** published field test results from a rural photovoltaic system installed near Kalyani, West Bengal. This system was used to supply power to a community centre, and 300 W DC centrifugal pump rated for 3-5 m head, to be used for irrigation. The pump was tested with and without battery backup, and found to be slightly more efficient with battery storage. The entire system was built, installed and operated with Indian expertise, the modules produced by CEL. Villagers were enthusiastic about the system and convinced it could solve their irrigation problems.

Deep well PV systems were also being tested for irrigation. in 1983 **Assabghy and**

Derrick reported on a deep well PV irrigation system operating in Sadat City, between Cairo and Alexandria in Egypt. The 96 module, 3.1 kWp array was connected to 24 6 V lead acid batteries with a total capacity of 185 AH. These powered a DC deep well progressive cavity screw pump, which moved water through a total head of 49 m to a 10 m^3 storage tank. The shaft bearings and down pipe pump shaft were locally manufactured. The system also powered a PM DC centrifugal pump which moved water from the storage tank, pressurising drip and biwall irrigation tubing at 10-20 m. A controller turned the pumps on and off depending on the battery voltage and water level in the storage tank. The system met the water requirements of the Desert Development and Training Headquarters and the surrounding 3.4 ha Desert Botanical Experiment. Efficiency of the well pump subsystem was found to be high, approximately 60% compared to typical subsystem efficiencies between 30 and 45% for positive displacement and multistage centrifugal pumps operating at a 20 m head.

In 1985, **McGowan and Burril**, of the US based Associates for Rural Development published a review of PV irrigation in developing countries. By this time there were over 1000 PV pumps operating in less developed countries. Many of the earlier design problems had been worked out, and the newer generation of pumps had proven themselves to be efficient and reliable, with fewer outages than the electric power utilities. With rural electrification programs in countries like India proving more expensive than originally planned for, the potential for PV was considered enormous.

Farms sizes between 0.5 and 3 ha, with water requirements between 20 and 80 m^3/ha were common in less developed countries, and PV pumps were well suited to this range. Farms belts were often located near rivers, with subsequent low pumping heads. Centrifugal pumps were the most frequently used for irrigation and were good candidates for PV application. McGowan and Burril recommended PV pumps be used with drip irrigation systems because of the high application efficiency at comparatively low heads.

Channel and furrow irrigation were also considered feasible because of low head requirements, and moderate efficiencies. Flood irrigation was advised against because of its low application efficiency, and sprinkler irrigation because of the high head requirements.

Simplicity in design was recommended, since reliability of remote systems tended to be inversely proportional to complexity. Maximum power point trackers and passive gravity driven trackers could increase output by 15% and 40% respectively and were worth consideration. Computer driven tracking devices were found to be too complex and expensive, and users often failed to adhere to adjustment schedules for manual tracking arrays.

By the late 1980s the array/motor/pump system designs were largely worked out and studies were being done on refining and optimising the entire irrigation system. **Girard** (1988), of ERGO Industries in California, reported on tests of drip irrigation of strawberries using solar pumps. Girard used 8 45 Wp Kyocera modules mounted on a passive Zomeworks tracking device. This was used to test 2 different pumps: an AY McDonald 1500 Series impeller pump, with a 700 W DC brushed motor; and an ERGO reciprocating piston pump, with a 400 W brushless motor and internal maximum power point tracking. The pumps lifted water 3 m from ground level to a 5 m^3 tank. From the tank, water was gravity fed through 3 screen filters to a drip irrigation system. The drip system consisted of a 5.1 cm PVC submain supplying water to 84 1.58 cm diameter polyethylene laterals. The Monotube^R laterals, made by Spot Systems, were perforated every 30.5 cm with a 0.30 mm hole. These supplied water to 15,000 strawberry plants on a 0.46 ha field in Willow Creek Northern California.

The daily system efficiency of the DC centrifugal pump at an 8 m head was 2.1% with the tracker and 1.7% without the tracker. Efficiency dropped at low power levels. The

ERGO pump was not as sensitive to the level of input power because of its maximum power point tracking, displaying daily system efficiencies from 3.9 to 4.2%. The passive tracker increased output from the centrifugal pump by 42% and from the positive displacement pump by 35%.

Though the pumps could handle daily irrigation requirements, the Monotube[R] laterals required a flow rate of 210 l/min, much higher than that supplied by the pumps. A passive, automatic batch delivery system was designed to overcome this. The system used a float and toilet bowl type drain, which allowed the tank to fill slowly and deliver the full contents in 3 to 4 batches a day at an average flow rate of 240 l/min. This system was considered more practical than motor controlled valve systems for developing countries.

One goal of the study was to minimize the cost of irrigating with PV by establishing relationships between pressure, uniformity and irrigation efficiency for the monotube laterals. The array and pump costs (75% of the total system cost) were dependant on pressure head requirements to a much larger degree than conventional pumps. Decreasing pressure supplied at the field inlet increased variation in emitter flow rates along the length of the laterals. The coefficient of variation (a statistical parameter which takes into account variation in emitter flow due to pressure differences along the line and irregularities in manufacture) was found to decrease rapidly as pressure increased from 0 to 2.5 m. Further increases in head showed only slight decreases in the coefficient of variation. A 3.6 m high storage tank was therefore recommended. This would supply a 2.5 m head to the monotube laterals with extra head allowed to overcome losses through the pipes and filters.

Filter clogging occurred within 1 or 2 days, resulting in excessive pressure drops. A more adequate system, with media bed filtration and a sand separator/screen filter, would have been too expensive. Tests were conducted on Irrigro[R] porous tubing, made

of Tyvek^{R}, and manufactured by International Irrigation Systems. Porous tubing works at very low pressures and can handle contaminated water. Lengths of 110 m were tested at a 1.2 m head with very low flow rates. They showed good horizontal distribution, but no uniformity tests were conducted.

Overall irrigation efficiency was estimated at 55 to 65%. The low efficiency is attributed to low crop cover, poor root zone uniformity, and emitter design. Tensiometers showed adequate moisture for first year plants, with increases up to 15% for subsequent years. This could be easily accomplished with the addition of 2 more solar panels.

Behrendorf and Sutton (1988), working at the University of Sydney, Australia studied the use of PV systems for drip irrigation of vegetables. They recognized that the high cost of a PV water pumping system required maximum efficiency of water use and application to a high value crop, such as vegetables or flowers, to ensure economic viability. Behrendorf and Sutton tested 2 systems: a Grundfos SP8-4, 4 stage AC centrifugal pump, with a 21 module array (9.5 kWp) from BP Solar, and peak power tracking; and an ARCO single stage DC centrifugal pump with a 28 module (9.0 kWp) Solarex array, and no peak power tracking. The systems were used with Bi-Wall^{TM} drip irrigation tubing, to supply water to lettuce and tomato crops. Neither system incorporated battery storage.

Since optimum yields for vegetable crops result from daily irrigation, the systems were tested for their ability to supply the crop's daily irrigation requirements. According to the Monteith-Penman equation evapotranspiration requirements are a linear function of insolation. Pump output should, therefore, also be a linear function of insolation in a well matched system. Proper sizing becomes difficult when this is not the case. If a pump is sized for a clear day, output is smaller than required on a cloudy day, if sized for a cloudy day it is oversized for clear day. The test therefore, was to determine if the system

efficiency remained constant over a wide range of insolation, meaning water output would be a linear function of insolation, like water demand.

They found that a relatively constant system efficiency was achieved over a wide range of insolation with the Grundfos system operating at a head of 12 m. It was assumed that other Grundfos systems would show constant system efficiencies at other heads. A constant system efficiency was never achieved with the Arco system, but if the effect of peak power tracking were simulated, a reasonably constant system efficiency was achieved for an 8 m head over an insolation range of 600 to 1000 W/m^2.

Behrendorf and Sutton's work highlights the difficulties involved in the proper sizing of an PV irrigation system. It should be noted that their study did not take into account the effects of rainfall, which further complicates the sizing process, yet tends to balance the effects of lower output on cloudy days. Under low sunlight, irrigation requirements fall proportionately, but pump output declines faster. Rainfall should make up the difference between irrigation requirements and pump output, allowing for smaller pump sizings based on sunny day requirements, but such studies remain to be done.

In 1991, **Ratajczak and Kaszeta** wrote a section on agricultural applications of PV systems in a book titled "Solar Energy in Agriculture". They stressed that any photovoltaic system must be designed as a whole to achieve proper cost optimization. Brushed or brushless PM DC motors were recommended, followed by wound field DC, then AC motors for high power applications, though inverters were the least reliable system component and should be avoided if possible. Trickle or low loss channel irrigation was recommended as opposed to flood or sprinkler methods. Friction losses could be minimized by choosing larger pipe sizes. Water storage was recommended over battery storage, since batteries increased maintenance requirements and decreased reliability. The required storage volume depended on weather conditions and water use. Storage was not considered

critical for irrigation, since 2-3 days storage is usually available in the root zone, and water needs are lower when insolation levels are low. The authors suggested the use of portable arrays which could be moved to different fields as required, or shared by a number of owners.

Running in a similar vein to Behrendorff and Sutton's work, **Whiffen, Haman and Baird** (1992), of the American Society of Agricultural Engineers, published a detailed study of the reliability of PV for small irrigation systems. For this study they built a prototype PV system, measured the field efficiency of each component over 43 days, developed a model which calculated the land area that could be irrigated given radiation data, component efficiencies, and water demand, then ran the model using 10 years of meteorological data to determine the area that could be supported with an 80% degree of reliability, the criteria set by Florida water management authorities.

The system built used 6 60 Wp modules with aluminum covered sheet metal reflectors attached to the long edges at a 120° angle. The array was equipped with single axis east/west tracking, and manual tilt adjusted monthly. The array was directly connected, with no batteries, to a 0.4 kW (0.5 hp) PM DC motor and single stage centrifugal pump. An electronic switching unit was used to connect 2 sets of 3 modules each in parallel at low insolation levels, and series at high insolation levels. At an irradiance level of 250 W/m^2, the array produced 6 A at 14 V, at 1000 W/m^2 the array produced 12 A at 28 V. This matched the current demands of the load at the respective voltages.

Enough data was collected over 43 days in May and June of 1989 to evaluate the efficiency of the array, electronic controller, and pump/motor unit under different insolation levels. The average subsystem efficiencies were 11% for the array, 96% for the electronic switching unit, and 44% for the pump/motor unit, for an overall average of 4.6%. Expected

fluid power output was estimated for 7 randomly chosen days to validate the model. Results were good, though there was some difficulty in estimating output from the pump/motor unit due to external variables, such as pond cleanliness.

Next, 10 years of hourly solar radiation data were used to calculate the fluid power output of the system and land area that could be irrigated. The program calculated direct and diffuse radiation based on meterological data and array tilt, and including average reflector enhancement. This was used to power a theoretical system operating at a 5 m head (2 m pipe and filter losses, 3 m operating pressure). Daily potential evapotranspiration values were calculated from the same meteorological data using the Penman equation.

The land area that could be irrigated with an 84% reliability varied greatly from one day to the next, if the water storage capacity of the soil was assumed limited to 1 day. For example on Julienne date 72, 1.81 ha could be irrigated with 84% reliability, while on Julienne date 73, only 0.38 ha could be irrigated. If assumed water storage capacity was increased to 3 days, predictions levelled out somewhat, and the smallest land area that could be irrigated over the winter vegetable season (September to May) was 1.06 ha. The authors noted that effective rainfall was not taken into account in their model, and could be expected to increase the land area that could be reliably irrigated.

In 1992 **Foroud, Elser and Ethier**, of Agriculture Canada and UMA Engineering Developed a PV powered irrigation controller for automating surge flow surface irrigation systems. The automatic control system (ACS) consisted of a programmable logic controller (PLC), a PV power supply system, a Man Machine Interface (MMI-102), a regulated air system, and 4 valve controllers (VCs), and 4 Hasting's irrigation valves. The PLC was a teleSAFE 6000 configured with 4 relay output modules. The VCs used a 24 VDC solenoid valves and 3 way pilot valve to provide a switching interface between the

PLC programm and the Hasting's valves. A solar system consisting of 2 deep-cycle RV batteries, solar panels, regulators, and support structure, supplied 24 VDC power to the PLC, MMI-102, and solenoids.

The design was validated in laboratory and field tests and worked well, though the Hastings valves were not found to be suitable for automation. The PLC monitors the system, checking time remaining to complete irrigation, verifying the number of valves involved, and activating/deactivating valves in a sequence determined by the operator. It can provide variable cycle ratio, a combination of short and long ON times depending on the length of furrow, and can control up to 8 irrigation valves.

Although the photovoltaic array is not used to power a water pump in this case, it could be used in conjunction with a water pumping system to improve irrigation efficiency. Application efficiencies of less than 50% have been reported with border dyke and furrow irrigation, but efficiencies of 80 to 90% can be achieved. Surge flow irrigation is one of the more recent advances in this area. By applying water on an intermittent rather than continuous basis, it allows for a more uniform infiltration rate, reducing advance time and lowering percolation losses. It requires less energy to operate than a sprinkler system but is difficult to control manually. As suggested by Behrendorf and Sutton (1988) though, the applicability of an automated system to remote locations in developing countries is questionable.

Research in India conducted during the late 1980s lagged behind that going on in developed countries. Studies reviewing the suitability of PV pumping systems for irrigation, used simple locally manufactured, direct connected pumps with no consideration given to irrigation methods and compatibility of the entire system. One article on sizing PV systems for irrigation showed a basic lack of understanding of the requirements of a solar pump. In the early 1990s a study was done demonstrating the suitability of simple direct

connected pumps for irrigation, but the effect of low flows on irrigation practices was largely ignored.

In 1989, **Naik**, of the Orissa Renewable Development Agency, reviewed a DC monoblock centrifugal pump directly connected to a 21 module tracking array. The array had a peak open circuit voltage of 600 V, and a short circuit of 3.51 A. The pump lifted a maximum of 20 m^3/hr at a 30 m head. The pump was started at mid-day by turning the switch on and off, and opening the pump valve slowly. Recommended maintenance included cleaning the modules once a week, cleaning the foot valve and checking the electrical connections once a month, and changing the brushes once every six months. Naik concluded that the pumps were reliable, low maintenance, and trouble free.

Ghosh and Muherjee (1989), of Jadavpur University in Calcutta, published a review of systems installed in Kaikhali, an island village in the delta region of the Ganges known as Sunderban in eastern India. The centralized system provided power for domestic lighting and two separate stand alone systems supplied power to street lights and a pump. The pump provided water to the kitchen and guest house of the Ramakrishna Ashram and irrigated the kitchen garden. Again, the system was simple with 12 30 Wp panels connected via a switch to a 300 W DC pump. The pump lifted 90,000 l/day at a 1 m head. All systems had been installed two years prior to the study but only the pumping system was still working satisfactorily. Ghosh and Mukherjee concluded that the unit cost of energy was high and noted that the cost of panels on the international market was half that of locally produced panels, highlighting one of the problems in development of the solar industry in India.

Malhotra and Kaur (1989), published an highly flawed article on sizing a solar pump for irrigation. First, they outlined the technical configurations of various systems and the benefits of PV pumps. Then they generated 4 graphs to be used in determining water

demand for different crops grown in either alluvial or hard rock regions, on either small or large farms. The graphs were calculated according to Indian Standards, and gave water requirements in l/s. A standard equation was used to determine the pump power required, and manufacturers data used to choose a pump based on the capacity in l/min and total head in m.

Their paper highlights common misunderstandings of the intricacies of sizing solar systems. No mention was made of insolation data, or total volume or duration of application. The sizing was based on instantaneous flow rates, rather than average daily capacities. Instantaneous data given in the manufacturers literature is representative of conditions either at high noon or under battery operation (which the authors discouraged as less efficient and more costly). The articled showed little understanding of variable flow rate from a directly connected solar pump, or the effect this would have on irrigation practices. Any sizings based on instantaneous data would likely result in an enormously oversized, and prohibitively costly pump.

In 1992 **Thigle and Gorantiwar** of the Mahatma Phule Agricultural University in Rahuri, India began collecting data on a PV pump installed on a shallow open dug well. Their goal was to determine if the system was feasible for low head, low discharge irrigation systems. The system consisted of 20 36 cell modules, connected to a DC monoblock motor and centrifugal pump. They developed equations for hourly variation of solar radiation over a day, array power generated as a function of incoming radiation, pump discharge as a function of power generated, array conversion efficiency as a function of atmospheric temperature, and pumping efficiency as a function of head. The pump operated between 8:00 and 16:00 hrs, discharging 0.48 to 0.88 lps. Its use for low head irrigations systems requiring a small stream size was considered technically feasible. Thigle and Gorantiwar noted that in India, 70% of all irrigated product is from ground water, more than 20 M ha-m. Of the total ground water usage, 50% is from shallow open wells

or tube wells with 10 m or less depth to water table. Using PV systems for these wells would eliminate long transmission lines and the expense of fuel and its transport.

2. Economics

The first economic study of a solar powered irrigation system was preformed by **Matlin, Romaine and Fishbach** in 1978 on the Mead, Nebraska site. An economic analysis was done to determine the viability of PV irrigation systems for 4 of the 5 main irrigating states in the USA: Texas, Nebraska, Arizona and California. These 4 states, along with New Mexico consumed 70% of all power used for irrigation in the US. Their best case scenario assumed a discount rate of 5%, fuel inflation rate of 4%, array costs of $100/kWp, and support system costs of $550/kWp. Under this scenario they calculated that solar irrigation would become profitable for Arizona, Texas, and California by 1983, and for Nebraska by 1986. The conservative scenario assumed a discount rate of 8%, fuel inflation rate of 2%, array costs of $300/kWp, and support system costs of $1050/kWp. Under this scenario irrigation would become profitable for the Southwest by 1990, and for Nebraska by 2000. Government incentives and income tax benefits could bring the dates forward 1 to 3 years.

Phase I of the UNDP/World Bank study was published in 1981. In 1982, **Bentley** of the UK, published a study evaluating the cost of a concentrating photovoltaic pump, sized appropriately for micro-irrigation, with radiation data from India. He assumed a solar array using passively cooled silicon cells, with an overall efficiency of 13%, a cast acrylic lens to concentrate radiation, and flat reflective metal for secondary concentration. The array was to be manually adjusted three times per day. The efficiency of the PM (permanent magnet) DC motor, was assumed to be 77% at rated power and 72% at half

power. Bentley concluded that lifting water 5 m would cost between 5 and 9 pence/m^3 (1982 UK currency), approximately twice the UNDP goal.

In 1982 **Enochian**, of the US Department of Agriculture, published a review of the economics of 5 types of solar and wind powered irrigation systems. He reviewed work from the Soviet Union, France, Germany and the US. Most of the foreign PV installations were small 300 W to 1 kW systems. One Soviet experiment concluded that PV was already more favourable than internal combustion engines under certain conditions. Another in France showed PV had a definite advantage over thermal steam engines and concluded that further price drops would make large systems feasible.

Of the US studies reviewed, BMD Corporation (1978) suggested the use of PV for irrigation was limited by the low cost of conventional energy and the seasonal water requirements. The BMD study also suggested economic viability would depend on price reductions and as well as conjunctive use with other applications in the off-season. Another study by Scandia National Laboratories (1980) examined 50 potential agriculture applications for PV, and chose 4 promising ones for conceptual design. Though irrigation did not appear to be generally attractive because of the high energy requirements and seasonal demand pattern of most crops, year round irrigation of vegetable crops in California was 1 of the 4 applications chosen for further development. Two designs were hypothesised for a 200-acre vegetable farm: one a tracking, concentrating design and the other a fixed, non concentrating (flat plate) system. The flat plate system was found to be competitive with conventional electricity. Cost per kWh were estimated at $0.08 for conventional electricity, $0.09 for the flat plate system, and $0.13 for the concentrating system.

Enochian concluded that wind and non-concentrating PV systems were the most promising for irrigation, and would likely be economically feasible before the turn of the

century. PV systems seemed the most promising of the two because of the compatibility between energy supply and irrigation requirements. He noted that widespread use of PV depended on improving efficiency and reducing costs of solar cells. Efficiencies had already increased from 4% in 1975 to 11% in 1978, and were expected to rise to 16% by 1986. Prices had dropped from $200/Wp at the height of the space program to $10/Wp in 1978. Further prices drops were widely expected within the industry and many economic studies done at this time included predictions of future viability. In 1980, the Department of Energy had set price goals of $1-2/Wp for 1982, $0.5/Wp for 1986, and $0.15-0.40/Wp for 1990. Based on these goals Enochian predicted PV irrigation systems would become feasible in 5 to 6 years. These price reductions did not materialize on schedule.

Phase II of the UNDP/World Bank Study was published in 1983 (**Sir William Halcrow and Partners**, 1983). This study is reviewed in detail in Appendix B. The study concluded that PV system were suitable for small scale irrigation at low heads. Unit water costs were sensitive to the level of radiation in the critical month, the ratio of peak water demand to annual water demand, the subsystem efficiencies, capital costs and assumed discount rate. Comparative economics with other remote pumping applications were dependant on the wind resource, the price of diesel fuel and wages for handpump operation. With expected price reductions for PV systems, small scale PV irrigation systems would become economically viable over the full range of heads studied between 1993 and 1998.

In 1983, **Kwant and van den Toorn** of the Netherlands, carried out a in detailed socio-economic survey of farmers in the Ganga plains of India to determine the potential for solar and wind irrigation pumps. In this area the water table is 5-8 m below the ground surface. Paddy, jowar, and maize are grown without irrigation during the monsoon (June to September), wheat, pulses, and vegetables are grown using irrigation in the winter (November to March), and cultivation stopped in the summer.

The study compared potential renewable energy systems to current irrigation systems used in the area. They also used data from a nearby windmill project. The study looked at two farm size categories: large farms over 5 ha, and small farms of 2 ha. They assumed a small 2 ha farm would require a portable solar pump with a capacity of 25 m^3/day, and a large 5 ha farm would require a fixed mount pump. At the time of the study, most large farmers owned a diesel or electric pump, while small farmers were forced to buy water from large farmers. This resulted in a situation of dependency, exploitation, and unreliable supply.

Though diesel and electric pumps worked best for large farms, the type of pump which provided the highest rate of return for small farms, was dependant on whether or not summer crops were grown and alternative employment was available. Summer crops were not being grown in the area due to a shortage of both diesel and electricity. Using renewable energy would allow summer cultivation, but at the personal cost of hard working conditions and missed social events which tended to be concentrated in the summer months. Using a renewable pump increased the amount of time required for irrigation since the output is lower than that from a conventional pump. If no other employment is available this has no effect on the economic evaluation, if employment is available it must be taken into account. In addition, if the pump is permanently fixed, a requirement for a wind or large solar pump, it must be guarded against theft during the night as well.

The study looked at two cases for pricing of solar panels, 1981 prices at \$1000/m^2, and assumed 1995 prices at \$100/m^2. They concluded that the small farmer with alternative employment and no intention of cultivating summer crops would do best to continue to buy water. If however they do not have alternative employment, they should consider a windmill, or when prices drop to expected 1995 levels, a solar pump. If the small farmer does intend to cultivate summer crops renewable technologies are more feasible, with the windmill coming out ahead at current prices, and the solar pump gaining

advantage at reduced 1995 prices. At expected 1995 prices, the solar pump became comparable to diesel and electric pumps even for large 5 ha farms.

For small farmers with no alternative employment who were willing to grow summer crops were best to purchase a pump powered by renewable energy even when the discount rate was adjusted from 10 to 20% to reflect the high time preference of marginal farmers. In other cases margins are not great enough to justify the risk incurred with a new technology.

Comparing solar and wind energy, the study noted that, while available solar energy is relatively constant throughout the year, wind energy is significant only during monsoon when irrigation requirements are nonexistent. Though they mentioned that a wind pump would therefore have to be run year round, no mention is made of either battery or water storage in the cost estimates.

Kwant and van der Toorn concluded that the pumps were financially feasible with loans and subsidies available from the Block Development Office. Here money is available to establish a borehole, and if positive a 25% subsidy can be obtained for the pump together with a loan at 10% over 7 years. The loan could be repaid through increased vegetable production and income from other family members as was the case in the Ghazipur windmill project.

It was assumed that the current system of maintenance for diesel and electrical pumps, deemed acceptable by local farmers, would work equally well for renewable systems. The farmers oiled and greased the pumps themselves, and took them to local pump shops (less than a days ride by bike or bullock cart) for repairs. Maintenance costs were expected to increase for the first five years until local technicians learned how to repair problems with renewable systems.

In 1984 **Bhattacharjee** published a paper discussing successful PV irrigation systems in Tripura, India. In Tripura land holdings are typically 0.5 ha or less and mini-irrigation schemes of 2 to 3 acres support 3 or 4 cultivators. Ten pumps were used for 20 families from tribal and scheduled caste groups. Plans were under way to add 6 more pumps to supply another 20 families. Before the pumps were installed, the families practised mono-cropping during the monsoon, and depended on the government to ship in food 6 months of the year. After the pumps were installed they could produce 3 crops per year, and became self sufficient in regards to food, with excess left over for selling.

Electrification of rural pumpsets is a high prioritiy in India. Although Tribal people living in rural areas had been given priority for electrification under new development plans, the economics of running long lines was unfavourable to power supply authorities. In hilly areas like Tripura, rural electrification costs between 200,000 and 1,000,000 Rs, with the average being 650,000 Rs for a 10 km length of line. Taking into account generation, transmission, distribution and consumer installation, electrifying the pumpsets cost about 50,000 Rs per kW for remote areas, but could run as high as 100,000 Rs. A solar pump by comparison, costs about 75,000 to 80,000 Rs per kW. On an annual cost per ha basis, Bhattacharjee found solar pumps comparable to both diesel and electric irrigation schemes. Though diesel pumps had a lower initial cost, high maintenance and fuel costs, coupled with a shorter life span, tended to level out the benefits. In addition, with regards to financing, solar pumps were eligible for a 75% subsidy as opposed to the 50% subsidy available for conventional pumps.

McGowan and Burril's 1985 review of PV irrigation in developing countries showed PV was competitive with diesel for low heads and flows and high radiation using life cycle cost analysis. Unfortunately, it was rare for small farmers to have the capital required for a PV pumping system, or the willingness to risk that capital on a new technology. They recommended a carefully planned public awareness program, government financing

plans, and favourable import tariff rates. By that time India was already manufacturing all system components including modules, batteries, controllers, and small DC pumps, through extensive government subsidies.

The retail installed cost of **Girard's** (1988) PV pumping system and irrigation equipment (for strawberries) was estimated at $5000, and $3355 US respectively. Assuming the irrigation system and pump were replaced every 5 years, the annualized cost over 10 years was $1200 to $1500 depending on interest and inflation. This represented 27% of the total annual cost of strawberry production. Using flood irrigation, the size of the pumping system would have had to be doubled resulting in an annual cost in excess of $2000. At a 6 m head, the cost of water was estimated at about $0.33/$m^3$ with the centrifugal pump, $0.19/$m^3$ with the positive displacement pump, and $0.16/$m^3$ with a conventional AC pump powered by a central utility.

Girard concluded that though the economics of the system were currently marginal, its "scale, simplicity, and robustness" made it ideal for developing countries. Advantages included low operating cost, private ownership, simplicity, reliability, ease of maintenance, adaptability, environmental friendliness, possibility of local manufacture and reliance on a locally available fuel (the sun). On the down side, the system was capital intensive and total costs had to be paid up front by those unable to secure capital or credit. In addition, the life cycle cost analysis used to justify the initial expense exceeded the planning horizon of small farmers. Girard estimated that the initial cost of a PV system would approach that of diesel in 4 to 6 years, at which point solar irrigation systems would become widespread.

Whiffen, Haman and Baird's 1992 study of the reliability of PV for small irrigation systems included an economic comparison of the PV system they developed (a 360 Wp concentrating array with east/west tracking and manual tilt directly connected to a 0.5 hp PM DC motor and single stage centrifugal pump with no batteries) against a 3.7 kW diesel

system, a 2.2 kW gasoline system, a 0.2 kW electric motor, and a 0.2 kW electric motor with 3.2 km access line. The evaluation used net present worth of capital, operations and maintenance over a 20 year period using an 8.9% discount rate. The PV system was competitive for land areas less than 1.5 ha when electric access was not available.

In 1993 **Gosnell and Eberhard**, of the University of Capetown, published a detailed economic and social evaluation of a PV pumping system used for a community vegetable garden in a rural ward of KwaZulu, in Natal, South Africa. The 1 ha garden was shared by 46 women and the produce used mainly for sustenance. Data from this site was compared to similar gardens in the region, six of which had pumps at the time, 2 petrol and 4 diesel.

The PV systems were found to be competitive at low heads and flows. At 40m^4/day (head x flow) a well designed PV system cost about the same as a typical diesel system, but prices could double if the system were poorly designed. At 1200 m^4/day, a PV system cost 1.4 to 4 times that of a diesel system, depending on the design. PV pump prices increased much faster than diesel with rising head. When head increased from 7 to 30 m, PV prices jumped 70%, while diesel prices rose only 22%. The cost of both diesel and PV dropped rapidly as flow increased from 3 to 30 m^3/day, beyond this prices dropped gradually, but diesel dropped faster than PV. Even though a small PV system might cost more, gardeners indicated a willingness to pay up to twice costs of diesel for a PV pump, since it saved them time consuming, difficult, and dangerous trips into town to collect heavy barrels of fuel, and reduced the number of trips required for maintenance. In sizing the systems it was noted that the farmers used water very frugally, pouring it directly on the roots of each plant. The average water demand was 3 m^3/ha/day, with a maximum of 5.7 m^3/ha/day, compared to conventional figures for vegetable gardens of 33 m^3/ha/day. In spite of this the plants were healthy and showed no signs of wilting.

The plot's value was estimated at R730 per year per family, or 30% of the average

household income, based on local food prices minus expenses. Though reports of yield increases varied, the pump halved the amount of time the women spent in the garden (previously water was carried in from nearby rivers), increasing their productivity from R1,80 to R3,55 per hour. Locally available renumerative work paid only R0,40 per hour. Expanding the garden area for saleable produce was feasible but marketing mechanisms were not in place. It was therefore difficult for farmers to regain money to pay off the debt incurred in buying the pump.

Vandalism, theft and natural disasters presented another problem for PV systems in the poor and politically unstable region. Possible solutions included a frame which locks over the panels, an alarm, electric fence, and community education. The PV pump was an inherently high risk investment because all costs had to be paid up front, and expensive equipment was left out in the open. Insurance would have driven the price far above acceptable levels. Arranging financing with saving for potential damages was difficult for a group with low eduction levels. One possible solution was suggested by the local utility. Under this system the company would own the array and be responsible for its upkeep and users would pay a fee. This would allow the utility to extend their customer base to more remote areas, increase their revenue base, and encourage electricity consumption for further expansion. The users would benefit from the elimination of capital investment and loan requirements, less confusing information from high pressure sales pitches, reduced risk, a higher level of maintenance, and increased flexibility.

3. Conclusions

A study of the literature on the use of PV for microirrigation reveals that the main concerns revolve around economics and financing issues. Technical difficulties with pumping subsystems have been largely worked out, though work remains to be done on

the optimization of a complete irrigation system. Some problems pertaining to sizing remain to be worked out. Specifically, statistical studies of the land area that can be reliably irrigated with a PV system when rainfall is considered. This type of study could include a component assessing the need for storage and volume of storage required. In the area of economics, a number of comparative life cycle cost analysis studies have shown that PV pumps are competitive with diesel, and wind pumps under certain circumstances, generally low heads and flows, high radiation, and frequent irrigations. Few cost benefit studies have been done which consider returns from specific crops and identify a specific niche for PV irrigation systems.

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APPENDIX C

GLOBAL SOLAR RADIATION (G)

Correlation between
Global Solar Radiation and Hours of Bright Sunshine
and
Diffuse and Global Solar Radiation

Regression between ($\frac{G'}{ETR}$) and ($\frac{n}{N'}$)

Station	No. of months	a	b	r	r^2	S.E.
Ahmadabad	202	0.252	0.448	0.960	0.921	0.030
Bhavnagar	141	0.259	0.433	0.985	0.971	0.020
Bombay	100	0.283	0.397	0.920	0.847	0.046
Calcutta	248	0.271	0.378	0.897	0.807	0.040
Goa	175	0.270	0.423	0.914	0.835	0.048
Jodhpur	132	0.313	0.401	0.874	0.763	0.042
Kodaikanal	194	0.273	0.521	0.916	0.839	0.044
Madras	255	0.242	0.436	0.913	0.834	0.032
Mangalore	115	0.214	0.458	0.944	0.892	0.041
Nagpur	218	0.227	0.459	0.975	0.951	0.024
New Delhi	255	0.256	0.454	0.874	0.763	0.042
Port Blair	114	0.156	0.472	0.860	0.739	0.062
Pune	254	0.269	0.417	0.944	0.891	0.037
Shillong	140	0.225	0.463	0.920	0.847	0.044
Trivandrum	215	0.309	0.408	0.912	0.831	0.028
Vishakhapatnam	210	0.247	0.435	0.968	0.938	0.025

Regression between ($\frac{D'}{G'}$) and ($\frac{G'}{ETR}$)

Station	No. of months	c	d	r	r^2	S.E.
Ahmadabad	134	1.329	-1.701	-0.960	0.921	0.057
Bhavnagar	141	1.406	-1.809	-0.979	0.959	0.044
Bombay	44	1.306	-1.769	-0.953	0.909	0.063
Calcutta	147	1.124	-1.386	-0.860	0.740	0.076
Goa	142	1.285	-1.659	-0.941	0.885	0.072
Jodhpur	58	1.325	-1.703	-0.883	0.781	0.071
Madras	193	1.108	-1.351	-0.903	0.816	0.048
Nagpur	123	1.312	-1.761	-0.975	0.951	0.042
New Delhi	237	1.137	-1.373	-0.893	0.797	0.059
Port Blair	26	1.354	-1.801	-0.935	0.875	0.067
Pune	234	1.469	-1.963	-0.959	0.920	0.065
Shillong	116	1.211	-1.651	-0.921	0.848	0.079
Trivandrum	157	1.271	-1.632	-0.915	0.837	0.050
Vishakhapatnam	122	1.229	-1.587	-0.939	0.881	0.056

APPENDIX D

GLOBAL SOLAR RADIATION
(G)

Computed Values
for 145 Stations across India

MEAN DAILY GLOBAL SOLAR RADIATION, G (kWh/m2)

Stn	City	Lat(N)	Long(E)	Elev(m)	Mean Daily Global Solar Radiation, G (kWh/m2)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Aduthurai	11.0	79.5	19	5.56	6.30	6.73	6.59	6.31	5.85	5.51	5.74	6.02	5.30	4.98	4.84
2	Agartala	23.9	91.3	16	4.26	5.16	5.58	6.11	6.22	4.49	4.99	4.91	5.00	5.05	4.66	4.09
3	Agra	27.2	78.1	169	4.29	5.20	6.12	6.78	6.90	6.23	5.47	5.18	5.70	5.54	4.77	4.10
4	Ahmadabad	23.1	72.6	55	5.01	5.88	6.24	6.97	7.45	6.59	5.02	4.67	5.52	5.95	5.31	4.82
5	Akola	20.7	77.0	282	5.38	6.09	6.44	6.96	7.07	6.03	4.56	4.58	5.06	5.66	5.31	4.92
6	Aligarh (Kalai)	27.9	78.1	187	4.35	5.41	5.74	6.94	7.39	6.76	6.00	5.57	5.76	5.57	4.92	4.21
7	Allahabad	25.5	81.7	98	4.45	5.47	6.05	6.92	7.20	6.05	5.35	5.04	5.53	5.60	4.93	4.35
8	Amini Divi	11.1	72.7	4	5.13	5.77	6.27	6.04	4.98	3.93	3.78	4.27	4.95	4.68	4.73	4.67
9	Amritsar	31.6	74.9	234	3.64	4.60	5.41	6.62	7.38	7.13	6.54	6.31	5.89	5.27	4.26	3.49
10	Anakapalle	17.7	83.0	10	5.25	5.74	6.46	6.59	6.33	5.04	4.63	4.72	4.95	4.99	5.03	5.00
11	Annamalaimagar	11.4	79.7	6	5.63	6.31	6.82	6.88	6.00	5.94	5.49	5.82	6.12	5.36	4.82	4.78
12	Babbur (Hiriyur)	14.0	76.6	610	5.78	6.49	6.82	6.79	6.59	5.46	4.67	4.94	5.39	5.56	5.48	5.39
13	Bahadrabad	29.9	78.1	275	3.75	4.73	5.54	6.53	7.20	6.40	5.65	5.28	5.44	5.30	4.45	3.59
14	Bangalor	13.0	77.6	897	5.48	6.17	6.53	6.57	6.05	4.90	4.18	4.61	4.89	4.94	5.02	4.95
15	Barmer	25.8	71.4	194	4.69	5.62	6.57	7.47	8.06	7.89	6.55	6.26	6.62	6.07	5.07	4.48
16	Baroda	22.3	73.3	34	5.10	5.89	6.42	7.09	7.55	6.48	4.97	4.63	5.56	6.00	5.37	4.89
17	Barrakpore	22.8	88.4	9	4.49	5.32	5.92	6.26	6.32	5.08	4.75	4.68	4.70	5.02	4.97	4.10
18	Bellary	15.2	76.9	449	5.76	6.47	6.80	6.92	6.71	5.71	4.95	5.37	5.47	5.60	5.41	5.34
19	Berhampore	24.1	88.3	19	4.73	5.50	6.35	6.82	6.54	5.47	4.78	4.78	4.84	5.32	4.99	4.58
20	Bhavnagar	21.8	72.2	5	5.19	5.91	6.49	7.12	7.67	6.20	4.67	4.46	5.28	5.98	5.48	4.86
21	Bhopal	23.3	77.4	503	4.99	5.82	6.28	6.91	7.32	6.14	4.55	4.23	5.14	5.79	5.29	4.65
22	Bhubaneswar	20.3	85.9	26	5.22	6.01	6.51	6.91	7.02	5.63	5.09	5.14	5.31	5.48	5.28	5.13
23	Bhuj	23.3	69.7	80	4.96	5.82	6.20	6.92	7.44	6.54	5.31	5.19	5.88	5.93	5.28	4.77
24	Bikaner	28.0	73.3	224	4.46	5.37	6.38	7.49	8.12	8.15	7.29	6.83	6.79	5.96	4.80	4.21
25	Bikramganj	25.2	84.3	87	4.53	5.40	6.10	6.66	6.61	5.47	5.23	5.13	5.50	5.44	4.86	4.23
26	Bombay	19.1	72.9	14	5.12	5.83	6.31	6.81	6.91	5.49	4.40	4.45	5.05	5.66	5.33	4.95
27	Calcutta	22.7	88.5	6	4.36	5.09	5.58	6.21	6.22	4.88	4.74	4.60	4.59	4.70	4.54	4.17
28	Car Nicobar	9.2	92.8	10	4.54	5.22	5.54	5.17	4.21	3.69	3.90	4.01	4.20	4.25	4.22	4.43
29	Chandigarh	30.7	76.9	347	3.78	4.61	5.60	6.53	7.04	6.24	5.91	5.29	5.81	5.29	4.34	3.46
30	Chaubattia	29.8	79.7	1962	3.42	4.24	5.19	6.28	6.64	5.51	4.28	4.09	4.32	4.63	4.06	3.42
31	Chinsurah	22.9	88.4	9	4.93	5.68	6.31	6.93	6.92	5.60	5.20	5.17	5.24	5.33	5.10	4.77
32	Coimbatore	11.0	77.0	431	5.62	6.37	6.84	6.62	6.10	5.31	4.75	5.37	5.82	5.36	5.10	5.14
33	Cuddappah	14.5	78.8	130	5.37	6.16	6.77	6.77	6.42	5.37	4.55	4.91	5.04	5.01	4.85	4.96
34	Cuttack	20.5	85.9	24	5.14	5.82	6.16	6.55	6.86	5.28	4.64	4.82	4.95	5.29	5.20	4.96
35	Dehra Dun	30.3	78.0	683	3.59	4.40	5.47	6.36	6.95	6.06	5.25	4.81	5.32	5.13	4.22	3.53
36	Dharwar	15.4	75.1	679	5.60	6.23	6.56	6.42	6.11	4.73	3.89	4.33	4.86	5.19	5.26	5.25
37	Dhulia	20.9	74.8	245	4.98	5.72	6.28	6.79	7.06	5.88	4.69	4.50	5.31	5.75	5.23	4.69
38	Dibrugarh (Mohanbari)	27.5	95.0	111	3.66	4.10	4.97	4.78	5.09	4.63	4.79	5.22	4.46	4.60	4.23	3.74
39	Gannavaram	16.5	80.8	24	5.33	6.06	6.16	6.65	6.52	5.07	4.83	5.09	5.11	5.24	5.09	4.79
40	Gauhati	26.1	91.6	54	4.08	4.97	5.36	5.94	5.93	4.90	4.98	5.07	4.84	4.98	4.52	4.02
41	Goa	15.5	73.8	55	5.62	6.33	6.58	6.90	6.73	4.94	4.51	4.93	5.37	5.67	5.72	5.37
42	Golegaon	19.3	76.5	402	5.43	6.15	6.47	6.82	6.83	5.23	4.67	4.24	5.25	5.55	5.59	5.22
43	Gopalpur	19.3	84.9	17	5.20	5.90	6.59	6.38	6.52	5.53	4.60	4.95	5.45	5.22	5.06	4.94
44	Gorakhpur	27.0	83.5	79	4.10	5.23	5.79	6.79	7.21	6.30	5.71	5.18	5.30	5.16	4.63	3.95
45	Guna	24.7	77.3	478	4.64	5.56	6.52	7.29	7.08	6.95	5.42	5.00	5.75	5.89	5.09	4.50
46	Gurdaspur	32.1	76.4	267	3.39	4.48	5.19	6.64	7.34	7.13	6.31	6.22	5.77	5.31	4.36	3.50
47	Gwalior	26.2	78.3	207	4.47	5.47	6.19	7.01	7.12	6.64	5.25	5.01	5.64	5.61	5.00	4.30
48	Hagari	15.2	77.1	413	5.56	6.33	6.61	6.64	6.44	5.27	4.51	4.84	5.18	5.26	5.20	5.17
49	Hansi	29.1	76.0	217	3.95	4.81	5.59	6.73	6.77	5.96	5.93	5.80	5.75	5.44	4.56	3.74
50	Hanumangarh	29.5	74.3	221	3.92	4.94	5.85	6.49	6.67	5.96	6.28	6.04	6.15	5.55	4.57	3.77
51	Hanoghata	22.9	88.5	10	4.56	5.51	6.13	6.70	6.88	5.11	5.16	5.01	5.20	5.29	4.87	4.12
52	Hebbal	13.0	77.6	889	5.80	6.55	6.89	6.90	6.47	5.40	4.74	5.08	5.36	5.34	5.39	5.09
53	Hissar	29.2	75.8	221	3.95	4.94	5.93	6.72	6.91	5.97	5.99	5.95	6.19	5.51	4.65	3.95
54	Hoshangabad (Powerkhera)	22.8	77.8	302	4.97	5.89	6.22	6.90	7.06	6.20	4.44	4.22	4.95	5.63	5.26	4.87
55	Hunsur	12.3	76.1	826	5.84	6.28	6.70	6.61	5.99	5.12	4.45	4.95	5.27	5.22	5.38	5.19
56	Hyderabad	17.5	78.5	545	5.50	6.28	6.47	6.85	6.93	5.60	4.77	5.08	5.25	5.65	5.39	5.13
57	Ibrahimpatan	17.1	78.7	610	5.42	6.29	6.78	6.81	6.40	5.36	5.11	4.89	5.35	5.44	5.42	5.03
58	Imphal	24.8	93.9	781	4.59	5.32	6.09	6.63	5.86	4.90	4.69	4.81	4.78	4.85	4.66	4.36
59	Indore	22.7	75.8	567	5.11	5.95	6.41	7.10	7.50	6.18	4.61	4.25	5.20	5.91	5.35	4.77
60	Jabalpur (Adhartal)	23.2	80.0	411	4.57	5.73	6.03	6.64	6.45	5.57	4.34	4.28	5.03	5.37	4.92	4.52
61	Jagadalpur	19.1	82.0	553	5.22	5.95	6.60	6.82	6.51	5.33	4.30	4.31	4.68	5.27	5.11	4.95
62	Jaipur	26.8	75.8	390	4.58	5.53	6.18	6.93	7.14	6.33	5.34	5.19	5.95	5.92	5.10	4.46
63	Jaisalmer	26.9	70.9	231	4.61	5.56	6.49	7.48	8.11	8.24	7.44	7.08	6.81	6.06	5.00	4.36
64	Jalgaon	21.1	75.6	201	5.21	5.97	6.42	7.01	7.21	6.16	4.78	4.79	5.15	5.88	5.37	4.97
65	Jammu	32.7	74.8	367	3.45	4.26	5.38	6.36	7.70	7.96	6.28	6.19	6.12	5.27	3.87	3.26
66	Jamnagar	22.5	70.0	21	4.91	5.72	6.37	7.01	7.33	5.97	4.68	4.46	5.65	5.89	5.26	4.73
67	Jharsuguda	21.9	84.1	230	4.71	5.89	5.93	6.70	7.00	5.15	4.75	4.49	5.22	5.73	4.92	4.50
68	Jobner	27.0	75.1	427	4.58	5.53	6.60	7.25	7.29	7.03	6.33	5.82	6.40	5.79	5.06	4.50
69	Jodhpur	26.3	73.0	224	4.67	5.61	6.19	7.09	7.52	7.19	6.25	6.05	6.24	5.95	5.10	4.51
70	Jullundur	31.4	75.6	238	3.79	4.73	5.58	6.67	7.46	7.31	6.45	6.13	5.81	5.36	4.38	3.64
71	Kanniyakumari	8.1	77.5	37	5.88	6.40	6.74	6.23	5.63	5.32	5.42	5.45	5.99	5.69	5.36	5.08
72	Karimganj	24.7	92.5	16	4.49	5.13	5.72	5.90	5.75	4.75	4.71	4.86	4.97	5.00	4.66	4.39
73	Karjat	18.9	73.3	52	5.11	5.87	6.28	6.66	6.61	4.92	3.84	3.93	4.47	5.38	5.20	4.86
74	Kasargod	12.5	75.0	11	5.78	6.39	6.68	6.71	5.93	4.36	3.99	4.70	5.31	5.41	5.52	5.46
75	Kayamgulam	9.1	76.5	3	6.18	6.67	6.99	6.66	5.80	4.82	4.87	5.39	5.74	5.66	5.59	5.68

MEAN DAILY GLOBAL SOLAR RADIATION, G (kWh/m2)

Stn	City	Lat(N)	Long(E)	Elev(m)	Mean Daily Global Solar Radiation, G (kWh/m2)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
76	Kodaikanal	10.2	77.5	2345	6.03	6.78	6.96	6.64	6.02	5.04	4.49	4.95	5.13	4.88	4.86	5.19
77	Kolhapur	16.7	74.2	570	5.51	6.30	6.90	6.94	6.64	5.45	4.60	4.55	5.22	5.27	5.36	5.25
78	Kondul	7.5	93.7	8	4.62	4.62	5.00	4.85	4.25	3.77	3.84	3.93	4.00	3.87	4.18	4.18
79	Kota	25.2	75.5	257	4.87	5.81	6.39	7.17	7.61	7.00	5.51	5.15	5.87	5.89	5.15	4.67
80	Kottayam	9.5	76.5	73	6.21	6.58	6.91	6.48	5.85	5.02	4.51	5.05	5.66	5.17	5.43	5.36
81	Kovilpatti	9.2	77.9	92	5.71	6.32	6.66	6.37	6.13	5.83	5.57	5.87	6.00	5.40	5.17	5.12
82	Kuthulia	24.5	81.3	366	4.58	5.63	6.33	7.07	7.24	6.08	4.85	5.06	5.54	5.74	5.18	4.34
83	Leh	34.2	77.6	3514	3.33	4.29	5.35	6.71	7.61	8.39	7.99	7.17	6.80	5.44	4.26	3.25
84	Lucknow	26.8	80.9	128	4.45	5.43	5.97	6.76	7.14	6.06	5.50	5.33	5.52	5.64	4.78	4.20
85	Madhipura	25.8	86.7	42	4.27	5.25	6.06	6.48	6.72	5.82	5.13	5.42	5.14	5.33	4.89	4.26
86	Madras	13.0	80.2	16	5.38	6.29	6.59	6.72	6.32	5.52	5.04	5.28	5.41	5.14	4.85	4.71
87	Mandya	12.5	76.8	695	5.67	6.50	6.86	6.87	6.40	5.46	4.75	5.01	5.52	5.42	5.38	5.29
88	Mangalore	12.9	74.9	102	5.82	6.37	6.37	6.45	6.02	4.24	3.70	4.33	4.99	5.26	5.53	5.36
89	Minicoy	8.3	73.0	2	5.45	5.91	5.92	5.71	5.01	4.20	4.18	4.89	4.89	5.00	5.07	4.80
90	Musaffarnagar	29.5	77.7	240	4.12	4.97	5.86	6.83	7.32	6.82	6.04	5.59	5.74	5.44	4.59	3.87
91	Nagina	29.9	78.4	249	3.94	4.83	5.78	6.69	7.30	6.67	5.71	5.53	5.51	5.34	4.49	3.72
92	Nagpur	21.2	79.1	311	5.02	5.84	6.18	6.69	6.89	5.51	4.33	4.30	4.91	5.58	5.27	4.81
93	Nagrakata	26.9	88.9	229	4.04	4.59	5.36	5.69	5.69	4.66	4.42	4.58	4.59	4.97	4.60	4.06
94	Nagrifarm	26.9	88.2	1158	3.58	4.05	5.02	5.10	5.07	4.10	3.89	4.17	3.98	4.58	4.16	3.65
95	Nandi Hills	13.4	77.7	1479	6.08	6.46	7.10	7.19	6.21	4.53	4.31	4.48	4.60	5.54	4.10	4.67
96	Nellore	14.5	80.0	20	5.22	5.98	6.66	6.61	6.18	5.05	4.58	5.03	5.31	5.05	4.67	4.71
97	New Dehli	28.6	77.2	216	4.06	5.07	5.60	6.50	6.61	5.82	5.61	5.53	5.58	5.48	4.71	3.95
98	Niphad	20.1	74.1	550	5.22	6.06	6.57	6.96	7.11	6.09	4.58	4.55	5.11	5.69	5.38	5.01
99	Okha	22.5	69.1	7	4.80	5.67	6.11	6.72	6.95	5.92	4.92	4.84	5.81	5.85	5.12	4.32
100	Ollukara	10.5	76.3	22	5.77	6.24	6.47	6.19	5.25	4.39	3.97	4.30	4.85	5.03	5.23	5.10
101	Ootacamund	11.4	76.7	2218	5.94	6.47	6.81	6.54	5.93	4.91	4.21	4.73	5.03	5.09	5.15	5.26
102	Padegaon	18.2	74.2	556	5.27	6.03	6.45	6.77	6.87	5.84	4.64	4.82	5.22	5.56	5.27	4.98
103	Pantnagar	29.0	79.5	244	3.83	4.75	5.63	6.57	7.04	6.16	5.44	5.31	5.47	5.34	4.55	3.80
104	Parbhani	19.3	76.8	408	5.54	6.29	6.62	7.02	6.99	6.00	4.80	4.92	5.33	5.85	5.59	5.23
105	Patna	25.5	85.3	52	4.48	5.35	6.02	6.70	7.20	6.24	5.56	5.53	5.45	5.40	4.87	4.32
106	Pattambi	10.8	76.2	25	5.85	6.35	6.59	6.43	5.48	4.10	3.79	4.62	5.32	5.11	5.34	5.41
107	Port Blair	11.7	92.7	79	4.94	5.75	5.90	5.80	4.23	3.47	3.48	3.58	3.69	4.34	4.63	4.64
108	Pune	18.5	73.9	563	5.32	6.10	6.53	6.92	6.99	5.74	4.58	4.68	5.20	5.60	5.35	5.03
109	Pusa	26.0	85.7	52	4.42	5.24	5.81	6.52	6.98	6.10	5.31	5.23	5.19	5.30	4.83	4.26
110	Raichur	16.2	77.4	389	5.68	6.41	6.85	6.89	6.78	5.43	4.63	4.99	5.14	5.67	5.45	5.17
111	Raipur (Labhandi)	21.3	81.6	289	4.89	5.70	6.00	6.40	6.64	5.18	4.36	4.49	4.96	5.37	5.20	4.68
112	Rajahmundry	17.0	81.8	111	5.17	5.84	6.29	6.58	6.38	4.94	4.66	4.80	4.89	4.96	5.06	4.82
113	Rajendranagar	17.3	78.3	543	5.54	6.32	6.59	6.81	6.85	5.44	4.93	5.12	5.38	5.65	5.51	5.14
114	Rajkot	22.3	70.8	138	4.99	5.80	6.62	7.29	7.50	6.35	5.16	5.00	5.75	5.94	5.24	4.76
115	Ranchi (Kanka)	23.4	85.3	675	4.94	5.88	6.54	7.07	7.14	6.04	4.82	4.95	5.14	5.39	5.33	4.89
116	Ratnagiri	17.0	73.3	67	5.34	6.01	6.64	6.81	6.38	5.36	4.60	4.85	5.44	5.41	5.33	5.09
117	Rehmankhera	26.8	80.8	91	4.30	5.30	6.22	6.87	7.07	6.42	5.78	5.61	5.75	5.53	4.68	4.22
118	Saharanpur	30.0	77.6	275	3.81	4.90	5.77	6.76	7.26	6.79	5.99	5.56	5.75	5.35	4.50	3.72
119	Samalkot	17.1	82.2	9	5.29	6.00	6.40	6.73	6.53	5.14	4.78	4.96	4.97	5.06	5.06	4.94
120	Satna	24.6	80.8	317	4.56	5.53	6.49	7.20	7.62	6.60	5.10	4.90	5.54	5.83	5.07	4.54
121	Shahjanhanpur	27.9	79.9	155	4.31	5.27	5.90	6.94	7.51	6.51	5.59	5.40	5.48	5.49	4.82	4.06
122	Shakkarnagar	18.7	77.8	381	5.32	6.04	6.45	6.70	6.76	5.53	4.27	4.52	4.89	5.50	5.33	5.02
123	Shillong	25.6	91.9	1598	3.64	4.75	5.34	5.69	5.56	4.26	4.18	4.14	4.18	4.26	3.78	3.49
124	Silicuri	24.8	92.9	40	4.38	5.02	5.71	6.01	5.79	4.91	5.04	5.02	4.97	4.78	4.49	4.18
125	Sindewahi	20.3	79.7	222	5.18	6.03	6.40	6.82	7.15	5.45	4.44	4.50	5.04	5.73	5.43	4.94
126	Solapur	17.7	75.9	476	5.48	6.16	6.55	6.74	6.56	5.56	4.45	4.62	5.02	5.42	5.36	5.16
127	Srinagar	34.1	74.8	1587	2.28	3.25	4.26	5.39	6.39	6.90	6.64	6.20	5.57	4.65	3.55	2.47
128	Surat	21.2	72.9	11	5.10	5.88	6.38	7.01	7.19	6.00	4.71	4.66	5.34	5.88	5.32	4.86
129	Thirthahalli	13.7	75.3	628	5.67	6.16	6.54	6.68	6.24	4.45	3.74	4.02	4.67	5.05	5.35	5.35
130	Tiruchchirappalli	10.8	78.7	88	5.68	6.43	6.68	6.72	6.35	5.88	5.38	5.77	6.02	5.45	5.15	4.95
131	Titabar	26.6	94.2	99	3.76	4.39	4.80	5.03	4.97	4.66	4.66	4.79	4.64	4.41	3.97	3.54
132	Titlagarh	20.3	83.3	211	5.19	5.96	6.67	6.81	7.11	6.20	5.38	5.24	5.42	5.52	5.03	4.98
133	Tocklai	26.8	94.2	87	3.68	4.28	5.19	5.30	5.05	4.95	4.95	4.79	5.01	4.26	4.05	3.52
134	Trivandrum	8.5	77.0	64	6.08	6.56	6.69	6.24	5.78	5.00	5.06	5.64	5.85	5.52	5.33	5.50
135	Tuticorin	8.8	78.2	4	6.02	6.63	6.80	6.83	6.40	6.00	6.03	6.30	6.23	5.96	5.57	5.21
136	Udaipur	24.6	73.7	582	4.97	5.91	6.62	7.33	7.67	6.88	5.32	5.17	5.86	6.08	5.39	4.71
137	Varanasi	25.5	82.9	85	4.54	5.41	6.19	6.92	7.20	6.37	5.31	5.04	5.41	5.63	4.84	4.38
138	Vasad	22.5	73.1	34	5.06	5.88	6.52	7.13	7.48	6.55	5.05	4.95	5.63	5.95	5.30	4.79
139	Vedasandur	10.5	78.0	76	5.85	6.57	6.74	6.65	6.20	5.68	5.28	5.75	5.78	5.44	5.08	4.89
140	Vellore	12.9	79.2	214	5.24	5.93	6.63	6.47	6.13	5.39	4.84	5.08	5.28	5.15	4.69	4.80
141	Vengurla	15.9	73.6	9	5.67	6.31	6.88	6.96	6.38	4.94	4.28	4.57	4.70	5.26	5.28	5.42
142	Veraval	20.9	70.4	8	5.14	5.96	6.77	6.90	7.31	6.44	4.98	4.89	5.95	5.98	5.35	4.92
143	Viramgam	23.1	72.2	27	5.07	5.91	6.53	7.21	7.50	6.70	5.12	4.85	5.81	6.03	5.37	4.85
144	Vishakhapatnam	17.7	83.2	3	5.34	6.11	6.24	6.62	6.63	5.04	4.60	5.12	5.18	5.42	5.22	4.99
145	Vittal	13.0	75.4	91	5.90	6.50	6.72	6.77	6.78	4.35	3.73	4.52	5.14	5.28	5.58	5.48

APPENDIX E

GLOBAL SOLAR RADIATION (G)

TILT FACTORS

Latitude
Latitude +15°
Latitude -15°
Optimal Tilt Factor

TILT FACTORS - LATITUDE

Stn#	Station Name	Lat (N)	Long (E)	Elev (m)	Daily Global Radiation Tilt Factors: Latitude											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Aduthurai	11.0	79.5	19	1.11	1.08	1.02	0.98	0.94	0.93	0.94	0.96	1.00	1.04	1.09	1.11
2	Agartala	23.9	91.3	16	1.30	1.20	1.08	0.98	0.92	0.92	0.92	0.96	1.02	1.14	1.27	1.33
3	Agra	27.2	78.1	169	1.45	1.30	1.13	0.99	0.91	0.88	0.91	0.95	1.05	1.23	1.42	1.50
4	Ahmadabad	23.1	72.6	55	1.36	1.24	1.09	0.98	0.91	0.89	0.92	0.96	1.03	1.17	1.32	1.40
5	Akola	20.7	77.0	282	1.31	1.20	1.07	0.98	0.91	0.91	0.94	0.96	1.01	1.13	1.26	1.32
6	Aligarh (Kalai)	27.9	78.1	187	1.47	1.32	1.12	0.99	0.91	0.88	0.90	0.95	1.06	1.23	1.44	1.53
7	Allahabad	25.5	81.7	98	1.40	1.27	1.11	0.99	0.91	0.89	0.91	0.95	1.04	1.20	1.37	1.45
8	Amini Divi	11.1	72.7	4	1.10	1.07	1.02	0.98	0.96	0.96	0.97	0.98	1.00	1.03	1.08	1.10
9	Amritsar	31.6	74.9	234	1.52	1.34	1.15	1.00	0.91	0.88	0.89	0.96	1.08	1.28	1.50	1.59
10	Anakapalle	17.7	83.0	10	1.23	1.14	1.06	0.97	0.92	0.92	0.94	0.96	1.01	1.09	1.19	1.25
11	Annamalaimagar	11.4	79.7	6	1.12	1.08	1.03	0.97	0.94	0.93	0.94	0.96	1.00	1.05	1.09	1.12
12	Babbur (Hiriyur)	14.0	76.6	610	1.17	1.11	1.04	0.97	0.93	0.93	0.95	0.97	1.00	1.06	1.13	1.17
13	Bahadrabad	29.9	78.1	275	1.48	1.33	1.14	1.00	0.91	0.88	0.90	0.95	1.06	1.26	1.48	1.55
14	Bangalor	13.0	77.6	897	1.14	1.09	1.03	0.97	0.94	0.94	0.96	0.97	1.00	1.05	1.11	1.14
15	Barmer	25.8	71.4	194	1.43	1.29	1.13	0.99	0.90	0.87	0.90	0.95	1.06	1.23	1.39	1.48
16	Baroda	22.3	73.3	34	1.33	1.22	1.08	0.98	0.91	0.90	0.93	0.96	1.02	1.16	1.30	1.37
17	Barrakpore	22.8	88.4	9	1.31	1.21	1.08	0.98	0.92	0.91	0.92	0.96	1.02	1.14	1.29	1.33
18	Bellary	15.2	76.9	449	1.19	1.13	1.04	0.97	0.93	0.92	0.94	0.96	1.01	1.07	1.15	1.19
19	Berhampore	24.1	88.3	19	1.37	1.24	1.10	0.98	0.91	0.90	0.92	0.95	1.02	1.17	1.33	1.42
20	Bhavnagar	21.8	72.2	5	1.33	1.21	1.08	0.98	0.91	0.90	0.94	0.96	1.02	1.15	1.29	1.35
21	Bhopal	23.3	77.4	503	1.38	1.25	1.10	0.98	0.91	0.89	0.93	0.96	1.03	1.18	1.34	1.41
22	Bhubaneswar	20.3	85.9	26	1.29	1.19	1.07	0.98	0.91	0.91	0.92	0.96	1.02	1.12	1.24	1.32
23	Bhuj	23.3	69.7	80	1.36	1.24	1.09	0.98	0.91	0.89	0.92	0.96	1.03	1.17	1.32	1.40
24	Bikaner	28.0	73.3	224	1.50	1.33	1.15	1.00	0.90	0.86	0.89	0.95	1.08	1.26	1.44	1.55
25	Bikramganj	25.2	84.3	87	1.36	1.24	1.10	0.98	0.92	0.91	0.92	0.95	1.03	1.17	1.32	1.39
26	Bombay	19.1	72.9	14	1.27	1.17	1.07	0.98	0.91	0.91	0.94	0.96	1.01	1.12	1.24	1.30
27	Calcutta	22.7	88.5	6	1.30	1.20	1.08	0.98	0.92	0.91	0.92	0.96	1.02	1.13	1.26	1.33
28	Car Nicobar	9.2	92.8	10	1.07	1.05	1.01	0.98	0.97	0.97	0.97	0.98	1.00	1.02	1.05	1.08
29	Chandigarh	30.7	76.9	347	1.50	1.32	1.14	1.00	0.91	0.89	0.90	0.95	1.07	1.27	1.47	1.54
30	Chaubattia	29.8	79.7	1962	1.43	1.28	1.13	1.00	0.91	0.89	0.92	0.95	1.03	1.22	1.43	1.51
31	Chinsurah	22.9	88.4	9	1.35	1.23	1.09	0.98	0.91	0.90	0.91	0.95	1.03	1.15	1.30	1.39
32	Coimbatore	11.0	77.0	431	1.12	1.08	1.03	0.98	0.95	0.94	0.95	0.97	1.00	1.04	1.09	1.12
33	Cuddappah	14.5	78.8	130	1.17	1.11	1.04	0.97	0.93	0.93	0.94	0.96	1.00	1.06	1.13	1.18
34	Cuttack	20.5	85.9	24	1.29	1.19	1.07	0.98	0.92	0.91	0.93	0.96	1.01	1.12	1.25	1.32
35	Dehra Dun	30.3	78.0	683	1.48	1.32	1.15	1.00	0.91	0.88	0.90	0.95	1.07	1.27	1.48	1.57
36	Dharwar	15.4	75.1	679	1.20	1.13	1.04	0.97	0.93	0.94	0.96	0.97	1.00	1.07	1.15	1.21
37	Dhulia	20.9	74.8	245	1.29	1.19	1.07	0.98	0.91	0.91	0.94	0.96	1.02	1.13	1.25	1.31
38	Dibrugarh (Mohanbari)	27.5	95.0	111	1.34	1.20	1.08	0.98	0.93	0.91	0.92	0.95	1.02	1.16	1.33	1.41
39	Gannavaram	16.5	80.8	24	1.21	1.14	1.05	0.97	0.93	0.92	0.93	0.96	1.01	1.08	1.17	1.21
40	Gauhati	26.1	91.6	54	1.37	1.25	1.10	0.98	0.92	0.91	0.91	0.95	1.03	1.18	1.35	1.43
41	Goa	15.5	73.8	55	1.20	1.13	1.04	0.97	0.93	0.93	0.95	0.96	1.01	1.08	1.17	1.21
42	Golegaon	19.3	76.5	402	1.27	1.18	1.06	0.98	0.92	0.93	0.94	0.97	1.01	1.11	1.24	1.30
43	Gopalpur	19.3	84.9	17	1.27	1.18	1.07	0.98	0.92	0.91	0.93	0.96	1.02	1.11	1.23	1.30
44	Gorakhpur	27.0	83.5	79	1.38	1.27	1.11	0.99	0.91	0.89	0.91	0.95	1.04	1.19	1.36	1.43
45	Guna	24.7	77.3	478	1.39	1.26	1.11	0.99	0.91	0.88	0.91	0.95	1.04	1.20	1.36	1.44
46	Gurdaspur	32.1	76.4	267	1.49	1.34	1.14	1.00	0.91	0.88	0.90	0.96	1.08	1.29	1.53	1.61
47	Gwalior	26.2	78.3	207	1.44	1.30	1.12	0.99	0.91	0.88	0.91	0.95	1.05	1.22	1.41	1.49
48	Hagari	15.2	77.1	413	1.18	1.12	1.04	0.97	0.93	0.93	0.95	0.97	1.00	1.06	1.14	1.19
49	Hansi	29.1	76.0	217	1.46	1.30	1.13	1.00	0.91	0.89	0.90	0.95	1.06	1.25	1.44	1.51
50	Hanumangarh	29.5	74.3	221	1.47	1.32	1.14	1.00	0.91	0.89	0.90	0.95	1.07	1.26	1.46	1.54
51	Haringhata	22.9	88.5	10	1.32	1.22	1.09	0.98	0.91	0.91	0.92	0.95	1.03	1.15	1.28	1.33
52	Hebbal	13.0	77.6	889	1.15	1.10	1.03	0.97	0.94	0.93	0.95	0.97	1.00	1.06	1.12	1.15
53	Hissar	29.2	75.8	221	1.49	1.33	1.15	1.00	0.91	0.89	0.90	0.95	1.08	1.26	1.48	1.58
54	Hoshangabad (Powerkhera)	22.8	77.8	302	1.35	1.24	1.09	0.98	0.91	0.90	0.93	0.96	1.02	1.16	1.31	1.40
55	Hunsur	12.3	76.1	826	1.15	1.09	1.03	0.97	0.94	0.94	0.95	0.97	1.00	1.05	1.11	1.15
56	Hyderabad	17.5	78.5	545	1.23	1.15	1.05	0.97	0.92	0.92	0.94	0.96	1.01	1.09	1.19	1.24
57	Ibrahimpatan	17.1	78.7	610	1.22	1.15	1.06	0.97	0.93	0.92	0.93	0.96	1.01	1.09	1.19	1.23
58	Imphal	24.8	93.9	781	1.38	1.24	1.10	0.98	0.92	0.91	0.92	0.95	1.03	1.15	1.32	1.42
59	Indore	130.8	0.0		1.35	1.23	1.09	0.98	0.91	0.90	0.93	0.96	1.02	1.16	1.31	1.38
60	Jabalpur (Adhartal)	23.2	80.0	411	1.35	1.25	1.09	0.98	0.91	0.90	0.93	0.96	1.03	1.16	1.31	1.40
61	Jagadalpur	19.1	82.0	553	1.26	1.17	1.07	0.98	0.92	0.92	0.94	0.96	1.01	1.10	1.21	1.28
62	Jaipur	26.8	75.8	390	1.46	1.31	1.13	0.99	0.91	0.89	0.91	0.95	1.06	1.24	1.43	1.53
63	Jaisalmer	26.9	70.9	231	1.48	1.32	1.14	1.00	0.90	0.86	0.88	0.95	1.07	1.25	1.43	1.53
64	Jalgaon	21.1	75.6	201	1.31	1.20	1.08	0.98	0.91	0.91	0.93	0.96	1.01	1.14	1.27	1.34
65	Jammu	32.7	74.8	367	1.53	1.34	1.16	1.00	0.91	0.87	0.90	0.96	1.09	1.30	1.49	1.60
66	Jamnagar	22.5	70.0	21	1.34	1.22	1.09	0.98	0.91	0.90	0.93	0.96	1.03	1.16	1.30	1.37
67	Jharsuguda	21.9	84.1	230	1.31	1.22	1.08	0.98	0.91	0.91	0.93	0.96	1.02	1.15	1.27	1.34
68	Jobner	27.0	75.1	427	1.46	1.30	1.14	0.99	0.91	0.88	0.90	0.95	1.06	1.23	1.42	1.53
69	Jodhpur	26.3	73.0	224	1.45	1.30	1.12	0.99	0.90	0.88	0.90	0.95	1.06	1.23	1.41	1.51
70	Jullundur	31.4	75.6	238	1.53	1.35	1.15	1.00	0.91	0.87	0.90	0.96	1.08	1.28	1.51	1.60
71	Kanniyakumari	8.1	77.5	37	1.08	1.05	1.02	0.98	0.96	0.95	0.95	0.97	1.00	1.03	1.06	1.08
72	Karimganj	24.7	92.5	16	1.34	1.22	1.08	0.98	0.92	0.92	0.92	0.95	1.02	1.15	1.29	1.39
73	Karjat	18.9	73.3	52	1.25	1.16	1.06	0.98	0.92	0.93	0.96	0.97	1.00	1.10	1.21	1.27

TILT FACTORS - LATITUDE

Stn#	Station Name	Lat (N)	Long (E)	Elev (m)	Daily Global Radiation Tilt Factors: Latitude											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
74	Kasargod	12.5	75.0	11	1.15	1.10	1.03	0.97	0.94	0.95	0.96	0.97	1.00	1.06	1.12	1.16
75	Kayamgulam	9.1	76.5	3	1.10	1.06	1.02	0.98	0.96	0.95	0.96	0.97	1.00	1.04	1.08	1.10
76	Kodaikanal	10.2	77.5	2345	1.11	1.07	1.02	0.98	0.95	0.95	0.96	0.97	1.00	1.03	1.07	1.10
77	Kolhapur	16.7	74.2	570	1.22	1.14	1.05	0.97	0.93	0.92	0.94	0.97	1.01	1.08	1.18	1.24
78	Kondul	7.5	93.7	8	1.05	1.03	1.01	0.99	0.98	0.97	0.98	0.98	1.00	1.01	1.04	1.05
79	Kota	25.2	75.5	257	1.43	1.29	1.12	0.99	0.90	0.88	0.91	0.95	1.05	1.21	1.38	1.48
80	Kottayam	9.5	76.5	73	1.11	1.07	1.02	0.98	0.95	0.95	0.96	0.97	1.00	1.03	1.08	1.10
81	Kovilpatti	9.2	77.9	92	1.09	1.06	1.02	0.98	0.95	0.94	0.95	0.97	1.00	1.03	1.07	1.09
82	Kuthulia	24.5	81.3	366	1.39	1.27	1.11	0.99	0.90	0.89	0.92	0.95	1.04	1.20	1.37	1.43
83	Leh	34.2	77.6	3514	1.58	1.38	1.17	1.02	0.91	0.86	0.88	0.97	1.13	1.36	1.64	1.70
84	Lucknow	26.8	80.9	128	1.44	1.30	1.12	0.99	0.91	0.89	0.91	0.95	1.05	1.22	1.39	1.48
85	Madhipura	25.8	86.7	42	1.39	1.26	1.11	0.99	0.91	0.89	0.91	0.95	1.04	1.19	1.37	1.45
86	Madras	13.0	80.2	16	1.14	1.10	1.03	0.97	0.94	0.93	0.94	0.96	1.00	1.05	1.11	1.14
87	Mandya	12.5	76.8	695	1.14	1.10	1.03	0.97	0.94	0.93	0.95	0.97	1.00	1.06	1.12	1.15
88	Mangalore	12.9	74.9	102	1.15	1.10	1.03	0.97	0.94	0.95	0.96	0.97	1.00	1.05	1.12	1.16
89	Minicoy	8.3	73.0	2	1.08	1.05	1.01	0.98	0.96	0.97	0.97	0.98	1.00	1.03	1.06	1.08
90	Musaffarnagar	29.5	77.7	240	1.49	1.31	1.14	1.00	0.91	0.88	0.90	0.95	1.06	1.25	1.45	1.54
91	Nagina	29.9	78.4	249	1.48	1.32	1.14	1.00	0.91	0.88	0.91	0.95	1.06	1.25	1.46	1.54
92	Nagpur	21.2	79.1	311	1.31	1.21	1.08	0.98	0.91	0.91	0.94	0.96	1.02	1.14	1.28	1.35
93	Nagrakata	26.9	88.9	229	1.40	1.25	1.10	0.98	0.92	0.91	0.92	0.95	1.03	1.19	1.38	1.47
94	Nagrifarm	26.9	88.2	1158	1.32	1.19	1.08	0.98	0.93	0.92	0.93	0.95	1.01	1.16	1.32	1.39
95	Nandi Hills	13.4	77.7	1479	1.17	1.11	1.04	0.97	0.94	0.95	0.95	0.97	1.00	1.06	1.08	1.14
96	Nellore	14.5	80.0	20	1.16	1.11	1.04	0.97	0.93	0.93	0.94	0.96	1.00	1.06	1.12	1.16
97	New Dehli	28.6	77.2	216	1.46	1.31	1.13	0.99	0.91	0.89	0.90	0.95	1.06	1.24	1.45	1.53
98	Niphad	20.1	74.1	550	1.27	1.18	1.07	0.98	0.92	0.91	0.95	0.96	1.01	1.12	1.24	1.30
99	Okha	22.5	69.1	7	1.37	1.25	1.10	0.98	0.91	0.90	0.92	0.96	1.04	1.18	1.33	1.38
100	Ollukara	10.5	76.3	22	1.11	1.07	1.02	0.98	0.96	0.96	0.97	0.98	1.00	1.04	1.08	1.11
101	Ootacamund	11.4	76.7	2218	1.12	1.08	1.03	0.98	0.95	0.95	0.96	0.97	1.00	1.04	1.09	1.12
102	Padegaon	18.2	74.2	556	1.27	1.18	1.07	0.98	0.92	0.91	0.94	0.96	1.01	1.11	1.23	1.30
103	Pantnagar	29.0	79.5	244	1.43	1.29	1.12	0.99	0.91	0.89	0.91	0.95	1.05	1.23	1.43	1.50
104	Parbhani	19.3	76.8	408	1.28	1.18	1.07	0.98	0.92	0.91	0.94	0.96	1.01	1.12	1.23	1.30
105	Patna	25.5	85.3	52	1.37	1.25	1.10	0.99	0.91	0.89	0.91	0.95	1.03	1.18	1.34	1.42
106	Pattambi	10.8	76.2	25	1.12	1.08	1.02	0.98	0.95	0.96	0.96	0.97	1.00	1.04	1.09	1.13
107	Port Blair	11.7	92.7	79	1.11	1.08	1.02	0.98	0.96	0.97	0.97	0.98	1.00	1.03	1.08	1.12
108	Pune	18.5	73.9	563	1.25	1.17	1.06	0.98	0.92	0.92	0.94	0.96	1.01	1.11	1.22	1.27
109	Pusa	26.0	85.7	52	1.38	1.25	1.10	0.99	0.91	0.89	0.91	0.95	1.03	1.18	1.35	1.43
110	Raichur	16.2	77.4	389	1.21	1.14	1.05	0.97	0.93	0.93	0.95	0.96	1.01	1.08	1.17	1.22
111	Raipur (Labhandi)	21.3	81.6	289	1.30	1.20	1.07	0.98	0.92	0.92	0.94	0.96	1.02	1.13	1.27	1.33
112	Rajahmundry	17.0	81.8	111	1.21	1.14	1.05	0.97	0.93	0.93	0.94	0.96	1.01	1.08	1.17	1.22
113	Rajendranagar	17.3	78.3	543	1.23	1.15	1.05	0.97	0.92	0.92	0.94	0.96	1.01	1.09	1.19	1.24
114	Rajkot	22.3	70.8	138	1.33	1.22	1.09	0.98	0.91	0.90	0.92	0.96	1.03	1.16	1.30	1.37
115	Ranchi (Kanka)	23.4	85.3	675	1.36	1.24	1.10	0.98	0.91	0.90	0.92	0.95	1.03	1.16	1.33	1.42
116	Ratnagiri	17.0	73.3	67	1.23	1.15	1.06	0.97	0.92	0.92	0.94	0.96	1.01	1.09	1.19	1.24
117	Rehmankhera	26.8	80.8	91	1.43	1.29	1.13	0.99	0.91	0.88	0.90	0.95	1.05	1.22	1.39	1.49
118	Saharanpur	30.0	77.6	275	1.47	1.32	1.14	1.00	0.91	0.88	0.90	0.95	1.07	1.25	1.46	1.54
119	Samalkot	17.1	82.2	9	1.22	1.14	1.05	0.97	0.92	0.92	0.94	0.96	1.01	1.08	1.17	1.23
120	Satna	24.6	80.8	317	1.39	1.27	1.12	0.99	0.90	0.88	0.91	0.95	1.04	1.20	1.37	1.46
121	Shahjanhanpur	27.9	79.9	155	1.44	1.30	1.12	0.99	0.91	0.89	0.91	0.95	1.05	1.22	1.41	1.49
122	Shakkarnagar	18.7	77.8	381	1.25	1.16	1.06	0.98	0.92	0.92	0.95	0.96	1.01	1.10	1.21	1.27
123	Shillong	25.6	91.9	1598	1.34	1.25	1.10	0.98	0.92	0.92	0.92	0.95	1.02	1.15	1.29	1.38
124	Silicuri	24.8	92.9	40	1.34	1.21	1.09	0.98	0.92	0.91	0.92	0.95	1.02	1.14	1.29	1.37
125	Sindewahi	20.3	79.7	222	1.29	1.19	1.07	0.98	0.91	0.91	0.94	0.96	1.01	1.13	1.26	1.32
126	Solapur	17.7	75.9	476	1.24	1.15	1.06	0.97	0.93	0.92	0.95	0.96	1.01	1.09	1.19	1.25
127	Srinagar	34.1	74.8	1587	1.38	1.28	1.13	1.00	0.91	0.87	0.89	0.96	1.10	1.32	1.54	1.53
128	Surat	21.2	72.9	11	1.30	1.20	1.07	0.98	0.91	0.91	0.94	0.96	1.02	1.14	1.26	1.33
129	Thirthahalli	13.7	75.3	628	1.16	1.10	1.04	0.97	0.94	0.95	0.96	0.97	1.00	1.05	1.13	1.17
130	Tiruchchirappalli	10.8	78.7	88	1.12	1.08	1.03	0.97	0.94	0.93	0.94	0.96	1.00	1.05	1.09	1.12
131	Titabar	26.6	94.2	99	1.35	1.22	1.08	0.98	0.93	0.91	0.92	0.95	1.03	1.16	1.31	1.39
132	Titlagarh	20.3	83.3	211	1.30	1.20	1.08	0.98	0.91	0.90	0.92	0.95	1.02	1.13	1.24	1.33
133	Tocklai	26.8	94.2	87	1.33	1.20	1.09	0.98	0.93	0.91	0.92	0.95	1.03	1.14	1.30	1.37
134	Trivandrum	8.5	77.0	64	1.09	1.06	1.02	0.98	0.96	0.96	0.96	0.97	1.00	1.03	1.06	1.09
135	Tuticorin	8.8	78.2	4	1.10	1.06	1.02	0.98	0.95	0.94	0.94	0.96	1.00	1.04	1.08	1.09
136	Udaipur	24.6	73.7	582	1.40	1.27	1.11	0.99	0.91	0.88	0.92	0.95	1.04	1.20	1.37	1.44
137	Varanasi	25.5	82.9	85	1.39	1.26	1.11	0.99	0.91	0.89	0.91	0.95	1.04	1.20	1.35	1.44
138	Vasad	22.5	73.1	34	1.32	1.21	1.08	0.98	0.91	0.90	0.93	0.96	1.02	1.15	1.28	1.35
139	Vedasandur	10.5	78.0	76	1.11	1.07	1.02	0.98	0.95	0.94	0.95	0.97	1.00	1.04	1.08	1.10
140	Vellore	12.9	79.2	214	1.13	1.09	1.03	0.98	0.94	0.93	0.94	0.97	1.00	1.05	1.10	1.14
141	Vengurla	15.9	73.6	9	1.21	1.13	1.05	0.97	0.93	0.93	0.95	0.97	1.00	1.07	1.16	1.23
142	Veraval	20.9	70.4	8	1.32	1.21	1.09	0.98	0.91	0.89	0.92	0.96	1.03	1.15	1.28	1.35
143	Viramgam	23.1	72.2	27	1.37	1.24	1.10	0.98	0.91	0.89	0.92	0.96	1.03	1.18	1.33	1.40
144	Vishakhapetnam	17.7	83.2	3	1.24	1.16	1.05	0.97	0.92	0.92	0.94	0.96	1.01	1.10	1.19	1.25
145	Vittal	13.0	75.4	91	1.16	1.10	1.03	0.97	0.93	0.95	0.96	0.97	1.00	1.05	1.12	1.16

Stn#	Station Name	Lat (N)	Long (E)	Elev (m)	Daily Global Radiation Tilt Factors: Latitude - 15 degrees											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	Aduthurai	11.0	79.5	19	0.95	0.97	0.98	1.00	1.02	1.02	1.02	1.01	0.99	0.98	0.96	0.95
2	Agartala	23.9	91.3	16	1.13	1.09	1.04	1.01	0.98	0.98	0.98	1.00	1.02	1.07	1.12	1.14
3	Agra	27.2	78.1	169	1.23	1.16	1.08	1.02	0.98	0.96	0.97	1.00	1.05	1.13	1.22	1.26
4	Ahmadabad	23.1	72.6	55	1.14	1.10	1.05	1.01	0.98	0.97	0.98	1.00	1.02	1.08	1.13	1.16
5	Akola	20.7	77.0	282	1.10	1.07	1.03	1.00	0.98	0.98	0.99	1.00	1.01	1.05	1.08	1.10
6	Aligarh (Kalai)	27.9	78.1	187	1.25	1.18	1.08	1.02	0.98	0.96	0.97	1.00	1.05	1.14	1.23	1.28
7	Allahabad	25.5	81.7	98	1.19	1.14	1.07	1.01	0.98	0.97	0.98	1.00	1.04	1.10	1.18	1.21
8	Amini Divi	11.1	72.7	4	0.96	0.97	0.99	1.00	1.01	1.01	1.01	1.00	0.99	0.98	0.97	0.96
9	Amritsar	31.6	74.9	234	1.31	1.22	1.11	1.03	0.98	0.95	0.97	1.00	1.07	1.19	1.30	1.35
10	Anakapalle	17.7	83.0	10	1.04	1.03	1.01	1.00	0.99	0.99	0.99	1.00	1.01	1.02	1.03	1.04
11	Annamalaimagar	11.4	79.7	6	0.96	0.97	0.99	1.00	1.01	1.02	1.01	1.01	0.99	0.98	0.97	0.96
12	Babbur (Hiriyur)	14.0	76.6	610	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99
13	Bahadrabad	29.9	78.1	275	1.28	1.20	1.10	1.03	0.98	0.96	0.97	1.00	1.06	1.16	1.28	1.31
14	Bangalor	13.0	77.6	897	0.97	0.98	0.99	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.98	0.97
15	Barmer	25.8	71.4	194	1.21	1.14	1.08	1.02	0.97	0.96	0.97	1.00	1.05	1.12	1.19	1.23
16	Baroda	22.3	73.3	34	1.13	1.09	1.04	1.01	0.98	0.97	0.99	1.00	1.02	1.07	1.11	1.14
17	Barrakpore	22.8	88.4	9	1.12	1.09	1.04	1.01	0.98	0.98	0.98	1.00	1.02	1.06	1.12	1.13
18	Bellary	15.2	76.9	449	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	Berhampore	24.1	88.3	19	1.16	1.11	1.06	1.01	0.98	0.97	0.98	1.00	1.02	1.08	1.14	1.18
20	Bhavnagar	21.8	72.2	5	1.12	1.08	1.04	1.01	0.98	0.98	0.99	1.00	1.02	1.06	1.11	1.13
21	Bhopal	23.3	77.4	503	1.15	1.11	1.05	1.01	0.98	0.97	0.98	1.00	1.02	1.08	1.14	1.16
22	Bhubaneswar	20.3	85.9	26	1.09	1.06	1.03	1.00	0.99	0.98	0.99	1.00	1.01	1.04	1.07	1.10
23	Bhuj	23.3	69.7	80	1.15	1.10	1.05	1.01	0.98	0.97	0.98	1.00	1.03	1.08	1.13	1.16
24	Bikaner	28.0	73.3	224	1.26	1.18	1.10	1.02	0.97	0.95	0.96	1.00	1.06	1.15	1.24	1.29
25	Bikramganj	25.2	84.3	87	1.17	1.12	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.09	1.15	1.18
26	Bombay	19.1	72.9	14	1.07	1.05	1.02	1.00	0.99	0.99	0.99	1.00	1.01	1.03	1.06	1.07
27	Calcutta	22.7	88.5	6	1.12	1.08	1.04	1.01	0.98	0.98	0.98	1.00	1.02	1.06	1.11	1.13
28	Car Nicobar	9.2	92.8	10	0.95	0.96	0.98	1.00	1.01	1.01	1.01	1.01	0.99	0.98	0.96	0.94
29	Chandigarh	30.7	76.9	347	1.29	1.20	1.10	1.03	0.98	0.96	0.97	1.00	1.07	1.17	1.28	1.31
30	Chaubattia	29.8	79.7	1962	1.25	1.17	1.09	1.02	0.98	0.96	0.98	0.99	1.04	1.14	1.25	1.29
31	Chinsurah	22.9	88.4	9	1.14	1.09	1.05	1.01	0.98	0.97	0.98	1.00	1.02	1.07	1.12	1.15
32	Coimbatore	11.0	77.0	431	0.95	0.97	0.98	1.00	1.01	1.02	1.01	1.01	0.99	0.98	0.96	0.95
33	Cuddappah	14.5	78.8	130	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
34	Cuttack	20.5	85.9	24	1.09	1.06	1.03	1.00	0.99	0.98	0.99	1.00	1.01	1.04	1.08	1.10
35	Dehra Dun	30.3	78.0	683	1.28	1.19	1.10	1.03	0.98	0.96	0.97	1.00	1.06	1.17	1.28	1.33
36	Dharwar	15.4	75.1	679	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01
37	Dhulia	20.9	74.8	245	1.09	1.06	1.03	1:00	0.98	0.98	0.99	1.00	1.01	1.05	1.08	1.10
38	Dibrugarh (Mohanbari)	27.5	95.0	111	1.18	1.11	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.10	1.18	1.21
39	Gannavaram	16.5	80.8	24	1.02	1.02	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.02	1.02
40	Gauhati	26.1	91.6	54	1.18	1.13	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.10	1.17	1.21
41	Goa	15.5	73.8	55	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01
42	Golegaon	19.3	76.5	402	1.07	1.05	1.02	1.00	0.99	0.99	0.99	1.00	1.01	1.03	1.06	1.08
43	Gopalpur	19.3	84.9	17	1.07	1.05	1.02	1.00	0.99	0.98	0.99	1.00	1.01	1.03	1.06	1.08
44	Gorakhpur	27.0	83.5	79	1.20	1.15	1.07	1.02	0.98	0.97	0.97	1.00	1.04	1.11	1.19	1.22
45	Guna	24.7	77.3	478	1.17	1.12	1.06	1.01	0.98	0.96	0.98	1.00	1.03	1.10	1.16	1.19
46	Gurdaspur	32.1	76.4	267	1.30	1.22	1.11	1.03	0.98	0.95	0.97	1.00	1.07	1.19	1.32	1.37
47	Gwalior	26.2	78.3	207	1.21	1.15	1.08	1.02	0.98	0.96	0.97	1.00	1.04	1.12	1.20	1.24
48	Hagari	15.2	77.1	413	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
49	Hansi	29.1	76.0	217	1.26	1.18	1.09	1.02	0.98	0.96	0.97	1.00	1.06	1.15	1.25	1.28
50	Hanumangarh	29.5	74.3	221	1.27	1.19	1.10	1.02	0.98	0.96	0.97	1.00	1.06	1.16	1.26	1.30
51	Haringhata	22.9	88.5	10	1.13	1.09	1.05	1.01	0.98	0.98	0.98	1.00	1.02	1.07	1.12	1.13
52	Hebbal	13.0	77.6	889	0.97	0.98	0.99	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.98	0.97
53	Hissar	29.2	75.8	221	1.27	1.19	1.10	1.02	0.98	0.96	0.97	1.00	1.07	1.16	1.27	1.32
54	Hoshangabad (Powerkhera)	22.8	77.8	302	1.14	1.10	1.05	1.01	0.98	0.97	0.99	1.00	1.02	1.07	1.12	1.15
55	Hunsur	12.3	76.1	826	0.96	0.98	0.99	1.00	1.01	1.01	1.01	1.00	1.00	0.98	0.97	0.96
56	Hyderabad	17.5	78.5	545	1.04	1.03	1.01	1.00	0.99	0.99	0.99	1.00	1.01	1.02	1.03	1.04
57	Ibrahimpatan	17.1	78.7	610	1.03	1.02	1.01	1.00	0.99	0.99	0.99	1.00	1.00	1.02	1.03	1.03
58	Imphal	24.8	93.9	781	1.17	1.12	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.08	1.15	1.19
59	Indore	130.8	0.0		1.14	1.10	1.05	1.01	0.98	0.97	0.99	1.00	1.02	1.07	1.12	1.15
60	Jabalpur (Adhartal)	23.2	80.0	411	1.14	1.11	1.05	1.01	0.98	0.97	0.98	1.00	1.02	1.07	1.13	1.16
61	Jagadalpur	19.1	82.0	553	1.06	1.04	1.02	1.00	0.99	0.99	0.99	1.00	1.01	1.03	1.05	1.07
62	Jaipur	26.8	75.8	390	1.23	1.16	1.08	1.02	0.98	0.96	0.97	1.00	1.05	1.13	1.22	1.26
63	Jaisalmer	26.9	70.9	231	1.24	1.17	1.09	1.02	0.97	0.95	0.96	1.00	1.06	1.14	1.22	1.26
64	Jalgaon	21.1	75.6	201	1.10	1.07	1.03	1.00	0.98	0.98	0.99	1.00	1.01	1.05	1.09	1.11
65	Jammu	32.7	74.8	367	1.33	1.22	1.12	1.03	0.98	0.95	0.97	1.00	1.09	1.20	1.31	1.37
66	Jamnagar	22.5	70.0	21	1.13	1.09	1.04	1.01	0.98	0.98	0.99	1.00	1.02	1.07	1.12	1.14
67	Jharsuguda	21.9	84.1	230	1.11	1.09	1.04	1.01	0.98	0.98	0.98	1.00	1.02	1.06	1.10	1.12
68	Jobner	27.0	75.1	427	1.23	1.16	1.09	1.02	0.98	0.96	0.97	1.00	1.05	1.13	1.22	1.27
69	Jodhpur	26.3	73.0	224	1.22	1.15	1.08	1.02	0.98	0.96	0.97	1.00	1.05	1.12	1.21	1.25
70	Jullundur	31.4	75.6	238	1.32	1.22	1.11	1.03	0.98	0.95	0.97	1.00	1.07	1.19	1.31	1.36
71	Kanniyakumari	8.1	77.5	37	0.92	0.94	0.97	1.01	1.03	1.03	1.03	1.01	0.99	0.96	0.94	0.92
72	Karimganj	24.7	92.5	16	1.15	1.10	1.05	1.01	0.98	0.98	0.98	1.00	1.03	1.08	1.14	1.17
73	Karjat	18.9	73.3	52	1.06	1.04	1.02	1.00	0.99	0.99	1.00	1.00	1.01	1.03	1.05	1.06
74	Kasargod	12.5	75.0	11	0.97	0.98	0.99	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.97	0.96
75	Kayamgulam	9.1	76.5	3	0.93	0.95	0.98	1.00	1.02	1.02	1.02	1.01	0.99	0.97	0.94	0.93

Stn	Station Name	Lat (N)	Long (E)	Elev (m)	Daily Global Radiation Tilt Factors: Latitude - 15 degrees											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
76	Kodaikanal	10.2	77.5	2345	0.94	0.96	0.98	1.00	1.02	1.02	1.01	1.01	0.99	0.98	0.96	0.95
77	Kolhapur	16.7	74.2	570	1.03	1.02	1.01	1.00	1.00	0.99	1.00	1.00	1.00	1.01	1.02	1.03
78	Kondul	7.5	93.7	8	0.94	0.96	0.98	1.00	1.02	1.02	1.02	1.01	0.99	0.98	0.95	0.94
79	Kota	25.2	75.5	257	1.20	1.14	1.07	1.01	0.98	0.96	0.98	1.00	1.04	1.11	1.18	1.22
80	Kottayam	9.5	76.5	73	0.93	0.95	0.98	1.00	1.02	1.02	1.02	1.01	0.99	0.97	0.95	0.93
81	Kovilpatti	9.2	77.9	92	0.93	0.95	0.98	1.00	1.02	1.03	1.02	1.01	0.99	0.97	0.95	0.94
82	Kuthulia	24.5	81.3	366	1.17	1.13	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.10	1.17	1.19
83	Leh	34.2	77.6	3514	1.37	1.26	1.14	1.04	0.98	0.95	0.96	1.01	1.11	1.25	1.41	1.44
84	Lucknow	26.8	80.9	128	1.22	1.16	1.08	1.02	0.98	0.96	0.97	1.00	1.04	1.12	1.20	1.24
85	Madhipura	25.8	86.7	42	1.18	1.13	1.07	1.01	0.98	0.97	0.98	1.00	1.03	1.10	1.18	1.21
86	Madras	13.0	80.2	16	0.98	0.98	0.99	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.98	0.98
87	Mandya	12.5	76.8	695	0.97	0.98	0.99	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.97	0.97
88	Mangalore	12.9	74.9	102	0.97	0.98	0.99	1.00	1.01	1.01	1.00	1.00	1.00	0.99	0.98	0.97
89	Minicoy	8.3	73.0	2	0.93	0.95	0.98	1.00	1.02	1.02	1.02	1.01	0.99	0.97	0.94	0.93
90	Musaffarnagar	29.5	77.7	240	1.27	1.19	1.10	1.02	0.98	0.96	0.97	1.00	1.06	1.15	1.26	1.30
91	Nagina	29.9	78.4	249	1.28	1.19	1.10	1.02	0.98	0.96	0.97	1.00	1.06	1.16	1.26	1.30
92	Nagpur	21.2	79.1	311	1.11	1.07	1.04	1.00	0.98	0.98	0.99	1.00	1.01	1.05	1.09	1.11
93	Nagrakata	26.9	88.9	229	1.21	1.13	1.07	1.01	0.98	0.97	0.98	1.00	1.03	1.11	1.20	1.24
94	Nagrifarm	26.9	88.2	1158	1.17	1.11	1.06	1.01	0.98	0.98	0.98	0.99	1.02	1.09	1.17	1.20
95	Nandi Hills	13.4	77.7	1479	0.98	0.98	0.99	1.00	1.01	1.01	1.00	1.00	1.00	0.99	0.99	0.98
96	Nellore	14.5	80.0	20	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
97	New Dehli	28.6	77.2	216	1.25	1.18	1.09	1.02	0.98	0.96	0.97	1.00	1.05	1.15	1.25	1.28
98	Niphad	20.1	74.1	550	1.08	1.06	1.03	1.00	0.99	0.98	0.99	1.00	1.01	1.04	1.07	1.09
99	Okha	22.5	69.1	7	1.15	1.11	1.05	1.01	0.98	0.97	0.98	1.00	1.03	1.08	1.14	1.15
100	Ollukara	10.5	76.3	22	0.95	0.96	0.98	1.00	1.01	1.01	1.01	1.01	0.99	0.98	0.96	0.95
101	Ootacamund	11.4	76.7	2218	0.96	0.97	0.99	1.00	1.01	1.01	1.01	1.00	1.00	0.98	0.97	0.96
102	Padegaon	18.2	74.2	556	1.07	1.05	1.02	1.00	0.99	0.98	0.99	1.00	1.01	1.03	1.06	1.08
103	Pantnagar	29.0	79.5	244	1.24	1.17	1.09	1.02	0.98	0.96	0.97	1.00	1.05	1.14	1.24	1.28
104	Parbhani	19.3	76.8	408	1.07	1.05	1.02	1.00	0.99	0.99	0.99	1.00	1.01	1.03	1.06	1.08
105	Patna	25.5	85.3	52	1.18	1.12	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.09	1.16	1.20
106	Pattambi	10.8	76.2	25	0.95	0.96	0.98	1.00	1.01	1.01	1.01	1.01	0.99	0.98	0.96	0.94
107	Port Blair	11.7	92.7	79	0.96	0.97	0.99	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.97	0.96
108	Pune	18.5	73.9	563	1.06	1.04	1.02	1.00	0.99	0.99	0.99	1.00	1.01	1.03	1.05	1.06
109	Pusa	26.0	85.7	52	1.18	1.13	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.10	1.17	1.21
110	Raichur	16.2	77.4	389	1.02	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.02	1.02
111	Raipur (Labhandi)	21.3	81.6	289	1.10	1.07	1.03	1.00	0.98	0.98	0.99	1.00	1.02	1.05	1.09	1.11
112	Rajahmundry	17.0	81.8	111	1.03	1.02	1.01	1.00	0.99	0.99	1.00	1.00	1.00	1.01	1.02	1.03
113	Rajendranagar	17.3	78.3	543	1.04	1.03	1.01	1.00	0.99	0.99	0.99	1.00	1.01	1.02	1.03	1.04
114	Rajkot	22.3	70.8	136	1.13	1.09	1.05	1.01	0.98	0.97	0.98	1.00	1.02	1.07	1.11	1.14
115	Ranchi (Kanka)	23.4	85.3	675	1.15	1.11	1.05	1.01	0.98	0.97	0.98	1.00	1.02	1.07	1.14	1.17
116	Ratnagiri	17.0	73.3	67	1.03	1.02	1.01	1.00	0.99	0.99	1.00	1.00	1.01	1.01	1.03	1.03
117	Rehmankhera	26.8	80.8	91	1.22	1.15	1.08	1.02	0.98	0.96	0.97	1.00	1.04	1.12	1.20	1.25
118	Saharanpur	30.0	77.6	275	1.27	1.19	1.10	1.03	0.98	0.96	0.97	1.00	1.06	1.16	1.27	1.31
119	Samalkot	17.1	82.2	9	1.03	1.02	1.01	1.00	0.99	0.99	1.00	1.00	1.00	1.01	1.03	1.03
120	Satna	24.6	80.8	317	1.18	1.13	1.07	1.01	0.98	0.96	0.98	1.00	1.03	1.10	1.17	1.20
121	Shahjanhanpur	27.9	79.9	155	1.24	1.17	1.08	1.02	0.98	0.96	0.97	1.00	1.04	1.13	1.22	1.26
122	Shakkarnagar	18.7	77.8	381	1.06	1.04	1.02	1.00	0.99	0.99	0.99	1.00	1.01	1.03	1.05	1.06
123	Shillong	25.6	91.9	1598	1.16	1.13	1.06	1.01	0.98	0.98	0.98	1.00	1.03	1.08	1.14	1.18
124	Silicuri	24.8	92.9	40	1.15	1.10	1.05	1.01	0.98	0.98	0.98	1.00	1.03	1.07	1.13	1.17
125	Sindewahi	20.3	79.7	222	1.09	1.06	1.03	1.00	0.99	0.98	0.99	1.00	1.01	1.04	1.08	1.09
126	Solapur	17.7	75.9	476	1.04	1.03	1.01	1.00	0.99	0.99	1.00	1.00	1.01	1.02	1.03	1.04
127	Srinagar	34.1	74.8	1587	1.25	1.20	1.11	1.03	0.98	0.95	0.96	1.01	1.09	1.22	1.35	1.34
128	Surat	21.2	72.9	11	1.10	1.07	1.03	1.00	0.98	0.98	0.99	1.00	1.01	1.05	1.09	1.11
129	Thirthahalli	13.7	75.3	628	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.98
130	Tiruchchirappalli	10.8	78.7	88	0.95	0.96	0.98	1.00	1.02	1.02	1.02	1.01	0.99	0.97	0.96	0.95
131	Titabar	26.6	94.2	99	1.18	1.12	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.09	1.16	1.19
132	Titlagarh	20.3	83.3	211	1.09	1.06	1.03	1.00	0.98	0.98	0.99	1.00	1.01	1.04	1.07	1.10
133	Tocklai	26.8	94.2	87	1.17	1.11	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.08	1.16	1.19
134	Trivandrum	8.5	77.0	64	0.92	0.95	0.98	1.01	1.02	1.03	1.02	1.01	0.99	0.97	0.94	0.92
135	Tuticorin	8.8	78.2	4	0.92	0.95	0.98	1.01	1.03	1.04	1.03	1.02	0.99	0.96	0.94	0.93
136	Udaipur	24.6	73.7	582	1.18	1.13	1.06	1.01	0.98	0.97	0.98	1.00	1.03	1.10	1.17	1.20
137	Varanasi	25.5	82.9	85	1.19	1.13	1.07	1.01	0.98	0.97	0.98	1.00	1.03	1.10	1.17	1.21
138	Vasad	22.5	73.1	34	1.12	1.09	1.04	1.01	0.98	0.97	0.99	1.00	1.02	1.07	1.11	1.13
139	Vedasandur	10.5	78.0	76	0.95	0.96	0.98	1.00	1.02	1.02	1.02	1.01	0.99	0.98	0.96	0.95
140	Vellore	12.9	79.2	214	0.98	0.98	0.99	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.98	0.97
141	Vengurla	15.9	73.6	9	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01
142	Veraval	20.9	70.4	8	1.10	1.07	1.04	1.00	0.98	0.98	0.99	1.00	1.02	1.06	1.09	1.11
143	Viramgam	23.1	72.2	27	1.15	1.10	1.05	1.01	0.98	0.97	0.98	1.00	1.03	1.08	1.13	1.16
144	Vishakhapatnam	17.7	83.2	3	1.04	1.03	1.01	1.00	0.99	0.99	0.99	1.00	1.01	1.02	1.04	1.04
145	Vittal	13.0	75.4	91	0.97	0.98	0.99	1.00	1.01	1.01	1.00	1.00	1.00	0.99	0.98	0.97

Stn	Station Name	Lat (N)	Long (E)	Elev (m)	Daily Global Radiation Tilt Factors: Latitude + 15 degrees											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Aduthurai	11.0	79.5	19	1.22	1.13	1.01	0.90	0.83	0.81	0.83	0.88	0.96	1.06	1.16	1.21
2	Agartala	23.9	91.3	16	1.39	1.24	1.05	0.91	0.82	0.84	0.83	0.88	0.97	1.15	1.36	1.45
3	Agra	27.2	78.1	169	1.58	1.36	1.11	0.91	0.80	0.77	0.81	0.87	1.01	1.26	1.53	1.66
4	Ahmadabad	23.1	72.6	55	1.49	1.30	1.07	0.90	0.79	0.78	0.84	0.88	0.98	1.20	1.43	1.56
5	Akola	20.7	77.0	282	1.44	1.26	1.06	0.90	0.80	0.80	0.86	0.89	0.97	1.15	1.36	1.47
6	Aligarh (Kalai)	27.9	78.1	187	1.60	1.38	1.10	0.92	0.80	0.77	0.80	0.87	1.01	1.26	1.56	1.69
7	Allahabad	25.5	81.7	98	1.52	1.33	1.09	0.91	0.80	0.78	0.81	0.87	0.99	1.23	1.48	1.61
8	Amini Divi	11.1	72.7	4	1.19	1.11	1.01	0.91	0.87	0.89	0.90	0.91	0.96	1.04	1.14	1.20
9	Amritsar	31.6	74.9	234	1.63	1.39	1.12	0.93	0.80	0.76	0.79	0.87	1.03	1.31	1.61	1.73
10	Anakapalle	17.7	83.0	10	1.35	1.20	1.04	0.90	0.82	0.82	0.85	0.89	0.96	1.10	1.27	1.38
11	Annamalaimagar	11.4	79.7	6	1.23	1.13	1.01	0.90	0.84	0.81	0.83	0.88	0.96	1.06	1.15	1.22
12	Babbur (Hiriyur)	14.0	76.6	610	1.28	1.17	1.02	0.90	0.83	0.83	0.87	0.90	0.96	1.08	1.21	1.30
13	Bahadrabad	29.9	78.1	275	1.61	1.38	1.12	0.92	0.80	0.77	0.80	0.87	1.01	1.29	1.59	1.69
14	Bangalor	13.0	77.6	897	1.25	1.15	1.01	0.90	0.84	0.84	0.88	0.90	0.96	1.06	1.18	1.25
15	Barmer	25.8	71.4	194	1.57	1.35	1.11	0.91	0.78	0.74	0.79	0.86	1.01	1.26	1.51	1.64
16	Baroda	22.3	73.3	34	1.46	1.28	1.07	0.90	0.80	0.79	0.85	0.89	0.98	1.18	1.40	1.52
17	Barrakpore	22.8	88.4	9	1.43	1.26	1.06	0.91	0.81	0.81	0.83	0.88	0.97	1.15	1.39	1.45
18	Bellary	15.2	76.9	449	1.31	1.18	1.03	0.90	0.82	0.82	0.85	0.88	0.96	1.09	1.23	1.33
19	Berhampore	24.1	88.3	19	1.50	1.30	1.09	0.91	0.81	0.80	0.83	0.88	0.98	1.19	1.43	1.57
20	Bhavnagar	21.8	72.2	5	1.46	1.27	1.07	0.90	0.79	0.79	0.86	0.89	0.97	1.18	1.41	1.50
21	Bhopal	23.3	77.4	503	1.52	1.32	1.08	0.90	0.79	0.78	0.84	0.89	0.98	1.21	1.45	1.56
22	Bhubaneswar	20.3	85.9	26	1.41	1.25	1.06	0.90	0.80	0.80	0.83	0.88	0.97	1.14	1.34	1.47
23	Bhuj	23.3	69.7	80	1.49	1.30	1.07	0.91	0.80	0.78	0.83	0.88	0.99	1.20	1.43	1.55
24	Bikaner	28.0	73.3	224	1.64	1.39	1.13	0.92	0.79	0.74	0.77	0.86	1.03	1.30	1.56	1.71
25	Bikramganj	25.2	84.3	87	1.47	1.29	1.08	0.91	0.82	0.81	0.82	0.87	0.98	1.19	1.42	1.52
26	Bombay	19.1	72.9	14	1.39	1.23	1.05	0.90	0.80	0.81	0.86	0.89	0.97	1.14	1.34	1.44
27	Calcutta	22.7	88.5	6	1.41	1.25	1.06	0.91	0.81	0.82	0.83	0.88	0.97	1.14	1.35	1.46
28	Car Nicobar	9.2	92.8	10	1.14	1.08	1.00	0.92	0.90	0.90	0.90	0.92	0.96	1.02	1.09	1.16
29	Chandigarh	30.7	76.9	347	1.62	1.37	1.12	0.92	0.81	0.78	0.80	0.87	1.02	1.29	1.58	1.67
30	Chaubattia	29.8	79.7	1962	1.53	1.33	1.10	0.92	0.81	0.79	0.83	0.87	0.98	1.24	1.53	1.65
31	Chinsurah	22.9	88.4	9	1.48	1.28	1.07	0.90	0.80	0.80	0.82	0.87	0.98	1.17	1.41	1.54
32	Coimbatore	11.0	77.0	431	1.22	1.13	1.01	0.90	0.84	0.83	0.86	0.89	0.96	1.06	1.16	1.23
33	Cuddappah	14.5	78.8	130	1.28	1.17	1.03	0.90	0.82	0.82	0.85	0.89	0.96	1.07	1.20	1.30
34	Cuttack	20.5	85.9	24	1.41	1.24	1.05	0.90	0.81	0.81	0.84	0.88	0.97	1.13	1.34	1.46
35	Dehra Dun	30.3	78.0	683	1.60	1.36	1.12	0.92	0.80	0.78	0.81	0.87	1.02	1.29	1.59	1.72
36	Dharwar	15.4	75.1	679	1.32	1.18	1.03	0.90	0.83	0.84	0.88	0.90	0.96	1.08	1.24	1.34
37	Dhulia	20.9	74.8	245	1.41	1.24	1.05	0.90	0.80	0.80	0.86	0.89	0.97	1.16	1.35	1.44
38	Dibrugarh (Mohanbari)	27.5	95.0	111	1.42	1.22	1.05	0.91	0.84	0.82	0.83	0.87	0.97	1.17	1.41	1.53
39	Gannavaram	16.5	80.8	24	1.33	1.20	1.03	0.90	0.81	0.82	0.84	0.88	0.96	1.10	1.25	1.34
40	Gauhati	26.1	91.6	54	1.48	1.30	1.07	0.91	0.82	0.81	0.82	0.87	0.98	1.19	1.44	1.57
41	Goa	15.5	73.8	55	1.31	1.19	1.03	0.90	0.82	0.84	0.86	0.89	0.96	1.10	1.26	1.35
42	Golegaon	19.3	76.5	402	1.40	1.23	1.05	0.90	0.81	0.84	0.86	0.90	0.96	1.12	1.34	1.44
43	Gopalpur	19.3	84.9	17	1.40	1.24	1.06	0.90	0.81	0.80	0.84	0.88	0.97	1.13	1.32	1.45
44	Gorakhpur	27.0	83.5	79	1.49	1.32	1.08	0.91	0.81	0.78	0.81	0.87	0.99	1.20	1.46	1.56
45	Guna	24.7	77.3	478	1.52	1.32	1.10	0.91	0.80	0.76	0.81	0.87	0.99	1.23	1.47	1.59
46	Gurdaspur	32.1	76.4	267	1.60	1.39	1.11	0.93	0.81	0.76	0.79	0.87	1.03	1.32	1.64	1.76
47	Gwalior	26.2	78.3	207	1.57	1.36	1.11	0.91	0.80	0.76	0.81	0.87	1.00	1.25	1.53	1.65
48	Hagari	15.2	77.1	413	1.29	1.18	1.02	0.90	0.83	0.84	0.87	0.90	0.96	1.07	1.22	1.31
49	Hansi	29.1	76.0	217	1.58	1.35	1.10	0.92	0.81	0.79	0.80	0.87	1.01	1.27	1.55	1.65
50	Hanumangarh	29.5	74.3	221	1.59	1.38	1.12	0.92	0.81	0.79	0.79	0.87	1.02	1.29	1.57	1.68
51	Haringhata	22.9	88.5	10	1.43	1.27	1.07	0.90	0.81	0.81	0.82	0.87	0.98	1.17	1.38	1.45
52	Hebbal	13.0	77.6	889	1.27	1.16	1.02	0.90	0.83	0.82	0.86	0.89	0.96	1.07	1.20	1.26
53	Hissar	29.2	75.8	221	1.62	1.39	1.13	0.92	0.80	0.78	0.79	0.87	1.03	1.29	1.60	1.74
54	Hoshangabad (Powerkhera)	22.8	77.8	302	1.48	1.30	1.07	0.90	0.80	0.79	0.85	0.89	0.97	1.18	1.42	1.56
55	Hunsur	12.3	76.1	826	1.26	1.15	1.01	0.90	0.83	0.83	0.86	0.89	0.96	1.06	1.20	1.26
56	Hyderabad	17.5	78.5	545	1.35	1.21	1.03	0.90	0.81	0.82	0.86	0.89	0.96	1.11	1.28	1.37
57	Ibrahimpatan	17.1	78.7	610	1.34	1.21	1.04	0.90	0.82	0.82	0.84	0.89	0.96	1.10	1.28	1.36
58	Imphal	24.8	93.9	781	1.50	1.30	1.08	0.91	0.82	0.81	0.83	0.87	0.98	1.17	1.42	1.56
59	Indore	130.8	0.0		1.48	1.29	1.07	0.90	0.80	0.79	0.85	0.89	0.97	1.19	1.42	1.53
60	Jabalpur (Adhartal)	23.2	80.0	411	1.47	1.31	1.08	0.90	0.81	0.79	0.84	0.88	0.98	1.19	1.42	1.55
61	Jagadalpur	19.1	82.0	553	1.38	1.22	1.05	0.90	0.82	0.82	0.86	0.89	0.96	1.11	1.30	1.41
62	Jaipur	26.8	75.8	390	1.60	1.37	1.11	0.91	0.80	0.78	0.81	0.87	1.01	1.27	1.56	1.70
63	Jaisalmer	26.9	70.9	231	1.63	1.39	1.13	0.92	0.78	0.73	0.77	0.86	1.03	1.29	1.56	1.70
64	Jalgaon	21.1	75.6	201	1.44	1.26	1.06	0.90	0.80	0.79	0.85	0.89	0.97	1.17	1.37	1.49
65	Jammu	32.7	74.8	367	1.64	1.38	1.13	0.93	0.80	0.75	0.79	0.87	1.04	1.33	1.58	1.73
66	Jamnagar	22.5	70.0	21	1.46	1.28	1.07	0.90	0.80	0.79	0.85	0.89	0.98	1.19	1.41	1.53
67	Jharsuguda	21.9	84.1	230	1.43	1.29	1.06	0.90	0.80	0.81	0.84	0.88	0.98	1.18	1.37	1.48
68	Jobner	27.0	75.1	427	1.59	1.37	1.12	0.91	0.80	0.76	0.80	0.87	1.01	1.26	1.54	1.70
69	Jodhpur	26.3	73.0	224	1.59	1.37	1.10	0.91	0.79	0.76	0.80	0.86	1.01	1.26	1.54	1.68
70	Jullundur	31.4	75.6	238	1.65	1.40	1.13	0.93	0.80	0.76	0.79	0.87	1.03	1.31	1.62	1.76
71	Kanniyakumari	8.1	77.5	37	1.19	1.11	1.00	0.90	0.85	0.83	0.84	0.89	0.96	1.05	1.14	1.18
72	Karimganj	24.7	92.5	16	1.45	1.26	1.06	0.91	0.83	0.83	0.84	0.88	0.97	1.16	1.38	1.52
73	Karjat	18.9	73.3	52	1.36	1.22	1.04	0.90	0.82	0.84	0.89	0.91	0.96	1.11	1.30	1.40
74	Kasargod	12.5	75.0	11	1.26	1.15	1.02	0.90	0.84	0.86	0.88	0.89	0.96	1.07	1.21	1.29
75	Kayamgulam	9.1	76.5	3	1.21	1.12	1.00	0.90	0.85	0.86	0.86	0.89	0.96	1.05	1.15	1.22

Stn#	Station Name	Lat (N)	Long (E)	Elev (m)	Daily Global Radiation Tilt Factors: Latitude + 15 degrees											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
76	Kodaikanal	10.2	77.5	2345	1.21	1.12	1.01	0.90	0.85	0.86	0.88	0.90	0.96	1.03	1.12	1.20
77	Kolhapur	16.7	74.2	570	1.34	1.20	1.04	0.90	0.82	0.82	0.86	0.90	0.96	1.09	1.27	1.37
78	Kondul	7.5	93.7	8	1.12	1.05	0.99	0.93	0.90	0.90	0.90	0.93	0.96	1.01	1.08	1.12
79	Kota	25.2	75.5	257	1.58	1.36	1.10	0.91	0.79	0.76	0.81	0.87	1.00	1.24	1.50	1.65
80	Kottayam	9.5	76.5	73	1.22	1.12	1.00	0.90	0.85	0.85	0.87	0.90	0.96	1.04	1.15	1.21
81	Kovilpatti	9.2	77.9	92	1.19	1.11	1.00	0.91	0.84	0.82	0.84	0.88	0.96	1.05	1.14	1.19
82	Kuthulia	24.5	81.3	366	1.53	1.34	1.10	0.91	0.79	0.78	0.82	0.87	0.99	1.23	1.50	1.59
83	Leh	34.2	77.6	3514	1.70	1.43	1.15	0.94	0.80	0.74	0.77	0.87	1.08	1.40	1.77	1.85
84	Lucknow	26.8	80.9	128	1.57	1.36	1.10	0.91	0.80	0.78	0.81	0.87	1.00	1.25	1.50	1.64
85	Madhipura	25.8	86.7	42	1.51	1.32	1.09	0.91	0.81	0.79	0.82	0.87	0.99	1.21	1.48	1.60
86	Madras	13.0	80.2	16	1.24	1.15	1.02	0.90	0.83	0.82	0.84	0.88	0.96	1.07	1.17	1.24
87	Mandya	12.5	76.8	695	1.26	1.16	1.02	0.90	0.82	0.82	0.85	0.89	0.96	1.07	1.20	1.27
88	Mangalore	12.9	74.9	102	1.27	1.15	1.01	0.90	0.84	0.87	0.89	0.90	0.96	1.07	1.21	1.28
89	Minicoy	8.3	73.0	2	1.17	1.10	1.00	0.91	0.87	0.88	0.89	0.90	0.96	1.04	1.13	1.17
90	Musaffarnagar	29.5	77.7	240	1.61	1.37	1.12	0.92	0.80	0.77	0.80	0.87	1.01	1.27	1.56	1.69
91	Nagina	29.9	78.4	249	1.60	1.37	1.12	0.92	0.80	0.77	0.81	0.87	1.01	1.27	1.56	1.68
92	Nagpur	21.2	79.1	311	1.45	1.27	1.06	0.90	0.80	0.80	0.85	0.89	0.97	1.17	1.39	1.50
93	Nagrakata	26.9	88.9	229	1.52	1.29	1.08	0.91	0.82	0.82	0.83	0.87	0.98	1.21	1.49	1.62
94	Nagrifarm	26.9	88.2	1158	1.41	1.22	1.06	0.91	0.84	0.84	0.85	0.88	0.96	1.16	1.40	1.51
95	Nandi Hills	13.4	77.7	1479	1.29	1.16	1.02	0.89	0.83	0.86	0.87	0.90	0.96	1.08	1.13	1.24
96	Nellore	14.5	80.0	20	1.26	1.15	1.02	0.90	0.83	0.83	0.85	0.89	0.96	1.07	1.18	1.27
97	New Dehli	28.6	77.2	216	1.59	1.37	1.10	0.92	0.81	0.79	0.80	0.87	1.01	1.27	1.56	1.68
98	Niphad	20.1	74.1	550	1.39	1.24	1.05	0.90	0.81	0.81	0.87	0.90	0.96	1.13	1.33	1.44
99	Okha	22.5	69.1	7	1.51	1.31	1.08	0.90	0.80	0.79	0.83	0.88	0.99	1.21	1.45	1.52
100	Ollukara	10.5	76.3	22	1.22	1.12	1.00	0.91	0.86	0.87	0.89	0.91	0.96	1.05	1.15	1.21
101	Ootacamund	11.4	76.7	2218	1.23	1.13	1.01	0.90	0.85	0.86	0.89	0.91	0.96	1.05	1.15	1.23
102	Padegaon	18.2	74.2	556	1.40	1.24	1.05	0.90	0.81	0.81	0.86	0.89	0.97	1.13	1.33	1.44
103	Pantnagar	29.0	79.5	244	1.54	1.33	1.10	0.92	0.81	0.78	0.81	0.87	1.00	1.25	1.53	1.64
104	Parbhani	19.3	76.8	408	1.40	1.24	1.05	0.90	0.81	0.81	0.86	0.89	0.97	1.14	1.33	1.44
105	Patna	25.5	85.3	52	1.49	1.30	1.08	0.91	0.81	0.79	0.82	0.87	0.99	1.19	1.44	1.56
106	Pattambi	10.8	76.2	25	1.23	1.13	1.01	0.90	0.85	0.87	0.89	0.90	0.96	1.05	1.17	1.25
107	Port Blair	11.7	92.7	79	1.20	1.12	1.01	0.91	0.89	0.90	0.91	0.93	0.96	1.03	1.14	1.21
108	Pune	18.5	73.9	563	1.38	1.23	1.05	0.90	0.81	0.81	0.87	0.89	0.96	1.12	1.31	1.41
109	Pusa	26.0	85.7	52	1.49	1.30	1.08	0.91	0.81	0.79	0.82	0.87	0.98	1.19	1.45	1.56
110	Raichur	16.2	77.4	389	1.33	1.20	1.03	0.90	0.82	0.83	0.86	0.89	0.96	1.10	1.26	1.34
111	Raipur (Labhandi)	21.3	81.6	289	1.42	1.26	1.06	0.90	0.81	0.82	0.85	0.89	0.97	1.15	1.37	1.47
112	Rajahmundry	17.0	81.8	111	1.32	1.19	1.03	0.90	0.82	0.83	0.85	0.89	0.96	1.09	1.25	1.34
113	Rajendranagar	17.3	78.3	543	1.35	1.21	1.04	0.90	0.81	0.83	0.85	0.89	0.96	1.11	1.28	1.37
114	Rajkot	22.3	70.8	138	1.46	1.28	1.08	0.90	0.79	0.78	0.83	0.88	0.98	1.19	1.40	1.52
115	Ranchi (Kanka)	23.4	85.3	675	1.49	1.31	1.08	0.91	0.80	0.79	0.83	0.88	0.98	1.18	1.44	1.58
116	Ratnagiri	17.0	73.3	67	1.35	1.21	1.04	0.90	0.82	0.82	0.85	0.89	0.97	1.11	1.29	1.38
117	Rehmankhera	26.8	80.8	91	1.55	1.35	1.11	0.91	0.80	0.77	0.80	0.87	1.00	1.24	1.50	1.65
118	Saharanpur	30.0	77.6	275	1.58	1.38	1.12	0.92	0.80	0.77	0.80	0.87	1.02	1.28	1.57	1.68
119	Samalkot	17.1	82.2	9	1.33	1.20	1.03	0.90	0.82	0.82	0.85	0.88	0.96	1.09	1.26	1.36
120	Satna	24.6	80.8	317	1.53	1.33	1.10	0.91	0.79	0.76	0.82	0.87	0.99	1.24	1.49	1.62
121	Shahjanhanpur	27.9	79.9	155	1.57	1.35	1.10	0.92	0.80	0.78	0.81	0.87	1.00	1.24	1.52	1.63
122	Shakkarnagar	18.7	77.8	381	1.37	1.22	1.04	0.90	0.81	0.82	0.88	0.90	0.96	1.12	1.30	1.40
123	Shillong	25.6	91.9	1598	1.44	1.30	1.08	0.91	0.82	0.83	0.84	0.88	0.97	1.16	1.37	1.50
124	Silicuri	24.8	92.9	40	1.44	1.26	1.06	0.91	0.83	0.82	0.83	0.88	0.97	1.15	1.37	1.50
125	Sindewahi	20.3	79.7	222	1.42	1.25	1.06	0.90	0.80	0.82	0.86	0.89	0.97	1.15	1.36	1.46
126	Solapur	17.7	75.9	476	1.36	1.21	1.04	0.90	0.82	0.82	0.87	0.90	0.96	1.10	1.28	1.39
127	Srinagar	34.1	74.8	1587	1.44	1.30	1.10	0.92	0.81	0.76	0.78	0.87	1.05	1.34	1.64	1.63
128	Surat	21.2	72.9	11	1.42	1.25	1.06	0.90	0.80	0.80	0.86	0.89	0.97	1.16	1.36	1.47
129	Thirthahalli	13.7	75.3	628	1.28	1.16	1.02	0.90	0.83	0.86	0.89	0.91	0.96	1.06	1.21	1.30
130	Tiruchchirappalli	10.8	78.7	88	1.23	1.14	1.01	0.90	0.82	0.80	0.83	0.87	0.96	1.07	1.17	1.23
131	Titabar	26.6	94.2	99	1.45	1.26	1.06	0.91	0.84	0.82	0.83	0.87	0.98	1.16	1.39	1.50
132	Titlagarh	20.3	83.3	211	1.43	1.26	1.07	0.90	0.80	0.78	0.82	0.87	0.97	1.15	1.34	1.48
133	Tocklai	26.8	94.2	87	1.42	1.23	1.06	0.91	0.84	0.82	0.82	0.87	0.98	1.14	1.37	1.47
134	Trivandrum	8.5	77.0	64	1.19	1.11	1.00	0.91	0.85	0.85	0.86	0.89	0.96	1.04	1.13	1.20
135	Tuticorin	8.8	78.2	4	1.21	1.12	1.00	0.90	0.83	0.80	0.82	0.87	0.96	1.06	1.16	1.20
136	Udaipur	24.6	73.7	582	1.54	1.33	1.10	0.91	0.79	0.77	0.83	0.88	0.99	1.23	1.49	1.60
137	Varanasi	25.5	82.9	85	1.52	1.32	1.09	0.91	0.80	0.78	0.81	0.87	0.99	1.22	1.46	1.59
138	Vasad	22.5	73.1	34	1.45	1.27	1.07	0.90	0.80	0.79	0.85	0.89	0.97	1.18	1.38	1.49
139	Vedasandur	10.5	78.0	76	1.22	1.13	1.01	0.90	0.84	0.82	0.84	0.88	0.96	1.06	1.15	1.20
140	Vellore	12.9	79.2	214	1.23	1.13	1.01	0.90	0.83	0.82	0.85	0.89	0.96	1.06	1.16	1.24
141	Venguria	15.9	73.6	9	1.33	1.19	1.04	0.90	0.82	0.84	0.87	0.89	0.96	1.09	1.25	1.37
142	Veraval	20.9	70.4	8	1.45	1.28	1.07	0.90	0.79	0.77	0.83	0.88	0.98	1.18	1.39	1.51
143	Viramgam	23.1	72.2	27	1.50	1.31	1.08	0.90	0.79	0.77	0.83	0.88	0.99	1.21	1.44	1.56
144	Vishakhapatnam	17.7	83.2	3	1.36	1.22	1.04	0.90	0.81	0.82	0.85	0.88	0.97	1.11	1.29	1.39
145	Vittal	13.0	75.4	91	1.27	1.16	1.02	0.90	0.82	0.86	0.89	0.90	0.96	1.07	1.21	1.29

St#	Station Name	Lat (N)	Long (E)	Elev (m)	Daily Global Radiation Tilt Factors - Optimal											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Aduthurai	11.0	79.5	19	1.22	1.13	1.02	1.00	1.02	1.02	1.02	1.01	1.00	1.06	1.16	1.21
2	Agartala	23.9	91.3	16	1.39	1.24	1.08	1.01	0.98	0.98	0.98	1.00	1.02	1.15	1.36	1.45
3	Agra	27.2	78.1	169	1.58	1.36	1.13	1.02	0.98	0.96	0.97	1.00	1.05	1.26	1.53	1.66
4	Ahmadabad	23.1	72.6	55	1.49	1.30	1.09	1.01	0.98	0.97	0.98	1.00	1.03	1.20	1.43	1.56
5	Akola	20.7	77.0	282	1.44	1.26	1.07	1.00	0.98	0.98	0.99	1.00	1.01	1.15	1.36	1.47
6	Aligarh (Kalai)	27.9	78.1	187	1.60	1.38	1.12	1.02	0.98	0.96	0.97	1.00	1.06	1.26	1.56	1.69
7	Allahabad	25.5	81.7	98	1.52	1.33	1.11	1.01	0.98	0.97	0.98	1.00	1.04	1.23	1.48	1.61
8	Amini Divi	11.1	72.7	4	1.19	1.11	1.02	1.00	1.01	1.01	1.01	1.00	1.00	1.04	1.14	1.20
9	Amritsar	31.6	74.9	234	1.63	1.39	1.15	1.03	0.98	0.95	0.97	1.00	1.08	1.31	1.61	1.73
10	Anakapalle	17.7	83.0	10	1.35	1.20	1.06	1.00	0.99	0.99	0.99	1.00	1.01	1.10	1.27	1.38
11	Annamalaimagar	11.4	79.7	6	1.23	1.13	1.03	1.00	1.01	1.02	1.01	1.01	1.00	1.06	1.15	1.22
12	Babbur (Hiriyur)	14.0	76.6	610	1.28	1.17	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.08	1.21	1.30
13	Bahadrabad	29.9	78.1	275	1.61	1.38	1.14	1.03	0.98	0.96	0.97	1.00	1.06	1.29	1.59	1.69
14	Bangalor	13.0	77.6	897	1.25	1.15	1.03	1.00	1.01	1.01	1.01	1.00	1.00	1.06	1.18	1.25
15	Barmer	25.8	71.4	194	1.57	1.35	1.13	1.02	0.97	0.96	0.97	1.00	1.06	1.26	1.51	1.64
16	Baroda	22.3	73.3	34	1.46	1.28	1.08	1.01	0.98	0.97	0.99	1.00	1.02	1.18	1.40	1.52
17	Barrakpore	22.8	88.4	9	1.43	1.26	1.08	1.01	0.98	0.98	0.98	1.00	1.02	1.15	1.39	1.45
18	Bellary	15.2	76.9	449	1.31	1.18	1.04	1.00	1.00	1.00	1.00	1.00	1.01	1.09	1.23	1.33
19	Berhampore	24.1	88.3	19	1.50	1.30	1.10	1.01	0.98	0.97	0.98	1.00	1.02	1.19	1.43	1.57
20	Bhavnagar	21.8	72.2	5	1.46	1.27	1.08	1.01	0.98	0.98	0.99	1.00	1.02	1.18	1.41	1.50
21	Bhopal	23.3	77.4	503	1.52	1.32	1.10	1.01	0.98	0.97	0.98	1.00	1.03	1.21	1.45	1.56
22	Bhubaneswar	20.3	85.9	26	1.41	1.25	1.07	1.00	0.99	0.98	0.99	1.00	1.02	1.14	1.34	1.47
23	Bhuj	23.3	69.7	80	1.49	1.30	1.09	1.01	0.98	0.97	0.98	1.00	1.03	1.20	1.43	1.55
24	Bikaner	28.0	73.3	224	1.64	1.39	1.15	1.02	0.97	0.95	0.96	1.00	1.08	1.30	1.56	1.71
25	Bikramganj	25.2	84.3	87	1.47	1.29	1.10	1.01	0.98	0.97	0.98	1.00	1.03	1.19	1.42	1.52
26	Bombay	19.1	72.9	14	1.39	1.23	1.07	1.00	0.99	0.99	0.99	1.00	1.01	1.14	1.34	1.44
27	Calcutta	22.7	88.5	6	1.41	1.25	1.08	1.01	0.98	0.98	0.98	1.00	1.02	1.14	1.35	1.46
28	Car Nicobar	9.2	92.8	10	1.14	1.08	1.01	1.00	1.01	1.01	1.01	1.01	1.00	1.02	1.09	1.16
29	Chandigarh	30.7	76.9	347	1.62	1.37	1.14	1.03	0.98	0.96	0.97	1.00	1.07	1.29	1.58	1.67
30	Chaubattia	29.8	79.7	1962	1.53	1.33	1.13	1.02	0.98	0.96	0.98	0.99	1.04	1.24	1.53	1.65
31	Chinsurah	22.9	88.4	9	1.48	1.28	1.09	1.01	0.98	0.97	0.98	1.00	1.03	1.17	1.41	1.54
32	Coimbatore	11.0	77.0	431	1.22	1.13	1.03	1.00	1.01	1.02	1.01	1.01	1.00	1.06	1.16	1.23
33	Cuddappah	14.5	78.8	130	1.28	1.17	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.07	1.20	1.30
34	Cuttack	20.5	85.9	24	1.41	1.24	1.07	1.00	0.99	0.98	0.99	1.00	1.01	1.13	1.34	1.46
35	Dehra Dun	30.3	78.0	683	1.60	1.36	1.15	1.03	0.98	0.96	0.97	1.00	1.07	1.29	1.59	1.72
36	Dharwar	15.4	75.1	679	1.32	1.18	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.08	1.24	1.34
37	Dhulia	20.9	74.8	245	1.41	1.24	1.07	1.00	0.98	0.98	0.99	1.00	1.02	1.16	1.35	1.44
38	Dibrugarh (Mohanbari)	27.5	95.0	111	1.42	1.22	1.08	1.01	0.98	0.97	0.98	1.00	1.03	1.17	1.41	1.53
39	Gannavaram	16.5	80.8	24	1.33	1.20	1.05	1.00	1.00	1.00	1.00	1.00	1.01	1.10	1.25	1.34
40	Gauhati	26.1	91.6	54	1.48	1.30	1.10	1.01	0.98	0.97	0.98	1.00	1.03	1.19	1.44	1.57
41	Goa	15.5	73.8	55	1.31	1.19	1.04	1.00	1.00	1.00	1.00	1.00	1.01	1.10	1.26	1.35
42	Golegaon	19.3	76.5	402	1.40	1.23	1.06	1.00	0.99	0.99	0.99	1.00	1.01	1.12	1.34	1.44
43	Gopalpur	19.3	84.9	17	1.40	1.24	1.07	1.00	0.99	0.98	0.99	1.00	1.02	1.13	1.32	1.45
44	Gorakhpur	27.0	83.5	79	1.49	1.32	1.11	1.02	0.98	0.97	0.97	1.00	1.04	1.20	1.46	1.56
45	Guna	24.7	77.3	478	1.52	1.32	1.11	1.01	0.98	0.96	0.98	1.00	1.04	1.23	1.47	1.59
46	Gurdaspur	32.1	76.4	267	1.60	1.39	1.14	1.03	0.98	0.95	0.97	1.00	1.08	1.32	1.64	1.76
47	Gwalior	26.2	78.3	207	1.57	1.36	1.12	1.02	0.98	0.96	0.97	1.00	1.05	1.25	1.53	1.65
48	Hagari	15.2	77.1	413	1.29	1.18	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.07	1.22	1.31
49	Hansi-	29.1	76.0	217	1.58	1.35	1.13	1.02	0.98	0.96	0.97	1.00	1.06	1.27	1.55	1.65
50	Hanumangarh	29.5	74.3	221	1.59	1.38	1.14	1.02	0.98	0.96	0.97	1.00	1.07	1.29	1.57	1.68
51	Haringhata	22.9	88.5	10	1.43	1.27	1.09	1.01	0.98	0.98	0.98	1.00	1.03	1.17	1.38	1.45
52	Hebbal	13.0	77.6	889	1.27	1.16	1.03	1.00	1.01	1.01	1.01	1.00	1.00	1.07	1.20	1.26
53	Hissar	29.2	75.8	221	1.62	1.39	1.15	1.02	0.98	0.96	0.97	1.00	1.08	1.29	1.60	1.74
54	Hoshangabad (Powerkhera)	22.8	77.8	302	1.48	1.30	1.09	1.01	0.98	0.97	0.99	1.00	1.02	1.18	1.42	1.56
55	Hunsur	12.3	76.1	826	1.26	1.15	1.03	1.00	1.01	1.01	1.01	1.00	1.00	1.06	1.20	1.26
56	Hyderabad	17.5	78.5	545	1.35	1.21	1.05	1.00	0.99	0.99	0.99	1.00	1.01	1.11	1.28	1.37
57	Ibrahimpatan	17.1	78.7	610	1.34	1.21	1.06	1.00	0.99	0.99	0.99	1.00	1.01	1.10	1.28	1.36
58	Imphal	24.8	93.9	781	1.50	1.30	1.10	1.01	0.98	0.97	0.98	1.00	1.03	1.17	1.42	1.56
59	Indore	130.8	0.0		1.48	1.29	1.09	1.01	0.98	0.97	0.99	1.00	1.02	1.19	1.42	1.53
60	Jabalpur (Adhartal)	23.2	80.0	411	1.47	1.31	1.09	1.01	0.98	0.97	0.98	1.00	1.03	1.19	1.42	1.55
61	Jagadalpur	19.1	82.0	553	1.38	1.22	1.07	1.00	0.99	0.99	0.99	1.00	1.01	1.11	1.30	1.41
62	Jaipur	26.8	75.8	390	1.60	1.37	1.13	1.02	0.98	0.96	0.97	1.00	1.06	1.27	1.56	1.70
63	Jaisalmer	26.9	70.9	231	1.63	1.39	1.14	1.02	0.97	0.95	0.96	1.00	1.07	1.29	1.56	1.70
64	Jalgaon	21.1	75.6	201	1.44	1.26	1.08	1.00	0.98	0.98	0.99	1.00	1.01	1.17	1.37	1.49
65	Jammu	32.7	74.8	367	1.64	1.38	1.16	1.03	0.98	0.95	0.97	1.00	1.09	1.33	1.58	1.73
66	Jamnagar	22.5	70.0	21	1.46	1.28	1.09	1.01	0.98	0.98	0.99	1.00	1.03	1.19	1.41	1.53
67	Jharsuguda	21.9	84.1	230	1.43	1.29	1.08	1.01	0.98	0.98	0.98	1.00	1.02	1.18	1.37	1.48
68	Jobner	27.0	75.1	427	1.59	1.37	1.14	1.02	0.98	0.96	0.97	1.00	1.06	1.26	1.54	1.70
69	Jodhpur	26.3	73.0	224	1.59	1.37	1.12	1.02	0.98	0.96	0.97	1.00	1.06	1.26	1.54	1.68
70	Jullundur	31.4	75.6	238	1.65	1.40	1.15	1.03	0.98	0.95	0.97	1.00	1.08	1.31	1.62	1.76
71	Kanniyakumari	8.1	77.5	37	1.19	1.11	1.02	1.01	1.03	1.03	1.03	1.01	1.00	1.05	1.14	1.18
72	Karimganj	24.7	92.5	16	1.45	1.26	1.08	1.01	0.98	0.98	0.98	1.00	1.03	1.16	1.38	1.52
73	Karjat	18.9	73.3	52	1.36	1.22	1.06	1.00	0.99	0.99	1.00	1.00	1.01	1.11	1.30	1.40
74	Kasargod	12.5	75.0	11	1.26	1.15	1.03	1.00	1.01	1.01	1.01	1.00	1.00	1.07	1.21	1.29
75	Kayamgulam	9.1	76.5	3	1.21	1.12	1.02	1.00	1.02	1.02	1.02	1.01	1.00	1.05	1.15	1.22

St#	Station Name	Lat (N)	Long (E)	Elev (m)	Daily Global Radiation Tilt Factors - Optimal											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
76	Kodaikanal	10.2	77.5	2345	1.21	1.12	1.02	1.00	1.02	1.02	1.01	1.01	1.00	1.03	1.12	1.20
77	Kolhapur	16.7	74.2	570	1.34	1.20	1.05	1.00	1.00	0.99	1.00	1.00	1.01	1.09	1.27	1.37
78	Kondul	7.5	93.7	8	1.12	1.05	1.01	1.00	1.02	1.02	1.02	1.01	1.00	1.01	1.08	1.12
79	Kota	25.2	75.5	257	1.58	1.36	1.12	1.01	0.98	0.96	0.98	1.00	1.05	1.24	1.50	1.65
80	Kottayam	9.5	76.5	73	1.22	1.12	1.02	1.00	1.02	1.02	1.02	1.01	1.00	1.04	1.15	1.21
81	Kovilpatti	9.2	77.9	92	1.19	1.11	1.02	1.00	1.02	1.03	1.02	1.01	1.00	1.05	1.14	1.19
82	Kuthulia	24.5	81.3	366	1.53	1.34	1.11	1.01	0.98	0.97	0.98	1.00	1.04	1.23	1.50	1.59
83	Leh	34.2	77.6	3514	1.70	1.43	1.17	1.04	0.98	0.95	0.96	1.01	1.13	1.40	1.77	1.85
84	Lucknow	26.8	80.9	128	1.57	1.36	1.12	1.02	0.98	0.96	0.97	1.00	1.05	1.25	1.50	1.64
85	Madhipura	25.8	86.7	42	1.51	1.32	1.11	1.01	0.98	0.97	0.98	1.00	1.04	1.21	1.48	1.60
86	Madras	13.0	80.2	16	1.24	1.15	1.03	1.00	1.01	1.01	1.01	1.00	1.00	1.07	1.17	1.24
87	Mandya	12.5	76.8	695	1.26	1.16	1.03	1.00	1.01	1.01	1.01	1.00	1.00	1.07	1.20	1.27
88	Mangalore	12.9	74.9	102	1.27	1.15	1.03	1.00	1.01	1.01	1.00	1.00	1.00	1.07	1.21	1.28
89	Minicoy	8.3	73.0	2	1.17	1.10	1.01	1.00	1.02	1.02	1.02	1.01	1.00	1.04	1.13	1.17
90	Musaffarnagar	29.5	77.7	240	1.61	1.37	1.14	1.02	0.98	0.96	0.97	1.00	1.06	1.27	1.56	1.69
91	Nagina	29.9	78.4	249	1.60	1.37	1.14	1.02	0.98	0.96	0.97	1.00	1.06	1.27	1.56	1.68
92	Nagpur	21.2	79.1	311	1.45	1.27	1.08	1.00	0.98	0.98	0.99	1.00	1.02	1.17	1.39	1.50
93	Nagrakata	26.9	88.9	229	1.52	1.29	1.10	1.01	0.98	0.97	0.98	1.00	1.03	1.21	1.49	1.62
94	Nagrifarm	26.9	88.2	1158	1.41	1.22	1.08	1.01	0.98	0.98	0.98	0.99	1.02	1.16	1.40	1.51
95	Nandi Hills	13.4	77.7	1479	1.29	1.16	1.04	1.00	1.01	1.01	1.00	1.00	1.00	1.08	1.13	1.24
96	Nellore	14.5	80.0	20	1.26	1.15	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.07	1.18	1.27
97	New Dehli	28.6	77.2	216	1.59	1.37	1.13	1.02	0.98	0.96	0.97	1.00	1.06	1.27	1.56	1.68
98	Niphad	20.1	74.1	550	1.39	1.24	1.07	1.00	0.99	0.98	0.99	1.00	1.01	1.13	1.33	1.44
99	Okha	22.5	69.1	7	1.51	1.31	1.10	1.01	0.98	0.97	0.98	1.00	1.04	1.21	1.45	1.52
100	Ollukara	10.5	76.3	22	1.22	1.12	1.02	1.00	1.01	1.01	1.01	1.01	1.00	1.05	1.15	1.21
101	Ootacamund	11.4	76.7	2218	1.23	1.13	1.03	1.00	1.01	1.01	1.01	1.00	1.00	1.05	1.15	1.23
102	Padegaon	18.2	74.2	556	1.40	1.24	1.07	1.00	0.99	0.98	0.99	1.00	1.01	1.13	1.33	1.44
103	Pantnagar	29.0	79.5	244	1.54	1.33	1.12	1.02	0.98	0.96	0.97	1.00	1.05	1.25	1.53	1.64
104	Parbhani	19.3	76.8	408	1.40	1.24	1.07	1.00	0.99	0.99	0.99	1.00	1.01	1.14	1.33	1.44
105	Patna	25.5	85.3	52	1.49	1.30	1.10	1.01	0.98	0.97	0.98	1.00	1.03	1.19	1.44	1.56
106	Pattambi	10.8	76.2	25	1.23	1.13	1.02	1.00	1.01	1.01	1.01	1.01	1.00	1.05	1.17	1.25
107	Port Blair	11.7	92.7	79	1.20	1.12	1.02	1.00	1.01	1.01	1.01	1.00	1.00	1.03	1.14	1.21
108	Pune	18.5	73.9	563	1.38	1.23	1.06	1.00	0.99	0.99	0.99	1.00	1.01	1.12	1.31	1.41
109	Pusa	26.0	85.7	52	1.49	1.30	1.10	1.01	0.98	0.97	0.98	1.00	1.03	1.19	1.45	1.56
110	Raichur	16.2	77.4	389	1.33	1.20	1.05	1.00	1.00	1.00	1.00	1.00	1.01	1.10	1.26	1.34
111	Raipur (Labhandi)	21.3	81.6	289	1.42	1.26	1.07	1.00	0.98	0.98	0.99	1.00	1.02	1.15	1.37	1.47
112	Rajahmundry	17.0	81.8	111	1.32	1.19	1.05	1.00	0.99	0.99	1.00	1.00	1.01	1.09	1.25	1.34
113	Rajendranagar	17.3	78.3	543	1.35	1.21	1.05	1.00	0.99	0.99	0.99	1.00	1.01	1.11	1.28	1.37
114	Rajkot	22.3	70.8	138	1.46	1.28	1.09	1.01	0.98	0.97	0.98	1.00	1.03	1.19	1.40	1.52
115	Ranchi (Kanka)	23.4	85.3	675	1.49	1.31	1.10	1.01	0.98	0.97	0.98	1.00	1.03	1.18	1.44	1.58
116	Ratnagiri	17.0	73.3	67	1.35	1.21	1.06	1.00	0.99	0.99	1.00	1.00	1.01	1.11	1.29	1.38
117	Rehmankhera	26.8	80.8	91	1.55	1.35	1.13	1.02	0.98	0.96	0.97	1.00	1.05	1.24	1.50	1.65
118	Saharanpur	30.0	77.6	275	1.58	1.38	1.14	1.03	0.98	0.96	0.97	1.00	1.07	1.28	1.57	1.68
119	Samalkot	17.1	82.2	9	1.33	1.20	1.05	1.00	0.99	0.99	1.00	1.00	1.01	1.09	1.26	1.36
120	Satna	24.6	80.8	317	1.53	1.33	1.12	1.01	0.98	0.96	0.98	1.00	1.04	1.24	1.49	1.62
121	Shahjanhanpur	27.9	79.9	155	1.57	1.35	1.12	1.02	0.98	0.96	0.97	1.00	1.05	1.24	1.52	1.63
122	Shakkarnagar	18.7	77.8	381	1.37	1.22	1.06	1.00	0.99	0.99	0.99	1.00	1.01	1.12	1.30	1.40
123	Shillong	25.6	91.9	1598	1.44	1.30	1.10	1.01	0.98	0.98	0.98	1.00	1.03	1.16	1.37	1.50
124	Silicuri	24.8	92.9	40	1.44	1.26	1.09	1.01	0.98	0.98	0.98	1.00	1.03	1.15	1.37	1.50
125	Sindewahi	20.3	79.7	222	1.42	1.25	1.07	1.00	0.99	0.98	0.99	1.00	1.01	1.15	1.36	1.46
126	Solapur	17.7	75.9	476	1.36	1.21	1.06	1.00	0.99	0.99	1.00	1.00	1.01	1.10	1.28	1.39
127	Srinagar	34.1	74.8	1587	1.44	1.30	1.13	1.03	0.98	0.95	0.96	1.01	1.10	1.34	1.64	1.63
128	Surat	21.2	72.9	11	1.42	1.25	1.07	1.00	0.98	0.98	0.99	1.00	1.02	1.16	1.36	1.47
129	Thirthahalli	13.7	75.3	628	1.28	1.16	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.06	1.21	1.30
130	Tiruchchirappalli	10.8	78.7	88	1.23	1.14	1.03	1.00	1.02	1.02	1.02	1.01	1.00	1.07	1.17	1.23
131	Titabar	26.6	94.2	99	1.45	1.26	1.08	1.01	0.98	0.97	0.98	1.00	1.03	1.16	1.39	1.50
132	Titlagarh	20.3	83.3	211	1.43	1.26	1.08	1.00	0.98	0.98	0.99	1.00	1.02	1.15	1.34	1.48
133	Tocklai	26.8	94.2	87	1.42	1.23	1.09	1.01	0.98	0.97	0.98	1.00	1.03	1.14	1.37	1.47
134	Trivandrum	8.5	77.0	64	1.19	1.11	1.02	1.01	1.02	1.03	1.02	1.01	1.00	1.04	1.13	1.20
135	Tuticorin	8.8	78.2	4	1.21	1.12	1.02	1.01	1.03	1.04	1.03	1.02	1.00	1.06	1.16	1.20
136	Udaipur	24.6	73.7	582	1.54	1.33	1.11	1.01	0.98	0.97	0.98	1.00	1.04	1.23	1.49	1.60
137	Varanasi	25.5	82.9	85	1.52	1.32	1.11	1.01	0.98	0.97	0.98	1.00	1.04	1.22	1.46	1.59
138	Vasad	22.5	73.1	34	1.45	1.27	1.08	1.01	0.98	0.97	0.99	1.00	1.02	1.18	1.38	1.49
139	Vedasandur	10.5	78.0	76	1.22	1.13	1.02	1.00	1.02	1.02	1.02	1.01	1.00	1.06	1.15	1.20
140	Vellore	12.9	79.2	214	1.23	1.13	1.03	1.00	1.01	1.01	1.01	1.00	1.00	1.06	1.16	1.24
141	Vengurla	15.9	73.6	9	1.33	1.19	1.05	1.00	1.00	1.00	1.00	1.00	1.00	1.09	1.25	1.37
142	Veraval	20.9	70.4	8	1.45	1.28	1.09	1.00	0.98	0.98	0.99	1.00	1.03	1.18	1.39	1.51
143	Viramgam	23.1	72.2	27	1.50	1.31	1.10	1.01	0.98	0.97	0.98	1.00	1.03	1.21	1.44	1.56
144	Vishakhapatnam	17.7	83.2	3	1.36	1.22	1.05	1.00	0.99	0.99	0.99	1.00	1.01	1.11	1.29	1.39
145	Vittal	13.0	75.4	91	1.27	1.16	1.03	1.00	1.01	1.01	1.00	1.00	1.00	1.07	1.21	1.29

APPENDIX F

GLOBAL SOLAR RADIATION ON AN OPTIMALLY TILTED ARRAY (Gs)

MEAN DAILY SOLAR RADIATION ON AN OPTIMALLY TILTED ARRAY (kWh/m2)

St#	City	Lat(N)	Long(E)	Elev(m)	Mean Daily Radiation on an Optimally Tilted Surface (kWh/m2)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Aduthurai	11.0	79.5	19	6.78	7.12	6.86	6.59	6.44	5.97	5.62	5.80	6.02	5.62	5.78	5.86
2	Agartala	23.9	91.3	16	5.92	6.40	6.03	6.17	6.10	4.40	4.89	4.91	5.10	5.81	6.34	5.93
3	Agra	27.2	78.1	169	6.78	7.07	6.92	6.92	6.76	5.98	5.31	5.18	5.99	6.98	7.30	6.81
4	Ahmadabad	23.1	72.6	55	7.46	7.64	6.80	7.04	7.30	6.39	4.92	4.67	5.69	7.14	7.59	7.52
5	Akola	20.7	77.0	282	7.75	7.67	6.89	6.96	6.93	5.91	4.51	4.58	5.11	6.51	7.22	7.23
6	Aligarh (Kalai)	27.9	78.1	187	6.96	7.47	6.43	7.08	7.24	6.49	5.82	5.57	6.11	7.02	7.68	7.11
7	Allahabad	25.5	81.7	98	6.76	7.28	6.72	6.99	7.06	5.87	5.24	5.04	5.75	6.89	7.30	7.00
8	Amini Divi	11.1	72.7	4	6.10	6.40	6.40	6.04	5.03	3.97	3.82	4.27	4.95	4.87	5.39	5.60
9	Amritsar	31.6	74.9	234	5.93	6.39	6.22	6.82	7.23	6.77	6.34	6.31	6.36	6.90	6.86	6.04
10	Anakapalle	17.7	83.0	10	7.09	6.89	6.85	6.59	6.27	4.99	4.58	4.72	5.00	5.49	6.39	6.90
11	Annamalaimagar	11.4	79.7	6	6.92	7.13	7.02	6.88	6.06	6.06	5.54	5.88	6.12	5.68	5.54	5.83
12	Babbur (Hiriyur)	14.0	76.6	610	7.40	7.59	7.09	6.79	6.59	5.46	4.67	4.94	5.39	6.00	6.63	7.01
13	Bahadrabad	29.9	78.1	275	6.04	6.53	6.32	6.73	7.06	6.14	5.48	5.28	5.77	6.84	7.08	6.07
14	Bangalor	13.0	77.6	897	6.85	7.10	6.73	6.57	6.11	4.95	4.22	4.61	4.89	5.24	5.92	6.19
15	Barmer	25.8	71.4	194	7.36	7.59	7.42	7.62	7.82	7.57	6.35	6.26	7.02	7.65	7.66	7.35
16	Baroda	22.3	73.3	34	7.45	7.54	6.93	7.16	7.40	6.29	4.92	4.63	5.67	7.08	7.52	7.43
17	Barrakpore	22.8	88.4	9	6.42	6.70	6.39	6.32	6.19	4.98	4.66	4.68	4.79	5.77	6.91	5.95
18	Bellary	15.2	76.9	449	7.55	7.63	7.07	6.92	6.71	5.71	4.95	5.37	5.52	6.10	6 65	7.10
19	Berhampore	24.1	88.3	19	7.10	7.15	6.99	6.89	6.41	5.31	4.68	4.78	4.94	6.33	7.14	7.19
20	Bhavnagar	21.8	72.2	5	7.58	7.51	7.01	7.19	7.52	6.08	4.62	4.46	5.39	7.06	7.73	7.29
21	Bhopal	23.3	77.4	503	7.58	7.68	6.91	6.98	7.17	5.96	4.46	4.23	5.29	7.01	7.67	7.25
22	Bhubaneswar	20.3	85.9	26	7.36	7.51	6.97	6.91	6.95	5.52	5.04	5.14	5.42	6.25	7.08	7.54
23	Bhuj	23.3	69.7	80	7.39	7.57	6.76	6.99	7.29	6.34	5.20	5.19	6.06	7.12	7.55	7.39
24	Bikaner	28.0	73.3	224	7.31	7.46	7.34	7.64	7.88	7.74	7.00	6.83	7.33	7.75	7.49	7.20
25	Bikramganj	25.2	84.3	87	6.66	6.97	6.71	6.73	6.48	5.31	5 13	5.13	5.67	6.47	6.90	6 43
26	Bombay	19.1	72.9	14	7.12	7.17	6.75	6.81	6.84	5.44	4.36	4.45	5.10	6.45	7.14	7.13
27	Calcutta	22.7	88.5	6	6.15	6.36	6.03	6.27	6.10	4.78	4.65	4.60	4.68	5.36	6.13	6.09
28	Car Nicobar	9.2	92.8	10	5.18	5.64	5.60	5.17	4.25	3.73	3.94	4.05	4.20	4.34	4.60	5.14
29	Chandigarh	30.7	76.9	347	6.12	6.32	6.38	6.73	6.90	5.99	5.73	5.29	6.22	6.82	6.86	5.78
30	Chaubattia	29.8	79.7	1962	5.23	5.64	5.86	6.41	6.51	5.29	4.19	4.05	4.49	5.74	6.21	5.64
31	Chinsurah	22.9	88.4	9	7.30	7.27	6.88	7.00	6.78	5.43	5.10	5.17	5.40	6.24	7.19	7.35
32	Coimbatore	11.0	77.0	431	6.86	7.20	7.05	6.62	6.16	5.42	4.80	5.42	5.82	5.68	5.92	6.32
33	Cuddappah	14.5	78.8	130	6.87	7.21	7.04	6.77	6.42	5.37	4.55	4.91	5.04	5.36	5.82	6.45
34	Cuttack	20.5	85.9	24	7.25	7.22	6.59	6.55	6.79	5.17	4.59	4.82	5.00	5.98	6.97	7.24
35	Dehra Dun	30.3	78.0	683	5.74	5.98	6.29	6.55	6.81	5.82	5.09	4.81	5.69	6.62	6.71	6.07
36	Dharwar	15 4	75.1	679	7.39	7.35	6.82	6.42	6.11	4.73	3.89	4.33	4.86	5.61	6.52	7.04
37	Dhulia	20.9	74.8	245	7.02	7.09	6.72	6.79	6.92	5.76	4.64	4.50	5.42	6 67	7.06	6.75
38	Dibrugarh (Mohanbari)	27.5	95.0	111	5.20	5.00	5.37	4.83	4.99	4.49	4.69	5.22	4.59	5.38	5.96	5.72
39	Gannavaram	16.5	80.8	24	7.09	7.27	6.47	6.65	6.52	5.07	4.83	5.09	5.16	5.76	6.36	6.42
40	Gauhati	26.1	91.6	54	6.04	6.46	5.90	6.00	5.81	4.75	4.88	5.07	4.99	5.93	6.51	6.31
41	Goa	15.5	73.8	55	7.36	7.53	6.84	6.90	6.73	4.94	4.51	4.93	5.42	6.24	7.21	7.25
42	Golegaon	19.3	76.5	402	7.60	7.56	6.86	6.82	6.76	5.18	4.62	4.24	5.30	6.22	7.49	7.52
43	Gopalpur	19.3	84.9	17	7.28	7.32	7.05	6.38	6.45	5.42	4.55	4.95	5.56	5.90	6 68	7.16
44	Gorakhpur	27.0	83.5	79	6.11	6.90	6.43	6.93	7.07	6.11	5.54	5.18	5.51	6.19	6.76	6.16
45	Guna	24.7	77.3	478	7.05	7.34	7.24	7.36	6.94	6.67	5.31	5.00	5.98	7.24	7.48	7.16
46	Gurdaspur	32.1	76.4	267	5.42	6.23	5.92	6.84	7.19	6.77	6.12	6.22	6.23	7.01	7.15	6.16
47	Gwalior	26.2	78.3	207	7.02	7.44	6.93	7.15	6.98	6.37	5 09	5.01	5.92	7.01	7.65	7.10
48	Hagari	15.2	77.1	413	7.17	7.47	6.87	6.64	6.44	5.27	4.51	4.84	5.18	5.63	6.34	6.77
49	Hansi	29.1	76.0	217	6.24	6.49	6.32	6.86	6.63	5.72	5.75	5.80	6.10	6.91	7.07	6.17
50	Hanumangarh	29.5	74.3	221	6.23	6.82	6.67	6.62	6.54	5.72	6.09	6.04	6.58	7.16	7.17	6.33
51	Hanrnghata	22.9	88.5	10	6.52	7.00	6.68	6.77	6.74	5.01	5.06	5.01	5.36	6.19	6.72	5.97
52	Hebbal	13.0	77.6	889	7.37	7.60	7.10	6.90	6.53	5.45	4.79	5.08	5.36	5.71	6.47	6.41
53	Hissar	29.2	75.8	221	6.40	6.87	6.82	6.85	6.77	5.73	5.81	5.95	6.69	7.11	7.44	6.87
54	Hoshangabad (Powerkhera)	22.8	77.8	302	7.36	7.66	6.78	6.97	6.92	6.01	4.40	4.22	5.05	6.64	7.47	7.60
55	Hunsur	12.3	76.1	826	7.36	7.22	6.90	6.61	6.05	5.17	4.49	4.95	5.27	5.53	6.46	6.54
56	Hyderabad	17.5	78.5	545	7.43	7.60	6.79	6.85	6.86	5.54	4.72	5.08	5.30	6.27	6.90	7.03
57	Ibrahimpatan	17.1	78.7	610	7.26	7.61	7.19	6.81	6.34	5.31	5.06	4.89	5.40	5.98	6.94	6.84
58	Imphal	24.8	93.9	781	6.89	6.92	6.70	6.70	5.74	4.75	4.60	4.81	4.92	5.67	6.62	6.80
59	Indore	22.7	75.8	567	7.56	7.68	6.99	7.17	7.35	5.99	4.56	4.25	5.30	7.03	7.60	7.30
60	Jabalpur (Adhartal)	23.2	80.0	411	6.72	7.51	6.57	6.71	6 32	5.40	4.25	4.28	5.18	6.39	6.99	7.01
61	Jagadalpur	19.1	82.0	553	7.20	7.26	7.06	6.82	6.44	5.28	4.26	4.31	4.73	5.85	6.64	6.98
62	Jaipur	26.8	75.8	390	7.33	7.58	6.98	7.07	7.00	6.08	5.18	5.19	6.31	7.52	7.96	7.58
63	Jaisalmer	26.9	70.9	231	7.51	7.73	7.40	7.63	7.87	7.83	7.14	7.08	7.29	7.82	7.80	7.41
64	Jalgaon	21.1	75.6	201	7.50	7.52	6.93	7.01	7.07	6.04	4.73	4.79	5.20	6.88	7.36	7.41
65	Jammu	32.7	74.8	367	5.66	5.88	6.24	6.55	7.55	7.56	6.09	6.19	6.67	7.01	6.11	5.64
66	Jamnagar	22.5	70.0	21	7.17	7.32	6.94	7.08	7.18	5.85	4.63	4.46	5.82	7.01	7.42	7.24
67	Jharsuguda	21.9	84.1	230	6.74	7.60	6.40	6.77	6.86	5.05	4.66	4.49	5.32	6.76	6.74	6.66
68	Jobner	27.0	75.1	427	7.28	7.58	7.52	7.40	7.14	6.75	6.14	5.82	6.78	7.30	7.79	7.65
69	Jodhpur	26.3	73.0	224	7.43	7.69	6.93	7.23	7.37	6.90	6.06	6.05	6.61	7.50	7.85	7.58
70	Jullundur	31.4	75.6	238	6.25	6.62	6.42	6.87	7.31	6.94	6.26	6.13	6.27	7.02	7.10	6.41
71	Kanniyakumari	8.1	77.5	37	7.00	7.10	6.87	6.29	5.80	5.48	5.58	5.50	5.99	5.97	6.11	5.99
72	Karimganj	24.7	92.5	16	6.51	6.46	6.18	5.96	5.64	4.66	4.62	4.86	5.12	5.80	6.43	6.67
73	Karjat	18.9	73.3	52	6.95	7.16	6.66	6.66	6.54	4.87	3.84	3.93	4.51	5.97	6.76	6.80

MEAN DAILY SOLAR RADIATION ON AN OPTIMALLY TILTED ARRAY (kWh/m2)

St#	City	Lat(N)	Long(E)	Elev(m)	Mean Daily Radiation on an Optimally Tilted Surface (kWh/m2) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
74	Kasargod	12.5	75.0	11	7.28	7.35	6.88	6.71	5.99	4.40	4.03	4.70	5.31	5.79	6.68	7.04
75	Kayamgulam	9.1	76.5	3	7.48	7.47	7.13	6.66	5.92	4.92	4.97	5.44	5.74	5.94	6.43	6.93
76	Kodaikanal	10.2	77.5	2345	7.30	7.59	7.10	6.64	6.14	5.14	4.53	5.00	5.13	5.03	5.44	6.23
77	Kolhapur	16.7	74.2	570	7.38	7.56	7.25	6.94	6.64	5.40	4.60	4.55	5.27	5.74	6.81	7.19
78	Kondul	7.5	93.7	8	5.17	4.85	5.05	4.85	4.34	3.85	3.92	3.97	4.00	3.91	4.51	4.68
79	Kota	25.2	75.5	257	7.69	7.90	7.16	7.24	7.46	6.72	5.40	5.15	6.16	7.30	7.73	7.71
80	Kottayam	9.5	76.5	73	7.58	7.37	7.05	6.48	5.97	5.12	4.60	5.10	5.66	5.38	6.24	6.49
81	Kovilpatti	9.2	77.9	92	6.79	7.02	6.79	6.37	6.25	6.00	5.68	5.93	6.00	5.67	5.89	6.09
82	Kuthulia	24.5	81.3	366	7.01	7.54	7.03	7.14	7.10	5.90	4.75	5.06	5.76	7.06	7.77	6.90
83	Leh	34.2	77.6	3514	5.66	6.13	6.26	6.98	7.46	7.97	7.67	7.24	7.68	7.62	7.54	6.01
84	Lucknow	26.8	80.9	128	6.99	7.38	6.69	6.90	7.00	5.82	5.34	5.33	5.80	7.05	7.17	6.89
85	Madhipura	25.8	86.7	42	6.45	6.93	6.73	6.54	6.59	5.65	5.03	5.42	5.35	6.45	7.24	6.82
86	Madras	13.0	80.2	16	6.67	7.23	6.79	6.72	6.38	5.58	5.09	5.28	5.41	5.50	5.67	5.84
87	Mandya	12.5	76.8	695	7.14	7.54	7.07	6.87	6.46	5.51	4.80	5.01	5.52	5.80	6.46	6.72
88	Mangalore	12.9	74.9	102	7.39	7.33	6.56	6.45	6.08	4.28	3.70	4.33	4.99	5.63	6.69	6.86
89	Minicoy	8.3	73.0	2	6.38	6.50	5.98	5.71	5.11	4.28	4.26	4.94	4.89	5.20	5.73	5.62
90	Musaffarnagar	29.5	77.7	240	6.63	6.81	6.68	6.97	7.17	6.55	5.86	5.59	6.08	6.91	7.16	6.54
91	Nagina	29.9	78.4	249	6.30	6.62	6.59	6.82	7.15	6.40	5.54	5.53	5.84	6.78	7.00	6.25
92	Nagpur	21.2	79.1	311	7.28	7.42	6.67	6.69	6.75	5.40	4.29	4.30	5.01	6.53	7.33	7.22
93	Nagrakata	26.9	88.9	229	6.14	5.92	5.90	5.75	5.58	4.52	4.33	4.58	4.73	6.01	6.85	6.58
94	Nagrifarm	26.9	88.2	1158	5.05	4.94	5.42	5.15	4.97	4.02	3.81	4.13	4.06	5.31	5.82	5.51
95	Nandi Hills	13.4	77.7	1479	7.84	7.49	7.38	7.19	6.27	4.58	4.31	4.48	4.60	5.98	4.63	5.79
96	Nellore	14.5	80.0	20	6.58	6.88	6.93	6.61	6.18	5.05	4.58	5.03	5.31	5.40	5.51	5.98
97	New Dehli	28.6	77.2	216	6.46	6.95	6.33	6.63	6.48	5.59	5.44	5.53	5.91	6.96	7.35	6.64
98	Niphad	20.1	74.1	550	7.26	7.51	7.03	6.96	7.04	5.97	4.53	4.55	5.16	6.43	7.16	7.21
99	Okha	22.5	69.1	7	7.25	7.43	6.72	6.79	6.81	5.74	4.82	4.84	6.04	7.08	7.42	6.57
100	Ottukara	10.5	76.3	22	7.04	6.99	6.60	6.19	5.30	4.43	4.01	4.34	4.85	5.28	6.01	6.17
101	Ootacamund	11.4	76.7	2218	7.31	7.31	7.01	6.54	5.99	4.96	4.25	4.73	5.03	5.34	5.92	6.47
102	Padegaon	18.2	74.2	556	7.38	7.48	6.90	6.77	6.80	5.72	4.59	4.82	5.27	6.28	7.01	7.17
103	Pantnagar	29.0	79.5	244	5.90	6.32	6.31	6.70	6.90	5.91	5.28	5.31	5.74	6.68	6.96	6.23
104	Parbhani	19.3	76.8	408	7.76	7.80	7.08	7.02	6.92	5.94	4.75	4.92	5.38	6.67	7.43	7.53
105	Patna	25.5	85.3	52	6.68	6.96	6.62	6.77	7.06	6.05	5.45	5.53	5.61	6.43	7.01	6.74
106	Pattambi	10.8	76.2	25	7.20	7.18	6.72	6.43	5.53	4.14	3.83	4.67	5.32	5.37	6.25	6.76
107	Port Blair	11.7	92.7	79	5.93	6.44	6.02	5.80	4.27	3.50	3.51	3.58	3.69	4.47	5.28	5.61
108	Pune	18.5	73.9	563	7.34	7.50	6.92	6.92	6.92	5.68	4.53	4.68	5.25	6.27	7.01	7.09
109	Pusa	26.0	85.7	52	6.59	6.81	6.39	6.59	6.84	5.92	5.20	5.23	5.35	6.31	7.00	6.65
110	Raichur	16.2	77.4	389	7.55	7.69	7.19	6.89	6.78	5.43	4.63	4.99	5.19	6.24	6.87	6.93
111	Raipur (Labhandi)	21.3	81.6	289	6.94	7.18	6.42	6.40	6.51	5.08	4.32	4.49	5.06	6.18	7.12	6.88
112	Rajahmundry	17.0	81.8	111	6.82	6.95	6.60	6.58	6.32	4.89	4.66	4.80	4.94	5.41	6.33	6.46
113	Rajendranagar	17.3	78.3	543	7.48	7.65	6.92	6.81	6.78	5.39	4.88	5.12	5.43	6.27	7.05	7.04
114	Rajkot	22.3	70.8	138	7.29	7.42	7.22	7.36	7.35	6.16	5.06	5.00	5.92	7.07	7.34	7.24
115	Ranchi (Kanka)	23.4	85.3	675	7.36	7.70	7.19	7.14	7.00	5.86	4.72	4.95	5.29	6.36	7.68	7.73
116	Ratnagiri	17.0	73.3	67	7.21	7.27	7.04	6.81	6.32	5.31	4.60	4.85	5.49	6.01	6.88	7.02
117	Rehmankhera	26.8	80.8	91	6.67	7.16	7.03	7.01	6.93	6.16	5.61	5.61	6.04	6.86	7.02	6.96
118	Saharanpur	30.0	77.6	275	6.02	6.76	6.58	6.96	7.11	6.52	5.81	5.56	6.15	6.85	7.07	6.25
119	Samalkot	17.1	82.2	9	7.04	7.20	6.72	6.73	6.46	5.09	4.78	4.96	5.02	5.52	6.38	6.72
120	Satna	24.6	80.8	317	6.98	7.35	7.27	7.27	7.47	6.34	5.00	4.90	5.76	7.23	7.55	7.35
121	Shahjanhanpur	27.9	79.9	155	6.77	7.11	6.61	7.08	7.36	6.25	5.42	5.40	5.75	6.81	7.33	6.62
122	Shakkarnagar	18.7	77.8	381	7.29	7.37	6.84	6.70	6.69	5.47	4.23	4.52	4.94	6.16	6.93	7.03
123	Shillong	25.6	91.9	1598	5.24	6.18	5.87	5.75	5.45	4.17	4.10	4.14	4.31	4.94	5.18	5.24
124	Silicuri	24.8	92.9	40	6.31	6.33	6.22	6.07	5.67	4.81	4.94	5.02	5.12	5.50	6.15	6.27
125	Sindewahi	20.3	79.7	222	7.36	7.54	6.85	6.82	7.08	5.34	4.40	4.50	5.09	6.59	7.38	7.21
126	Solapur	17.7	75.9	476	7.45	7.45	6.94	6.74	6.49	5.50	4.45	4.62	5.07	5.96	6.86	7.17
127	Srinagar	34.1	74.8	1587	3.28	4.23	4.81	5.55	6.26	6.56	6.37	6.26	6.13	6.23	5.82	4.03
128	Surat	21.2	72.9	11	7.24	7.35	6.83	7.01	7.05	5.88	4.66	4.66	5.45	6.82	7.24	7.14
129	Thirthahalli	13.7	75.3	628	7.26	7.15	6.80	6.68	6.24	4.45	3.74	4.02	4.67	5.35	6.47	6.96
130	Tiruchchirappalli	10.8	78.7	88	6.99	7.33	6.88	6.72	6.48	6.00	5.49	5.83	6.02	5.83	6.03	6.09
131	Titabar	26.6	94.2	99	5.45	5.53	5.18	5.08	4.87	4.52	4.57	4.79	4.78	5.12	5.52	5.31
132	Titlagarh	20.3	83.3	211	7.42	7.51	7.20	6.81	6.97	6.08	5.33	5.24	5.53	6.35	6.74	7.37
133	Tocklai	26.8	94.2	87	5.23	5.26	5.66	5.35	4.95	4.80	4.85	4.79	5.16	4.86	5.55	5.17
134	Trivandrum	8.5	77.0	64	7.24	7.28	6.82	6.30	5.90	5.15	5.16	5.70	5.85	5.74	6.02	6.60
135	Tuticorin	8.8	78.2	4	7.28	7.43	6.94	6.90	6.59	6.24	6.21	6.43	6.23	6.32	6.46	6.25
136	Udaipur	24.6	73.7	582	7.65	7.86	7.35	7.40	7.52	6.67	5.21	5.17	6.09	7.48	8.03	7.54
137	Varanasi	25.5	82.9	85	6.90	7.14	6.87	6.99	7.06	6.18	5.20	5.04	5.63	6.87	7.07	6.96
138	Vasad	22.5	73.1	34	7.34	7.47	7.04	7.20	7.33	6.35	5.00	4.95	5.74	7.02	7.31	7.14
139	Vedasandur	10.5	78.0	76	7.14	7.42	6.87	6.65	6.32	5.79	5.39	5.81	5.78	5.77	5.84	5.87
140	Vellore	12.9	79.2	214	6.45	6.70	6.83	6.47	6.19	5.44	4.89	5.08	5.28	5.46	5.44	5.95
141	Vengurla	15.9	73.6	9	7.54	7.51	7.22	6.96	6.38	4.94	4.28	4.57	4.70	5.73	6.60	7.43
142	Veraval	20.9	70.4	8	7.45	7.63	7.38	6.90	7.16	6.31	4.93	4.89	6.13	7.06	7.44	7.43
143	Viramgam	23.1	72.2	27	7.61	7.74	7.18	7.28	7.35	6.50	5.02	4.85	5.98	7.30	7.73	7.57
144	Vishakhapatnam	17.7	83.2	3	7.26	7.45	6.55	6.62	6.56	4.99	4.55	5.12	5.23	6.02	6.73	6.94
145	Vittal	13.0	75.4	91	7.49	7.54	6.92	6.77	6.85	4.39	3.73	4.52	5.14	5.65	6.75	7.07

APPENDIX G

EVAPOTRANSPIRATION
PENMAN METHOD

Program to Calculate
Mean Temperature and Precipitation
from ASCII Data Files

```
WATFOR-77 V3.1 Copyright WATCOM Systems Inc. 1984,1989  95/06/05 14:58:05

Options: list,disk,extensions,warnings,xtype,terminal,check,arraycheck

      c
      c     Kim Philip, May 14, 1995
      c
      c     a program to calculate mean climate data for
      c     stations across India from ascii datafiles
      c
    1 10    OPEN (3, FILE= 'C:\KIM\DATA\CLIMATE')
    2 20    OPEN (4, FILE= 'MEANS')
    3 30    REWIND (4)
    4 40    OPEN (5, FILE= 'STATIONS')
    5 50    REWIND (5)
    6 60    CALL WORKER
    7 70    OPEN (3, FILE= 'C:\KIM\DATA\CLIMATE2')
    8 80    CALL WORKER
    9 90    OPEN (3, FILE= 'C:\KIM\DATA\CLIMATE3')
   10 100   CALL WORKER
   11 110   OPEN (3, FILE= 'C:\KIM\DATA\CLIMATE4')
   12 120   CALL WORKER
   13 130   OPEN (3, FILE= 'C:\KIM\DATA\CLIMATE5')
   14 140   CALL WORKER
   15 150   OPEN (3, FILE= 'C:\KIM\DATA\CLIMATE6')
   16 160   CALL WORKER
   17 170   OPEN (3, FILE= 'C:\KIM\DATA\CLIMATE7')
   18 180   CALL WORKER
   19 190   OPEN (3, FILE= 'C:\KIM\DATA\CLIMATE8')
   20 200   CALL WORKER
   21 210   CLOSE (4)
   22 220   CLOSE (5)
   23 230   END
   24 1000  SUBROUTINE WORKER
   25 1010  CHARACTER STAT*30,INDIA*5,TYPE*50
   26 1020  INTEGER STATNO,YEAR,PTS(12),DATA(12),SUM(12),MEAN(12)
   27 1030  INTEGER MONTH,MARKER
   28 1040  REWIND (3)
   29 1050  FORMAT (I6,1X,A30,1X,A5)
   30 1060  FORMAT (A50)
   31 1070  FORMAT (I4,12(1X,I5))
   32 1080  FORMAT (I6,1X,A21,1X,A4,1X,I4,1X,I4,12(1X,I2))
   33 1090  FORMAT (A4,1X,A2,12(1X,I5))
   34 1100  MARKER=1
   35 1110  READ (3,1050) STATNO,STAT,INDIA
   36 1115  IF (STATNO.EQ.0) GOTO 1110
   37 1116  PRINT *, 'STATNO=',STATNO
   38 1117  PRINT *, 'STATION=',STAT
   39 1118  PRINT *, 'COUNTRY=',INDIA
   40 1120  READ (3,1060) TYPE
   41 1121  PRINT *,'TYPE=',TYPE
   42 1130  DO 1170 MONTH=1,12
   43 1140        DATA(MONTH)=0
   44 1150        PTS(MONTH)=0
   45 1160        SUM(MONTH)=0
```

```
 46 1170   CONTINUE
 47 1180   READ (3,1070,ERR=2010,END=2000)YEAR,(DATA(MONTH),MONTH=1,12)
 48 1190   IF (YEAR.EQ.0) GOTO 2010
 49 1195   IF (YEAR.GE.1958.AND.YEAR.LE.1967) THEN
 50 1199       PRINT 1070, YEAR,(DATA(MONTH),MONTH=1,12)
 51 1220       DO 1290 MONTH=1,12
 52 1230           IF (DATA(MONTH).EQ.99999) THEN
 53 1240               DATA(MONTH)=0
 54 1250               PTS(MONTH)=PTS(MONTH)-1
 55 1260           ENDIF
 56 1270           SUM(MONTH)=SUM(MONTH)+DATA(MONTH)
 57 1280           PTS(MONTH)=PTS(MONTH)+1
 58 1290       CONTINUE
 59 1295   ENDIF
 60 1300   GOTO 1180
 61 2000   MARKER=2
 62 2010   DO 2030 MONTH=1,12
 63 2015       IF (PTS(MONTH).EQ.0) THEN
 64 2016           MEAN(MONTH)=99999
 65 2017       ELSE
 66 2018           MEAN(MONTH)=INT((SUM(MONTH)/PTS(MONTH))+.5)
 67 2020       ENDIF
 68 2030   CONTINUE
 69 2040   WRITE (4,1090) STAT,TYPE,(MEAN(MONTH),MONTH=1,12)
 70 2041   PRINT 1090, STAT,TYPE,(MEAN(MONTH),MONTH=1,12)
 71 2045   WRITE (5,1080) STATNO,STAT,TYPE,(PTS(MONTH),MONTH=1,12)
 72 2047   PRINT 1080, STATNO,STAT,TYPE,(PTS(MONTH),MONTH=1,12)
 73 2050   DO 2080 MONTH=1,12
 74 2060       SUM(MONTH)=0
 75 2070       PTS(MONTH)=0
 76 2080   CONTINUE
 77 2090   GOTO (1110,3000),MARKER
 78 3000   CLOSE (3)
 79        RETURN
 80        END
```

```
Compile time:                 00.27  Execution time:          44.99
Size of object code:            1872  Number of extensions:       0
Size of local data area(s):      749  Number of warnings:         0
Size of global data area:        277  Number of errors:           0
Object/Dynamic bytes free:  301147/45564  Statements Executed:    220147
```

APPENDIX H

EVAPOTRANSPIRATION
PENMAN METHOD

SATURATION VAPOUR DEFICIT
(ea-ed)

Saturation Vapour Pressure Deficit. ea-ed (mbars)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	6.8	10.9	17.4	26.2	33.3	32.2	13.5	8.3	11.2	14.9	11.3	6.6
2	4	Ahmadabad	23.1	72.6	55	13.9	18.1	25.0	30.8	31.4	19.0	8.5	7.4	9.1	16.5	15.8	13.3
3	5	Akola	20.7	77.0	282	14.5	21.7	27.7	36.0	38.1	21.0	8.5	7.2	9.0	15.2	15.1	12.6
4	7	Allahabad	25.5	81.7	98	6.0	10.4	19.7	32.3	38.0	30.5	10.1	6.7	8.8	10.8	9.5	6.0
5	8	Amini Divi	11.1	72.7	4	10.7	11.1	11.7	11.0	10.2	7.0	6.4	5.8	7.3	7.8	8.6	9.5
6	9	Amritsar	31.6	74.9	234	3.6	5.6	8.7	16.5	25.2	26.7	12.0	8.7	9.8	10.4	6.8	4.2
7	14	Bangalor	13.0	77.6	897	8.6	10.4	16.0	16.8	12.7	6.6	5.5	5.6	5.0	5.6	4.7	5.9
8	21	Bhopal	23.3	77.4	503	10.0	15.7	22.8	30.4	37.0	21.8	6.8	4.7	7.1	14.5	13.4	10.6
9	24	Bikaner	28.0	73.3	224	7.8	11.6	17.4	27.0	35.4	31.9	19.9	15.8	17.1	21.0	13.1	8.1
10	26	Bombay	19.1	72.9	14	13.2	13.8	13.0	11.9	12.6	8.7	5.0	5.1	6.2	10.2	13.9	13.0
11	26	Bombay	19.1	72.9	14	12.9	13.1	12.4	12.0	12.7	8.4	5.0	4.9	5.9	9.6	13.1	12.4
12	27	Calcutta	22.7	88.5	6	7.1	9.1	12.6	13.8	12.0	8.1	5.9	5.9	5.5	7.2	7.8	6.8
13	27	Calcutta	22.7	88.5	6	7.1	9.7	12.9	13.8	12.1	8.1	6.1	5.9	5.6	7.2	8.2	6.9
14	34	Cuttack	20.5	85.9	24	8.7	12.2	16.2	17.5	18.6	13.4	6.8	6.6	7.4	9.1	10.5	9.2
15	36	Dharwar	15.4	75.1	679	9.6	11.1	12.5	12.5	10.9	6.8	4.1	4.2	4.7	7.1	9.2	9.0
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	3.6	4.6	7.2	6.9	5.2	5.1	4.8	4.6	5.1	5.0	4.4	3.6
17	39	Gannavaram	16.5	80.8	24	7.8	10.1	11.5	12.4	18.4	16.4	9.1	8.3	7.4	7.3	8.2	8.3
18	40	Gauhati	26.1	91.6	54	4.2	6.4	10.2	10.2	6.9	6.0	6.1	5.7	5.5	5.3	4.5	3.8
19	41	Goa	15.5	73.8	55	11.7	11.3	11.5	12.0	11.8	7.0	4.5	5.2	5.3	8.1	12.8	10.9
20	56	Hyderabad	17.5	78.5	545	10.5	16.3	21.6	24.9	29.3	15.9	8.3	7.3	7.1	8.9	9.1	9.6
21	59	Indore	22.7	75.8	567	11.0	16.8	21.7	31.2	35.0	19.3	7.4	5.2	8.7	16.9	15.1	11.6
22	61	Jagadalpur	19.1	82.0	553	8.7	12.7	18.4	19.9	21.6	11.1	4.7	4.3	5.3	7.3	7.8	7.6
23	62	Jaipur	26.8	75.8	390	8.8	12.9	20.8	30.7	36.6	29.4	12.1	8.3	10.3	17.5	13.2	10.2
24	69	Jodhpur	26.3	73.0	224	12.3	17.3	24.8	33.5	39.5	27.7	15.3	11.9	12.8	23.1	18.7	12.8
25	76	Kodaikanal	10.2	77.5	2345	4.1	5.4	6.1	4.3	3.8	3.4	2.3	2.4	2.5	2.0	2.4	3.4
26	79	Kota	25.2	75.5	257	10.5	16.2	24.2	36.6	43.5	30.1	13.1	8.5	11.2	19.2	15.6	10.5
27	86	Madras	13.0	80.2	16	7.1	8.4	10.0	11.1	16.0	16.8	13.8	10.7	9.5	7.1	5.7	6.2
28	89	Minicoy	8.3	73.0	2	8.1	7.9	8.2	9.7	9.0	7.2	7.0	7.1	7.3	6.9	7.3	7.0
29	92	Nagpur	21.2	79.1	311	10.5	17.0	23.6	31.7	40.2	20.4	8.0	5.8	7.1	11.2	10.9	9.1
30	97	New Dehli	28.6	77.2	216	5.4	9.3	14.5	25.5	32.5	30.9	13.8	8.4	10.8	13.2	10.0	5.8
31	99	Okha	22.5	69.1	7	8.8	7.0	7.1	5.9	7.7	7.0	5.9	5.1	6.6	5.9	10.4	10.6
32	100	Ollukara	10.5	76.3	22	9.2	9.1	9.1	8.3	6.4	4.1	3.6	3.9	4.5	5.0	6.8	8.2
33	105	Patna	25.5	85.3	52	7.0	10.6	17.6	27.0	26.3	18.3	7.8	6.3	7.1	8.4	7.9	6.2
34	107	Port Blair	11.7	92.7	79	7.5	7.4	7.9	8.0	5.2	4.5	4.0	3.9	3.5	4.1	5.3	6.6
35	108	Pune	18.5	73.9	563	12.3	16.3	21.5	24.2	18.9	10.9	5.4	4.9	5.8	10.3	10.4	10.3
36	123	Shillong	25.6	91.9	1598	4.0	5.3	8.0	7.8	5.7	3.5	3.4	3.4	3.0	3.8	4.1	3.9
37	124	Silicuri	24.8	92.9	40	6.3	7.9	11.3	10.3	8.1	5.5	5.5	5.5	6.1	6.6	7.0	6.0
38	127	Srinagar	34.1	74.8	1587	1.2	1.7	2.9	4.1	6.2	10.0	9.8	8.8	7.1	4.8	2.6	1.5
39	134	Trivandrum	8.5	77.0	64	9.3	10.3	9.7	8.0	6.6	4.8	4.2	4.8	5.1	4.8	5.8	7.6
40	135	Tuticorin	8.8	78.2	4	7.2	8.3	9.5	11.4	14.8	17.6	17.4	16.6	16.3	11.0	7.6	7.1
41	142	Veraval	20.9	70.4	8	12.1	10.8	8.9	8.4	7.1	6.9	4.6	4.5	6.2	10.0	13.3	12.9
42	144	Vishakhapatnam	17.7	83.2	3	7.7	9.2	10.6	11.1	13.0	12.6	8.4	8.3	7.1	7.8	9.1	8.7

Actual Water Vapour Pressure. ed (mbars)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	9.9	10.3	11.6	14.7	17.6	24.3	31.6	32.0	27.3	18.9	12.9	11.1
2	4	Ahmadabad	23.1	72.6	55	9.7	10.0	10.9	14.4	21.9	29.4	32.0	30.8	29.1	21.3	14.9	12.2
3	5	Akola	20.7	77.0	282	11.2	8.3	10.3	12.1	16.0	26.7	29.3	28.5	27.1	19.3	13.9	12.8
4	7	Allahabad	25.5	81.7	98	12.4	12.4	12.3	12.6	15.5	26.0	33.0	33.7	31.4	23.7	16.2	12.8
5	8	Amini Divi	11.1	72.7	4	27.5	29.3	31.0	33.9	34.8	31.6	31.4	30.8	30.5	30.7	29.6	28.5
6	9	Amritsar	31.6	74.9	234	10.2	11.3	13.6	15.2	15.1	21.7	30.9	32.3	28.6	19.9	13.3	10.5
7	14	Bangalor	13.0	77.6	897	16.4	17.8	16.5	19.3	23.0	23.9	23.1	23.0	23.6	22.9	21.0	18.4
8	21	Bhopal	23.3	77.4	503	10.1	9.2	9.1	10.6	13.5	23.3	27.4	27.3	25.1	17.4	13.1	10.8
9	24	Bikaner	28.0	73.3	224	8.0	9.0	11.2	13.3	15.3	24.5	30.4	29.9	25.6	15.0	10.7	8.9
10	26	Bombay	19.1	72.9	14	17.3	18.4	22.7	26.6	30.1	31.5	31.1	30.8	30.1	28.1	24.1	21.0
11	26	Bombay	19.1	72.9	14	16.9	17.4	21.9	26.7	30.3	30.3	30.9	29.3	28.6	26.5	22.8	20.1
12	27	Calcutta	22.7	88.5	6	16.4	17.8	23.2	29.4	33.1	34.9	32.8	34.3	33.1	29.1	20.8	16.8
13	27	Calcutta	22.7	88.5	6	16.6	19.0	23.7	29.4	33.1	34.9	34.2	34.3	33.1	29.2	21.7	17.1
14	34	Cuttack	20.5	85.9	24	17.8	19.9	23.9	27.9	31.8	32.0	31.8	32.1	32.8	28.7	21.3	17.5
15	36	Dharwar	15.4	75.1	679	17.0	17.9	21.6	25.4	25.4	23.8	23.2	23.9	24.0	23.3	19.3	17.7
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	15.0	16.1	17.9	22.0	26.7	30.6	31.8	31.9	30.9	26.7	19.7	16.2
17	39	Gannavaram	16.5	80.8	24	21.0	21.7	24.4	28.0	29.2	28.9	29.4	30.0	30.9	29.1	24.2	20.7
18	40	Gauhati	26.1	91.6	54	15.6	16.1	18.0	23.6	27.6	32.1	34.1	34.4	32.6	28.4	21.3	17.3
19	41	Goa	15.5	73.8	55	20.6	22.3	24.4	26.7	28.8	29.2	29.5	28.8	28.8	28.0	23.2	23.1
20	56	Hyderabad	17.5	78.5	545	15.0	13.5	14.6	17.7	18.4	24.3	25.5	25.2	25.2	22.8	17.8	15.3
21	59	Indore	22.7	75.8	567	9.1	7.3	8.8	9.2	12.8	23.3	26.7	26.6	23.0	13.6	10.3	9.8
22	61	Jagadalpur	19.1	82.0	553	15.1	15.4	16.0	20.9	23.7	27.3	27.5	27.7	27.2	24.5	18.7	15.8
23	62	Jaipur	26.8	75.8	390	9.0	8.5	9.1	9.9	11.7	21.1	28.5	29.6	26.3	16.1	10.8	9.8
24	69	Jodhpur	26.3	73.0	224	7.4	6.9	7.7	9.5	13.9	23.4	30.1	29.1	27.6	14.9	9.6	8.5
25	76	Kodaikanal	10.2	77.5	2345	10.8	10.1	10.8	13.1	14.1	14.3	14.0	14.5	14.3	14.3	12.6	11.2
26	79	Kota	25.2	75.5	257	9.4	9.2	9.9	11.1	13.0	23.5	29.3	29.3	26.8	17.0	12.7	11.5
27	86	Madras	13.0	80.2	16	23.3	25.2	28.1	31.8	32.2	29.0	28.9	30.0	31.0	30.7	26.7	24.4
28	89	Minicoy	8.3	73.0	2	26.1	26.4	28.3	28.7	29.4	29.3	29.1	28.8	28.5	29.0	28.4	27.4
29	92	Nagpur	21.2	79.1	311	13.4	11.5	12.4	13.9	16.1	27.3	28.4	29.9	28.7	22.4	16.2	14.4
30	97	New Dehli	28.6	77.2	216	10.7	10.5	12.5	12.8	15.3	22.5	31.1	32.0	27.7	19.3	13.5	11.3
31	99	Okha	22.5	69.1	7	15.4	20.1	24.8	29.9	32.6	33.9	32.5	31.5	29.6	30.1	21.7	16.0
32	100	Ollukara	10.5	76.3	22	26.6	27.1	29.1	30.4	31.5	30.0	30.0	29.7	29.3	29.3	29.0	27.5
33	105	Patna	25.5	85.3	52	14.0	12.1	14.6	18.4	24.2	32.4	34.8	34.2	33.3	27.8	19.1	14.9
34	107	Port Blair	11.7	92.7	79	26.7	27.0	28.1	30.4	31.2	29.9	30.1	30.1	30.2	30.0	29.2	27.4
35	108	Pune	18.5	73.9	563	12.8	10.8	12.4	16.3	22.0	25.4	26.3	25.3	24.8	21.6	16.9	15.0
36	123	Shillong	25.6	91.9	1598	8.4	8.7	9.9	15.6	18.2	20.6	21.8	21.8	20.6	16.1	11.2	9.3
37	124	Silicuri	24.8	92.9	40	13.7	14.7	16.9	22.1	26.2	30.5	31.0	30.9	30.4	27.1	19.7	15.2
38	127	Srinagar	34.1	74.8	1587	5.4	6.7	8.2	10.8	12.6	15.6	20.2	20.0	16.7	11.5	8.1	6.3
39	134	Trivandrum	8.5	77.0	64	25.2	25.8	28.4	30.5	31.2	29.5	29.5	29.1	29.1	29.3	28.5	26.7
40	135	Tuticorin	8.8	78.2	4	26.5	26.2	28.5	29.3	26.2	22.9	22.7	22.1	22.4	26.8	26.8	26.8
41	142	Veraval	20.9	70.4	8	13.5	17.3	21.8	26.1	31.4	33.5	32.0	31.5	29.8	26.2	20.4	15.5
42	144	Vishakhapatnam	17.7	83.2	3	20.8	22.8	27.3	31.8	34.8	32.8	31.9	32.0	31.6	28.7	23.4	20.1

Relative Humidity (%) - Average for Month

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	59.5	48.5	40.0	36.0	34.5	43.0	70.0	79.5	71.0	56.0	53.5	62.5
2	4	Ahmadabad	23.1	72.6	55	41.3	35.6	30.5	31.8	41.0	60.8	79.1	80.5	76.3	56.3	48.6	47.9
3	5	Akola	20.7	77.0	282	43.4	27.8	27.2	25.2	29.6	56.0	77.4	79.8	75.2	56.0	48.0	50.4
4	7	Allahabad	25.5	81.7	98	67.3	54.6	38.5	28.2	28.9	46.0	76.6	83.5	78.1	68.7	63.2	68.0
5	8	Amini Divi	11.1	72.7	4	72.0	72.5	72.5	75.4	77.3	81.9	83.2	84.1	80.8	79.8	77.4	75.1
6	9	Amritsar	31.6	74.9	234	74.0	66.9	60.9	47.8	37.4	44.8	72.0	78.9	74.5	65.8	66.2	71.6
7	14	Bangalor	13.0	77.6	897	65.5	63.0	50.8	53.5	64.4	78.4	80.8	80.4	82.5	80.5	81.6	75.9
8	21	Bhopal	23.3	77.4	503	50.2	37.0	28.5	25.9	26.7	51.7	80.2	85.2	77.8	54.6	49.4	50.6
9	24	Bikaner	28.0	73.3	224	50.8	43.5	39.0	33.0	30.3	43.5	60.5	65.5	60.0	41.8	45.0	52.5
10	26	Bombay	19.1	72.9	14	56.8	57.2	63.7	69.1	70.4	78.3	86.0	85.7	83.0	73.3	63.5	61.75
11	26	Bombay	19.1	72.9	14	56.8	57.2	63.7	69.1	70.4	78.3	86.0	85.7	83.0	73.3	63.5	61.75
12	27	Calcutta	22.7	88.5	6	69.8	66.3	64.9	68.0	73.3	81.1	84.8	85.4	85.6	80.3	72.6	71.3
13	27	Calcutta	22.7	88.5	6	69.8	66.3	64.9	68.0	73.3	81.1	84.8	85.4	85.6	80.3	72.6	71.3
14	34	Cuttack	20.5	85.9	24	67.0	62.0	59.5	61.5	63.0	70.5	82.5	83.0	81.5	76.0	67.0	65.5
15	36	Dharwar	15.4	75.1	679	64.0	61.8	63.3	67.1	70.1	77.9	84.9	85.0	83.8	76.6	67.8	66.3
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	80.5	77.7	71.3	76.2	83.6	85.6	86.9	87.4	85.8	84.3	81.9	81.8
17	39	Gannavaram	16.5	80.8	24	73.0	68.2	68.0	69.4	61.4	63.9	76.3	78.4	80.8	79.9	74.8	71.3
18	40	Gauhati	26.1	91.6	54	78.8	71.5	63.8	69.9	79.9	84.3	84.7	85.7	85.5	84.3	82.4	82.0
19	41	Goa	15.5	73.8	55	63.8	66.3	67.9	68.9	70.9	80.8	86.8	84.6	84.5	77.5	64.4	67.9
20	56	Hyderabad	17.5	78.5	545	58.9	45.2	40.4	41.6	38.5	60.5	75.4	77.5	77.9	72.0	66.3	61.6
21	59	Indore	22.7	75.8	567	45.5	30.1	28.7	22.7	26.8	54.7	78.4	83.8	72.6	44.6	40.5	45.6
22	61	Jagadalpur	19.1	82.0	553	63.3	55.0	46.5	51.3	52.3	71.2	85.3	86.7	83.8	77.0	70.5	67.5
23	62	Jaipur	26.8	75.8	390	50.5	39.5	30.4	24.3	24.3	41.8	70.1	78.1	71.9	47.9	44.9	48.9
24	69	Jodhpur	26.3	73.0	224	37.7	28.7	23.8	22.2	26.1	45.8	66.3	71.0	68.4	39.1	34.0	40.0
25	76	Kodaikanal	10.2	77.5	2345	72.3	65.5	63.9	75.1	78.8	80.7	86.0	85.9	85.4	87.8	84.1	76.4
26	79	Kota	25.2	75.5	257	47.2	36.2	29.0	23.2	23.0	43.8	69.2	77.6	70.6	47.0	45.0	52.2
27	86	Madras	13.0	80.2	16	76.7	74.9	73.7	74.1	66.8	63.3	67.8	73.7	76.5	81.3	82.3	79.9
28	89	Minicoy	8.3	73.0	2	76.2	76.8	77.5	74.6	76.6	80.2	80.7	80.3	79.7	80.8	79.7	79.8
29	92	Nagpur	21.2	79.1	311	56.1	40.3	34.3	30.5	28.6	57.2	77.9	83.9	80.3	66.6	59.7	61.3
30	97	New Dehli	28.6	77.2	216	66.3	53.1	46.2	33.5	31.9	42.2	69.3	79.3	71.9	59.3	57.3	65.9
31	99	Okha	22.5	69.1	7	63.7	74.0	77.8	83.5	81.0	82.9	84.6	86.0	81.8	83.5	67.5	60.3
32	100	Ollukara	10.5	76.3	22	74.3	74.8	76.2	78.5	83.0	87.8	89.2	88.3	86.7	85.3	81.0	77.2
33	105	Patna	25.5	85.3	52	66.5	53.3	45.2	40.5	47.9	63.8	81.7	84.3	82.5	76.9	70.6	70.8
34	107	Port Blair	11.7	92.7	79	78.1	78.4	78.0	79.0	85.8	86.9	88.2	88.6	89.8	88.0	84.6	80.7
35	108	Pune	18.5	73.9	563	51.0	39.8	36.7	40.1	53.8	69.9	82.8	83.7	81.0	67.7	61.9	59.4
36	123	Shillong	25.6	91.9	1598	67.8	62.0	55.2	66.5	76.0	85.5	86.7	86.4	87.3	80.8	73.5	70.8
37	124	Silicuri	24.8	92.9	40	68.5	65.3	60.0	68.3	76.5	84.8	85.0	85.0	83.3	80.5	73.8	71.8
38	127	Srinagar	34.1	74.8	1587	81.1	80.3	74.0	72.3	66.8	60.8	67.3	69.4	70.3	70.3	76.1	81.1
39	134	Trivandrum	8.5	77.0	64	72.9	71.5	74.5	79.3	82.6	86.1	87.7	85.9	85.0	85.8	83.2	77.8
40	135	Tuticorin	8.8	78.2	4	78.5	76.0	75.0	72.0	64.0	56.5	56.5	57.0	58.0	71.0	78.0	79.0
41	142	Veraval	20.9	70.4	8	52.9	61.5	71.1	75.7	81.6	83.0	87.4	87.6	82.9	72.5	60.5	54.6
42	144	Vishakhapatnam	17.7	83.2	3	73.0	71.3	72.1	74.1	72.7	72.2	79.2	79.4	81.8	78.7	71.9	69.7

Relative Humidity

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AVERAGE Bangalor	MAXIMUM Bangalor
Bangalor																										
Jan	62	58	64	70	70	70	74	84	72	64	56	49	42	34	31	30	30	40	48	54	60	64	70	74	54	94
Feb	77	68	67	65	67	69	70	84	76	61	53	47	44	41	39	36	39	44	49	53	57	64	68	72	61	95
Mar	61	69	64	64	74	74	77	73	63	51	45	36	34	32	31	30	30	33	38	45	49	57	62	66	50	97
Apr	61	67	71	75	77	78	74	71	61	54	47	41	37	35	33	33	35	37	40	44	46	49	54	59	53	98
May	77	74	71	70	69	69	70	69	61	55	51	47	45	44	43	43	47	49	51	57	62	61	63	74	64	97
Jun	90	81	82	82	83	81	81	79	74	69	64	61	60	60	61	60	61	63	71	77	80	80	86	86	73	93
Jul	90	91	92	87	85	84	84	81	74	70	67	64	64	64	65	67	67	74	78	80	81	85	87	89	80	98
Aug	90	89	92	93	94	94	94	91	84	74	70	66	65	62	62	66	67	70	74	80	81	85	87	89	80	94
Sept	91	93	93	94	94	95	95	91	84	81	75	70	67	65	65	67	69	73	73	81	84	88	90	91	82	95
Oct	92	93	94	95	95	95	95	91	82	74	67	63	61	61	61	63	66	72	74	81	83	87	89	91	80	95
Nov	92	92	93	94	94	95	93	91	84	77	70	66	64	63	64	66	70	75	80	84	87	89	90	91	81	95
Dec	90	92	93	94	94	94	94	94	86	76	69	64	58	54	52	51	52	55	61	69	74	79	82	84	79	95

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Bodaikana	Bodaikana
Bodaikana																										
Jan	74	74	73	72	71	70	67	65	60	58	58	60	64	67	71	74	80	84	87	85	83	81	77	75	71	87
Feb	69	69	68	67	66	64	65	61	58	54	49	51	58	57	61	65	69	75	81	82	78	75	72	70	64	91
Mar	69	68	66	65	63	62	59	56	49	45	44	49	53	57	60	63	67	72	79	81	81	77	74	71	63	94
Apr	80	79	77	76	75	73	71	66	57	49	51	55	61	65	69	74	77	80	85	83	80	81	84	84	75	91
May	83	83	82	81	81	80	78	75	69	64	63	65	69	73	77	80	81	82	89	88	87	86	85	84	76	89
Jun	91	91	91	91	91	90	87	82	71	67	59	57	62	69	74	77	79	84	89	87	85	88	89	87	80	89
Jul	87	88	86	85	88	86	87	85	81	79	79	79	80	82	84	87	86	91	92	90	89	89	86	87	84	94
Aug	87	87	87	87	86	86	85	83	78	76	76	78	80	83	85	89	90	94	95	91	91	89	89	88	85	95
Sept	86	86	86	87	87	87	86	83	76	74	75	77	79	84	85	87	90	93	94	95	90	89	88	87	85	95
Oct	91	92	92	92	92	93	91	87	82	79	77	77	79	81	83	85	89	92	94	91	91	91	92	92	87	98
Nov	88	88	87	86	86	86	87	86	79	75	74	74	75	76	78	81	85	88	90	90	90	89	89	89	84	94
Dec	81	81	80	80	79	79	77	75	70	64	65	65	67	69	71	75	79	83	83	83	83	82	81	79	76	87

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Chinagal	Chinagar
Chinagar																										
Jan	89	89	89	90	91	91	91	91	90	85	81	76	70	69	66	66	67	67	74	78	81	84	87	84	81	91
Feb	89	91	91	92	92	93	91	92	88	85	77	70	67	65	63	62	64	65	67	75	80	86	88	88	80	94
Mar	85	87	89	90	91	93	91	92	83	77	69	62	59	56	54	53	53	54	59	65	71	77	80	81	74	93
Apr	85	87	89	91	92	93	93	89	77	71	65	60	56	53	51	50	51	53	57	64	71	76	79	83	74	97
May	83	86	89	91	92	94	93	91	83	71	64	59	52	49	45	45	45	46	49	57	65	71	77	79	66	94
Jun	78	80	84	86	86	87	89	87	79	61	55	50	45	42	38	36	35	36	39	45	51	57	64	69	71	89
Jul	79	81	83	86	87	89	89	87	81	67	59	57	52	49	45	45	48	50	53	61	67	72	74	77	67	89
Aug	86	85	87	89	90	92	92	88	78	65	60	55	50	47	43	44	45	48	51	58	65	71	74	76	61	94
Sept	87	89	90	91	91	94	95	91	84	68	59	51	46	43	40	42	44	45	53	60	67	73	76	81	66	96
Oct	89	92	93	94	95	96	97	94	93	82	63	65	61	59	46	37	41	47	51	74	79	85	85	88	74	97
Nov	91	91	94	95	95	96	96	96	93	85	57	52	49	47	48	50	54	56	66	75	81	85	87	89	76	98
Dec	91	92	93	93	93	94	94	94	93	84	70	71	66	62	60	60	62	67	74	79	83	85	89	88	81	98

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Allahabad	Allahabad
Allahabad																										
Jan	86	85	87	88	89	90	91	89	73	61	51	46	41	38	38	39	43	51	60	65	70	74	77	81	67	91
Feb	69	73	75	77	79	80	82	76	60	47	39	38	38	38	37	37	38	45	51	59	59	62	67	69	54	82
Mar	50	53	55	58	60	61	63	58	41	34	29	28	28	27	19	18	17	18	22	28	32	35	39	43	46	83
Apr	35	37	39	42	44	46	47	39	31	26	24	21	19	17	15	14	14	14	19	23	26	28	30	33	28	87
May	36	37	40	42	44	46	45	34	31	28	24	21	19	17	15	15	15	17	19	23	27	29	31	33	24	88
Jun	53	55	57	59	60	61	59	56	47	41	36	35	34	33	32	33	34	36	39	43	46	49	50	52	44	91
Jul	65	66	67	67	69	69	67	63	56	51	47	44	44	42	42	43	45	49	54	57	60	61	62	64	54	89
Aug	91	91	92	92	93	93	92	88	84	79	75	73	72	72	72	73	75	79	82	85	87	88	89	90	81	93
Sept	89	89	90	91	91	92	91	85	77	71	66	65	61	60	61	62	65	71	77	84	85	85	84	83	73	92
Oct	84	86	88	89	90	91	92	86	87	68	63	62	60	60	59	65	70	82	79	80	81	82	84	84	74	92
Nov	61	65	65	67	69	70	70	69	61	50	42	37	34	32	32	34	40	50	57	66	68	73	74	79	61	90
Dec	69	67	69	70	71	72	72	69	72	57	49	45	40	38	36	38	45	56	62	68	73	77	80	83	68	92

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Amini Davi	Amini Davi
Amini Davi																										
Jan	81	81	82	82	82	82	81	82	76	66	60	58	58	59	60	60	61	65	70	73	75	77	79	80	70	82
Feb	81	82	82	82	82	82	82	82	75	61	63	60	60	59	60	60	62	65	70	73	76	77	79	81	72	82
Mar	80	81	81	81	81	81	80	78	67	64	62	60	60	60	60	61	63	67	72	76	78	77	78	79	72	81
Apr	82	82	83	83	83	84	84	81	75	71	67	64	65	65	65	66	69	73	75	77	78	78	80	81	75	88
May	82	82	82	83	83	83	82	81	77	74	72	70	69	69	69	70	72	74	77	79	80	81	82	82	77	87
Jun	83	83	83	83	83	83	84	83	82	81	81	80	80	80	79	79	80	81	82	83	83	83	83	83	81	84
Jul	84	84	84	84	84	84	84	83	83	83	82	82	82	82	82	82	82	82	82	83	84	84	84	84	83	87
Aug	86	87	87	87	87	87	87	87	87	86	86	87	87	87	87	87	87	87	87	87	87	87	87	87	87	89
Sept	83	83	83	83	83	84	83	82	81	80	79	78	77	77	78	78	79	80	81	81	82	82	82	82	80	84
Oct	82	84	84	83	84	84	84	83	80	79	78	78	78	78	78	78	78	79	80	81	82	82	82	82	79	84
Nov	84	84	84	85	85	85	85	84	77	74	71	69	68	68	68	68	69	72	75	77	80	81	82	84	77	85
Dec	83	83	83	84	84	84	84	81	79	72	67	65	64	64	64	65	69	69	73	76	77	79	80	82	75	88

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Amritsar	Amritsar
Amritsar																										
Jan	88	89	90	90	91	91	92	93	89	76	61	55	49	44	45	45	49	58	68	75	79	83	85	87	74	94
Feb	83	84	85	85	85	86	87	87	77	65	55	48	42	35	38	38	40	47	55	67	72	76	79	81	69	87
Mar	77	78	79	79	81	81	82	79	65	54	47	42	38	36	34	34	34	41	52	60	66	70	73	76	60	94
Apr	62	64	66	67	69	70	69	68	59	42	36	32	30	27	25	25	26	28	36	47	49	56	57	58	47	70
May	49	51	52	53	55	57	56	45	34	33	29	25	23	21	20	20	20	21	25	33	38	41	45	47	37	57
Jun	55	57	59	60	61	63	64	53	46	42	38	35	33	30	29	29	28	29	32	39	45	48	51	53	44	83
Jul	81	82	83	84	84	85	85	79	72	69	67	63	59	58	57	57	58	62	70	75	79	80	81	82	72	85
Aug	89	90	90	90	91	91	91	87	78	78	73	68	66	65	63	63	64	66	72	79	83	84	84	84	78	91
Sept	89	89	90	91	91	91	92	85	73	67	61	57	55	53	52	52	53	59	69	77	82	85	87	86	76	91
Oct	84	86	87	88	89	90	90	87	84	56	49	46	38	33	31	32	35	41	60	70	77	81	83	86	68	91
Nov	85	86	87	88	89	90	91	90	75	59	47	39	35	32	31	32	37	49	59	69	75	79	81	83	66	91
Dec	87	89	89	90	91	92	92	93	87	71	58	49	43	40	39	39	45	54	66	73	78	82	84	86	71	93

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Bhopal	Bhopal
Bhopal																										
Jan	60	62	64	67	69	69	70	70	61	53	45	39	35	31	29	28	28	34	40	46	47	51	53	57	50	70
Feb	65	67	51	53	55	58	60	59	49	40	32	26	22	19	17	16	16	19	25	29	32	36	40	43	37	69
Mar	34	37	39	41	43	45	47	44	37	30	25	20	17	15	14	13	13	15	19	22	25	28	30	32	26	87
Apr	30	32	34	36	38	40	41	37	31	27	23	20	18	16	15	15	15	15	17	20	22	24	27	29	23	91
May	30	32	35	37	40	42	44	41	34	31	26	23	19	16	14	14	14	14	16	19	21	24	26	28	24	44
Jun	57	60	62	64	67	70	70	69	63	57	50	43	38	34	33	33	35	36	42	48	49	51	54	56	46	92
Jul	57	58	59	63	66	91	94	89	85	81	77	73	69	67	66	67	69	71	75	78	81	83	84	84	60	91
Aug	91	91	92	94	94	93	93	92	89	86	83	79	76	74	73	74	75	79	82	85	87	88	89	90	85	97
Sept	88	88	90	91	91	92	91	89	82	76	70	66	64	64	64	59	56	61	66	74	78	81	83	85	74	91
Oct	69	71	73	74	76	79	80	71	56	45	41	35	31	30	29	29	29	32	40	47	52	56	60	63	48	79
Nov	61	64	65	67	69	70	71	68	53	45	38	33	30	28	27	27	29	35	43	47	50	53	57	60	49	71
Dec	62	65	67	69	71	72	73	70	59	49	42	35	31	29	29	28	29	35	41	45	49	53	57	59	50	73

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Dibrugarh	Dibrugarh
Dibrugarh																										
Jan	93	94	94	94	95	95	95	91	79	69	63	59	57	55	55	60	69	78	84	87	89	91	92	93	80	95
Feb	90	91	91	91	92	92	91	85	76	69	63	59	57	56	56	58	63	71	79	83	86	86	88	89	77	92
Mar	85	85	85	85	87	87	86	75	66	58	57	54	52	51	51	52	58	65	72	76	78	80	82	84	71	87
Apr	86	87	88	88	88	87	82	77	71	68	65	63	61	60	61	63	67	72	77	80	82	84	85	86	76	88
May	91	92	92	92	92	91	88	84	81	76	74	74	73	72	72	73	76	81	84	87	88	89	90	91	83	92
Jun	92	93	93	93	93	93	90	87	84	82	80	79	77	75	76	75	77	81	85	85	90	90	91	92	85	93
Jul	93	94	94	94	94	94	92	89	87	85	82	79	78	76	76	76	79	82	87	89	90	91	92	92	86	94
Aug	94	94	94	94	94	94	93	90	87	86	84	80	79	76	75	76	78	84	89	90	91	92	93	93	87	95
Sept	94	94	94	94	95	94	92	88	83	81	80	79	74	72	72	73	76	84	89	89	91	91	92	93	85	95
Oct	93	94	94	94	94	94	91	86	79	75	73	71	69	68	68	68	71	80	86	89	90	91	92	92	83	94
Nov	94	94	94	94	95	95	94	85	77	69	65	61	59	59	60	67	77	84	87	89	91	91	91	94	81	95

| Dec | 01 | 00 | 99 | 98 | 97 | 96 | 95 | 94 | 93 | 92 | 91 | 90 | 89 | 88 | 87 | 86 | 85 | 84 | 83 | 82 | 81 | 80 | 79 | 78 | 77 | 76 | 75 | 74 | 73 | 72 | 71 | 70 | 69 | 68 | 67 | 66 | 65 | 64 | 63 | 62 | 61 | 60 | 59 | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | Dec |
|---|---|---

Nov	71	70	69	69	69	69	69	67	65	63	63	64	64	64	64	63	63	67	70	74	76	76	75	73	71	70	67.5		74
Dec	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49.0		49

Patna	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Patna	Patna	Patna		
Jan	61	64	65	66	67	68	66	63	67	57	55	65	63	60	58	59	65	56	61	66	70	74	72	64		66.5		66
Feb	64	70	72	74	75	77	76	70	65	67	74	67	69	64	64	65	69	59	69	51	69	69	62	67		69.2		74
Mar	57	59	61	62	64	65	63	59	64	60	55	53	60	60	60	60	60	51	50	46	47	49	54	55		45.2		45
Apr	48	51	53	54	54	54	52	48	54	48	47	45	48	48	48	48	48	39	31	36	35	42	44	44		46.5		48
May	51	47	44	44	43	41	43	41	47	44	46	45	44	44	47	47	47	47	34	39	45	49	54	57		47.9		74
Jun	74	78	79	80	82	84	82	84	80	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84		84.0		84
Jul	69	70	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71		71.0		71
Aug	72	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73		73.0		73
Sept	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73		73.0		73
Oct	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73		73.0		73
Nov	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73		73.0		73
Dec	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73		73.0		73

Veraval	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Veraval	Veraval	Veraval		
Jan	56	56	56	56	55	55	55	54	51	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50		51.4		53
Feb	67	65	65	63	62	61	61	60	58	57	59	59	59	59	59	59	59	59	59	59	59	59	59	59		61.5		72
Mar	77	78	78	78	78	78	78	73	65	58	54	54	54	54	54	54	54	54	54	54	54	54	54	54		59.2		77
Apr	80	80	80	80	80	80	80	77	67	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60		65.7		80
May	85	85	85	85	85	85	85	84	73	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66		69.6		79
Jun	85	85	85	85	85	85	85	85	81	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80		81.6		85
Jul	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84		84.0		84
Aug	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84		84.0		84
Sept	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84		84.0		84
Oct	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84		84.0		84
Nov	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84		84.0		84
Dec	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84		84.0		84

Ahmedabad	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Ahmedabad	Ahmedabad	Ahmedabad		
Jan	50	51	54	55	57	59	60	59	60	61	35	30	29	28	27	26	22	25	31	37	41	48	46	40		41.2		40
Feb	42	45	47	49	51	53	57	56	47	39	26	27	23	20	19	17	17	17	22	27	31	35	37	39		35.6		57
Mar	39	39	41	44	47	50	52	51	47	37	23	23	19	17	15	14	13	13	16	20	24	27	30	33		30.5		52
Apr	35	38	42	47	51	55	59	59	51	40	24	25	20	17	15	13	14	14	16	20	24	27	30	33		31.4		47
May	42	51	57	59	62	64	67	63	60	50	26	22	19	17	17	17	18	24	30	36	40	43	45	47		40.8		59
Jun	69	71	73	75	77	79	79	74	64	54	53	46	47	40	39	39	43	50	57	61	64	65	67	68		59.3		81
Jul	84	86	87	88	90	91	91	87	84	81	77	72	69	67	66	65	66	69	72	77	79	81	84	86		78.3		91
Aug	87	86	89	90	91	91	91	91	86	82	77	73	70	68	65	65	66	69	74	79	81	84	87	89		80.4		91
Sept	88	87	88	89	90	91	89	89	87	79	69	61	59	57	57	58	62	68	75	79	81	84	87	89		78.1		91
Oct	78	76	77	78	79	80	81	82	82	65	39	35	31	26	25	31	43	49	54	60	64	69	71	74		61.4		82
Nov	68	63	64	65	66	67	69	68	63	48	27	27	30	28	27	28	38	46	49	53	55	57	59	61		53.4		69
Dec	56	49	51	53	55	44	57	44	53	47	49	34	32	29	27	29	34	38	44	49	51	54	56	57		47.9		47

Bombay	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Bombay	Bombay	Bombay		
Jan	69	71	74	77	79	80	78	72	56	46	37	32	33	35	37	39	43	50	57	61	63	64	66	67		54.4		78
Feb	72	72	74	75	76	77	75	74	56	44	37	34	35	36	37	39	42	47	53	60	62	64	65	65		57.2		75
Mar	74	77	79	80	81	81	78	61	49	43	43	45	47	47	47	48	49	51	54	59	62	64	66	67		57.9		81
Apr	61	61	61	61	64	64	64	59	45	57	55	56	56	56	55	55	54	54	54	49	53	53	54	54		54.9		64
May	77	79	79	80	80	81	81	77	64	63	61	60	59	59	59	59	59	59	61	63	71	73	75	75		66.1		81
Jun	82	82	83	81	84	84	83	82	79	77	75	73	72	72	72	72	73	73	73	73	73	74	75	77		76.6		84
Jul	89	89	88	87	86	85	85	85	87	86	84	84	83	83	83	84	84	84	85	86	87	87	91	91		85.1		91
Aug	87	87	88	88	88	88	88	86	86	84	84	84	83	83	83	83	83	84	84	85	86	87	87	87		85.1		89
Sept	87	87	87	87	86	86	86	86	85	83	81	80	78	77	76	76	77	78	80	82	82	84	85	87		82.0		88
Oct	84	85	85	85	85	85	85	71	66	59	55	54	54	54	57	61	64	70	74	79	80	81	83	84		74.1		85
Nov	79	79	79	79	79	79	79	77	54	50	41	38	38	40	41	44	51	60	66	69	72	77	78	78		63.4		79
Dec	77	76	77	77	77	77	76	73	58	49	42	38	37	39	41	45	49	59	65	68	69	72	73	73		61.6		77

Calcutta	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Calcutta	Calcutta	Calcutta		
Jan	84	84	86	88	90	90	90	85	69	57	49	45	41	41	41	42	47	54	61	75	79	82	85	87		67.9		90
Feb	84	87	87	91	88	88	89	91	66	55	47	42	40	38	37	38	41	47	48	63	72	79	81	84		64.1		89
Mar	85	87	87	88	88	88	88	88	68	60	37	36	35	36	36	36	36	47	57	64	72	77	82	84		64.4		88
Apr	83	84	85	86	87	87	85	76	66	59	51	47	44	41	41	41	49	58	66	74	76	79	82	84		64.6		87
May	84	84	84	87	87	86	87	78	70	65	60	57	55	54	55	57	66	69	72	77	80	82	84	84		73.3		87
Jun	84	84	86	86	86	85	86	78	74	71	69	67	67	69	70	74	76	77	81	83	86	87	90	91		81.1		91
Jul	91	92	92	92	92	92	92	87	84	79	76	75	75	75	76	76	80	81	85	87	88	89	90	91		84.7		92
Aug	91	91	92	92	92	92	91	91	83	82	79	76	75	75	76	76	79	81	84	86	88	89	90	90		84.4		91
Sept	92	92	91	91	91	91	88	88	81	77	75	76	76	76	76	77	81	85	87	89	90	91	92	92		85.4		92
Oct	91	91	91	91	91	91	91	75	69	64	62	62	63	64	71	77	81	85	87	89	90	91	91	91		80.2		91
Nov	83	84	91	91	90	91	90	85	84	67	64	64	67	68	69	69	67	75	79	83	85	87	89	89		78.4		91
Dec	88	89	90	91	90	91	91	84	67	59	51	44	44	43	43	44	51	64	72	78	81	84	86	87		71.2		91

Goa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Goa	Goa	Goa		
Jan	76	79	81	81	81	82	82	80	69	56	47	44	40	42	45	47	51	56	62	66	69	67	69	72		61.9		82
Feb	79	80	81	81	82	82	77	66	53	45	41	44	46	49	50	53	56	60	67	70	73	72	71	77		64.1		82
Mar	79	79	79	81	81	82	81	66	49	36	30	33	52	53	54	54	59	63	63	68	70	71	74	73		67.9		82
Apr	78	78	77	77	78	78	80	77	63	54	47	54	57	58	59	60	62	65	69	71	72	72	73	73		68.9		80
May	77	77	76	79	80	81	81	76	67	60	61	60	59	59	61	63	66	70	72	74	74	74	75	77		70.9		81
Jun	85	86	87	87	87	87	87	86	76	73	72	72	72	73	75	76	77	78	82	86	86	86	87	89		80.4		89
Jul	89	89	90	89	90	89	89	89	87	86	84	84	84	83	83	84	84	85	86	87	87	89	88	89		86.6		90
Aug	87	87	88	87	87	87	87	87	86	82	80	80	82	82	82	83	83	84	86	87	87	88	87	89		84.7		89
Sept	92	92	92	91	90	91	91	90	85	81	78	77	78	77	76	77	78	81	84	85	87	87	87	89		84.5		92
Oct	89	89	90	90	90	90	90	86	77	68	61	60	59	61	63	66	69	72	77	80	81	81	84	84		77.4		90
Nov	81	85	84	85	83	82	81	75	55	47	39	35	35	37	41	45	52	59	67	69	71	73	73	76		60.4		85
Dec	79	82	84	83	84	84	83	79	69	57	47	43	44	46	50	53	58	65	69	71	73	73	75	78		67.9		84

Jodhpur	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Jodhpur	Jodhpur	Jodhpur		
Jan	41	47	49	47	49	51	53	54	50	46	38	33	28	25	23	23	23	25	29	33	36	36	38	39		39.7		54
Feb	33	33	35	37	39	41	43	44	41	37	31	26	21	19	17	16	16	17	19	22	24	26	27	29		28.7		44
Mar	29	29	29	31	33	35	37	38	35	31	26	21	19	15	16	13	13	13	15	16	19	21	22	27		22.7		36
Apr	24	25	27	29	31	34	36	35	32	26	23	19	16	14	13	11	11	11	13	14	16	17	19	21		19.1		34
May	27	29	31	35	39	41	43	42	38	34	26	20	17	15	14	14	14	14	15	17	19	22	23	25		24.1		43
Jun	47	51	54	59	62	64	67	65	60	55	49	41	33	34	31	29	30	35	32	34	37	39	41	45		45.7		67
Jul	72	76	79	78	80	82	81	79	74	69	64	59	57	53	52	52	52	56	56	60	67	69	69	73		66.3		82
Aug	74	79	81	82	84	85	84	83	79	74	69	66	64	60	58	59	56	57	59	62	65	68	71	73		71.0		86
Sept	77	79	81	83	86	86	87	83	79	76	68	64	59	56	50	51	52	53	54	57	61	64	67	72		68.6		87
Oct	65	67	69	71	74	77	79	78	74	70	61	56	50	46	43	43	43	44	45	47	53	56	59	61		59.1		79
Nov	37	39	43	45	48	47	48	49	48	44	38	28	22	21	20	21	21	24	27	30	32	33	35	36		34.9		61
Dec	43	45	47	49	51	53	55	54	52	47	41	35	29	26	25	25	26	29	33	36	36	39	41	42		40.9		53

Madras	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Madras	Madras	Madras		
Jan	89	91	92	92	91	92	91	89	77	66	61	59	57	57	59	60	63	69	73	77	80	82	84	86		76.7		92
Feb	89	91	92	93	93	94	94	88	75	67	56	52	50	51	52	56	59	66	73	78	80	83	85	87		74.9		94
Mar	88	89	91	92	92	93	91	87	69	59	52	50	49	51	52	55	60	68	75	78	79	82	84	86		73.7		93
Apr	87	88	89	90	90	91	89	84	66	54	52	52	53	55	56	58	61	71	77	80	82	83	84	86		74.1		91
May	79	79	78	78	80	81	77	69	60	52	48	45	44	45	46	52	56	65	72	76	78	78	79	79		66.4		81
Jun	75	74	74	73	73	73	71	66	58	53	50	45	41	42	43	47	54	62	68	72	75	76	76	75		63.1		76
Jul	77	77	77	76	76	76	77	72	65	60	55	52	49	48	49	53	58	64	69	72	76	77	79	78		67.8		79
Aug	84	85	84	85	84	84	81	78	71	65	60	56	54	53	54	58	64	71	78	82	83	84	84	85		73.9		85
Sept	88	88	88	88	88	89	87	83	72	66	61	58	56	55	57	62	67	74	80	83	85	87	87	88		76.5		89

Oct	91	91	97	92	98	96	97	89	79	73	67	65	66	66	65	64	72	76	82	85	87	87	89	91	84	1	94
Nov	9.	93	93	94	94	94	94	94	79	74	71	69	68	69	69	70	75	79	81	87	85	87	89	90	82	5	94
Dec	91	91	91	93	93	93	93	89	78	71	66	64	63	6	66	66	69	74	79	81	84	86	89	89	79	4	93

Nagpur	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Nagpur		Nagpur	
Jan	71	73	75	77	74	80	81	78	81	81	81	76	75	76	70	69	71	73	77	79	81	83	84	84	56	1		81
Feb	81	83	84	85	81	83	84	84	87	89	87	85	85	84	83	83	83	85	86	87	89	90	91	87	60	3		87
Mar	83	84	87	90	91	94	95	89	89	91	89	84	84	81	79	79	81	83	85	87	89	90	91	87	61	3		87
Apr	78	80	81	83	85	87	87	81	85	83	81	80	80	78	76	76	78	81	83	85	87	89	90	84	63	4		85
May	73	75	77	79	81	83	85	77	74	73	70	68	68	67	65	65	67	69	71	73	75	77	78	74	64	4		81
Jun	66	67	69	69	71	71	73	68	64	63	61	60	60	61	61	63	65	66	68	70	72	73	74	68	64	4		73
Jul	69	69	70	70	70	71	71	67	63	62	61	60	60	61	61	62	64	65	67	69	70	71	72	67	64	4		71
Aug	73	73	74	74	74	74	74	71	68	67	66	65	65	65	65	66	67	68	69	70	71	72	73	69	64	4		72
Sept	71	72	73	73	73	73	73	70	67	66	65	64	64	64	64	65	66	67	68	69	70	71	72	68	64	4		71
Oct	83	84	84	84	84	84	84	81	78	77	76	75	75	75	75	76	77	78	79	80	81	82	83	79	64	4		81
Nov	77	78	79	80	81	82	84	85	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	84	64	4		86
Dec	79	80	82	83	85	86	87	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	86	64	4		88

New Delhi	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	New Delhi		New Delhi	
Jan	80	81	83	85	86	86	87	87	86	87	89	88	88	88	88	88	89	89	89	89	89	89	89	87	64	2		87
Feb	65	66	71	72	73	75	76	73	69	69	68	68	68	68	68	68	68	68	68	68	68	68	68	70	64	4		68
Mar	56	59	61	64	66	68	69	66	64	64	63	63	63	63	63	63	63	63	63	63	63	63	63	63	64	4		63
Apr	40	42	45	47	49	51	52	47	49	49	48	48	48	48	48	48	48	48	48	48	48	48	48	48	64	4		48
May	29	29	31	33	34	36	37	34	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	35	64	4		36
Jun	6*	6*	9*	11	13	14	16	14	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	15	64	4		16
Jul	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	64	4		76
Aug	87	88	89	89	90	90	90	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	64	4		89
Sept	83	84	85	85	86	86	87	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	64	4		86
Oct	73	75	77	78	79	80	80	78	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	64	4		76
Nov	76	77	78	78	78	79	80	79	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	64	4		78
Dec	79	80	81	83	84	85	86	84	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	64	4		78

Poona	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Poona		Poona	
Jan	64	65	71	74	76	79	80	78	81	83	84	84	84	84	84	84	84	84	84	84	84	84	84	84	51	0		82
Feb	51	54	57	60	62	65	67	65	62	63	64	64	64	64	64	64	64	64	64	64	64	64	64	64	51	0		64
Mar	47	49	51	53	55	58	59	55	45	47	48	48	48	48	48	48	48	48	48	48	48	48	48	48	51	0		48
Apr	38	42	44	46	48	50	51	48	43	45	46	46	46	46	46	46	46	46	46	46	46	46	46	46	51	0		46
May	27	29	31	33	34	36	37	34	30	32	33	33	33	33	33	33	33	33	33	33	33	33	33	33	51	0		33
Jun	19	20	22	24	25	27	28	25	21	23	24	24	24	24	24	24	24	24	24	24	24	24	24	24	51	0		24
Jul	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	51	0		16
Aug	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	51	0		19
Sept	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	51	0		21
Oct	42	43	44	45	46	47	48	46	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	51	0		44
Nov	56	57	58	59	60	61	62	60	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	51	0		58
Dec	74	75	76	77	78	79	80	78	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	51	0		74

Port Blair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	14	17	18	19	20	21	22	23	24	Port Blair		Port Blair	
Jan	87	88	88	89	89	89	89	88	85	78	69	63	62	63	63	64	69	75	79	81	83	85	86	87	79	1		83
Feb	91	92	93	94	94	94	94	93	86	80	71	65	64	65	65	65	70	76	80	84	86	87	89	91	79	4		84
Mar	94	95	96	96	96	96	96	95	88	81	73	67	66	67	67	67	72	78	82	85	87	89	91	92	79	4		85
Apr	94	95	95	95	95	95	95	94	87	80	72	66	65	66	66	66	71	77	82	85	87	89	91	92	79	4		85
May	94	94	94	94	94	94	94	93	86	79	71	65	64	65	65	65	70	76	81	84	86	88	90	91	79	4		84
Jun	94	94	94	93	93	93	93	92	85	78	70	64	63	64	64	64	69	75	80	83	85	87	89	90	79	4		83
Jul	93	93	93	93	93	93	93	92	85	78	70	64	63	64	64	64	69	75	80	83	85	87	89	90	79	4		83
Aug	94	94	94	94	94	94	94	93	86	79	71	65	64	65	65	65	70	76	81	84	86	88	90	91	79	4		84
Sept	95	95	95	95	95	95	95	94	87	80	72	66	65	66	66	66	71	77	82	85	87	89	91	92	79	4		85
Oct	95	95	95	95	95	95	95	94	87	80	72	66	65	66	66	66	71	77	82	85	87	89	91	92	79	4		85
Nov	95	95	95	95	95	95	95	94	87	80	72	66	65	66	66	66	71	77	82	85	87	89	91	92	79	4		85
Dec	95	95	95	95	95	95	95	94	87	80	72	66	65	66	66	66	71	77	82	85	87	89	91	92	79	4		85

Shillong	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	14	17	18	19	20	21	22	23	24	Shillong		Shillong	
Jan	75	76	76	76	72	72	68	59	58	6.	62	66	68	69	69	72	81	86	84	85	86	87	73	77	67	8		76
Feb	77	77	77	72	71	70	65	57	45	39	39	41	44	49	57	65	73	75	75	76	74	73	73	7.	61	8		70
Mar	64	64	64	65	67	64	59	51	40	37	36	36	39	39	49	59	70	81	85	85	85	85	84	69	55	4		64
Apr	75	75	77	77	77	74	69	61	51	50	51	50	52	53	55	58	65	72	75	75	75	75	75	77	64	5		72
May	83	81	81	80	8.	81	7.	73	64	64	66	65	64	66	68	71	75	80	83	88	87	87	87	82	74	0		78
Jun	89	90	90	90	91	90	85	84	80	79	78	78	78	79	80	81	84	86	89	89	89	89	89	89	85	4		91
Jul	92	92	93	93	93	93	90	89	81	80	79	79	79	79	79	82	85	87	89	90	91	92	92	93	86	7		93
Aug	91	91	91	92	92	92	89	85	80	79	78	77	78	77	79	81	83	85	88	90	91	91	90	90	84	6		92
Sept	90	91	91	91	91	90	87	81	79	80	80	81	81	81	83	85	87	89	91	91	91	91	91	91	87	5		91
Oct	88	88	88	8.	87	87	71	64	67	69	73	75	78	8.	87	90	91	90	87	85	84	84	87	87	8.	6		91
Nov	77	77	77	77	76	76	69	60	52	52	56	57	60	66	73	83	89	90	89	86	86	82	80	79	72	5		76
Dec	74	73	7.	73	73	72	69	59	49	46	50	51	53	60	72	82	88	89	89	87	83	81	77	75	70	4		69

Trivendru	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Trivendrum		Trivendrum	
Jan	85	86	87	87	87	87	87	86	82	79	76	74	73	73	73	73	77	79	81	83	85	86	87	87	72	9		87
Feb	84	85	85	85	84	84	85	83	78	74	71	69	68	68	68	68	72	76	79	81	83	84	85	85	71	5		84
Mar	86	87	88	89	89	90	90	87	83	80	77	75	74	74	74	74	78	82	85	87	89	90	91	91	78	5		90
Apr	90	91	91	92	93	93	93	90	86	82	79	77	76	76	76	76	79	83	86	88	90	91	92	92	79	3		91
May	91	92	92	92	93	93	94	92	88	84	81	79	78	78	78	78	81	84	87	89	91	92	93	93	82	6		92
Jun	94	94	94	94	94	94	94	93	89	85	82	80	79	79	79	79	82	85	88	90	91	92	93	93	84	7		93
Jul	94	94	94	94	94	94	94	93	89	86	83	81	80	80	80	80	83	86	88	90	91	92	93	93	85	7		93
Aug	94	94	94	94	94	94	94	93	89	86	83	81	80	80	80	80	83	86	88	90	91	92	93	93	85	7		93
Sept	94	94	94	94	94	94	94	93	89	86	83	81	80	80	80	80	83	86	88	90	91	92	93	93	85	7		93
Oct	94	94	94	94	94	94	94	93	89	86	83	81	80	80	80	80	83	86	88	90	91	92	93	93	85	7		93
Nov	93	93	93	93	93	93	94	91	87	83	80	78	77	77	77	77	80	83	86	88	90	91	92	92	83	7		92
Dec	90	90	91	90	90	90	90	88	83	79	76	74	73	73	73	73	77	80	83	85	87	89	89	89	79	7		91

Vishakapa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	14	17	18	19	20	21	22	23	24	Vishakapatn		Vishakapatn	
Jan	87	88	88	89	89	90	90	9.	87	84	83	84	84	84	84	84	84	84	84	84	84	84	84	84	73	0		90
Feb	87	88	89	90	90	91	91	89	85	82	80	80	80	80	80	80	80	80	80	80	80	80	80	80	73	0		80
Mar	86	87	88	89	89	89	89	87	83	80	78	77	76	76	76	76	76	76	76	76	76	76	76	76	73	0		76
Apr	87	87	88	88	88	88	88	86	83	81	79	78	77	77	77	77	77	77	77	77	77	77	77	77	73	0		77
May	88	88	88	88	88	88	88	87	84	82	80	79	78	78	78	78	78	78	78	78	78	78	78	78	73	0		78
Jun	91	91	91	91	91	91	91	90	87	84	82	80	79	79	79	79	79	79	79	79	79	79	79	79	73	0		79
Jul	89	89	89	89	89	89	89	87	83	79	77	76	76	76	76	76	76	76	76	76	76	76	76	76	73	0		76
Aug	87	87	87	87	87	87	87	85	81	78	76	75	74	74	74	74	74	74	74	74	74	74	74	74	73	0		74
Sept	90	90	91	91	91	91	91	89	86	83	81	80	79	79	79	79	79	79	79	79	79	79	79	79	73	0		79
Oct	89	89	90	90	90	90	90	89	86	83	81	80	79	79	79	79	79	79	79	79	79	79	79	79	73	0		79
Nov	85	86	87	88	88	88	88	87	84	82	80	79	78	78	78	78	78	78	78	78	78	78	78	78	73	0		78
Dec	84	84	86	85	86	86	85	85	82	80	78	77	76	76	76	76	76	76	76	76	76	76	76	76	73	0		76

Agra	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
6 30	73	62	50	03	69	69	75	84	77	61	59	70
17 70	66	35	70	29	29	37	65	75	65	69	68	55
Agra	59 5	68 5	69 0	36 0	36 5	43 0	70 0	79 5	71 0	56 0	53 5	62 5
Agra	73	62	50	03	69	69	75	84	77	63	59	70

Ahmda	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
5 30	58	37	35	33	3[illegible]	66	87	90	89	74	65	66
6 30	5.	36	36	31	38	65	81	84	88	62	53	56

12 30	35	23	23	20	21	50	70	72	65	68	37	40
17 30	29	14	17	17	15	39	49	61	64	38	33	35
23 30	45	29	27	25	27	55	62	69	81	62	52	57
Anola	43.6	27.8	27.4	25.2	29.4	54.0	77.6	79.8	75.2	54.0	41.0	50.6
Anola	58	37	35	33	33	66	87	90	89	78	65	69
Birener	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
5 30	36	43	56	50	47	59	74	80	76	63	45	71
7 30	62	54	66	58	51	62	69	72	69	67	64	54
11 30	39	34	34	29	29	46	53	54	51	37	35	43
17 30	32	25	26	18	23	37	46	50	48	32	31	35
Birener	50.8	43.5	38.6	33.0	30.3	43.5	64.5	65.5	60.0	41.8	45.0	51.5
Birener	70	63	56	50	47	63	76	80	76	63	65	73
Cutlack	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
8 30	81	77	74	71	71	75	85	84	80	75	74	74
19 30	53	47	45	52	55	61	62	81	74	71	54	55
Cutlack	67.6	62.0	59.5	61.5	63.0	70.5	82.5	82.0	81.5	74.4	67.6	65.5
Cutlack	81	77	74	71	71	75	85	84	80	75	74	74
Dharwar	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
5 30	74	64	71	66	69	92	94	94	95	84	81	89
8 30	79	58	61	68	77	84	84	88	89	80	74	77
11 30	69	57	57	62	50	65	74	71	69	57	54	57
17 30	47	41	39	39	48	64	75	73	68	56	50	51
23 30	61	52	59	64	61	89	92	91	91	79	69	67
Dharwar	54.6	46.6	52.0	54.2	64.0	78.2	84.4	83.6	84.0	71.6	65.6	66.6
Dharwar	74	64	71	66	69	92	94	94	95	84	81	89
Fota	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
5 30	62	69	69	57	72	58	78	85	87	69	63	66
8 30	56	44	55	45	57	50	71	80	78	53	50	60
11 30	39	29	26	39	39	34	66	71	60	39	32	61
17 30	31	22	19	35	34	32	59	72	61	31	31	39
23 30	69	36	32	29	28	69	76	80	79	53	50	57
Fota	47.6	36.0	29.0	37.6	37.0	43.0	69.2	77.6	70.6	47.0	45.0	52.2
Fota	62	69	69	57	72	58	78	85	87	69	63	66
Gilgarra	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
4 30	86	89	85	87	89	91	94	94	93	93	91	89
9 30	85	88	84	84	91	94	95	94	96	94	92	89
8 30	73	73	75	76	82	83	90	89	86	82	79	76
11 30	56	56	61	69	75	80	91	79	76	77	66	53
17 30	42	41	49	73	77	81	85	92	89	76	71	65
23 30	87	82	85	83	87	91	95	92	91	91	87	85
Gilgarra	74.3	74.6	74.2	78.5	83.0	87.6	89.2	93.2	86.7	85.3	81.0	77.2
Gilgarra	86	89	85	89	91	94	95	94	96	94	92	89
Gilgwa1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
5 30	88	84	79	66	90	95	97	96	94	94	91	90
8 30	74	72	65	70	79	84	87	87	89	80	78	75
11 30	51	47	46	55	67	72	75	75	72	68	57	53
17 30	41	38	37	62	72	81	81	81	81	66	72	69
Gilgwa1	64.5	61.3	49.0	64.3	76.5	84.0	85.5	85.0	83.3	67.5	71.3	71.0
Gilgwa1	89	88	79	84	90	95	97	97	96	94	91	90
Tuticorin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
8 30	79	77	76	77	65	61	60	59	60	73	69	61
17 30	78	75	76	73	67	52	53	55	56	69	76	77
Tuticorin	78.5	76.1	75.9	74.6	64.0	56.5	56.5	57.0	58.0	71.0	76.0	79.0
Tuticorin	79	77	76	73	67	61	60	59	60	73	80	81

Saturation Vapour Pressure. ea (mbars)

St# Eto	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Agra	27.2	78.0	169	16.7	21.2	29.0	40.9	50.9	56.5	45.1	40.3	38.5	33.8	24.2	17.7
2	Ahmadabad	23.1	72.6	55	23.6	28.1	35.9	45.2	53.3	48.4	40.5	38.2	38.2	37.8	30.7	25.5
3	Akola	20.7	77.0	282	25.7	30.0	38.0	48.1	54.1	47.7	37.8	35.7	36.1	34.5	29.0	25.4
4	Allahabad/Bamhrauli	25.5	81.7	98	18.4	22.8	32.0	44.9	53.5	56.5	43.1	40.4	40.2	34.5	25.7	18.8
5	Amini	11.1	72.7	4	38.2	40.4	42.7	44.9	45.0	38.6	37.8	36.6	37.8	38.5	38.2	38.0
6	Amritsar/Rajasansi	31.6	74.9	234	13.8	16.9	22.3	31.7	40.3	48.4	42.9	41.0	38.4	30.3	20.1	14.7
7	Bangalore	13.0	77.6	921	25.0	28.2	32.5	36.1	35.7	30.5	28.6	28.6	28.6	28.5	25.7	24.3
8	Sagar	23.9	78.8	551	20.1	24.9	31.9	41.0	50.5	45.1	34.2	32.0	32.2	31.9	26.5	21.4
9	Bikaner	28.0	73.3	224	15.8	20.6	28.6	40.3	50.7	56.4	50.3	45.7	42.7	36.0	23.8	17.0
10	Bombay/Colaba.India	18.9	72.8	11	30.5	32.2	35.7	38.5	42.7	40.2	36.1	35.9	36.3	38.3	38.0	34.0
11	Bombay/Santa Cruz	19.1	72.9	14	29.8	30.5	34.3	38.7	43.0	38.7	35.9	34.2	34.5	36.1	35.9	32.5
12	Calcutta/Alipore	22.5	88.3	6	23.5	26.9	35.8	43.2	45.1	43.0	38.7	40.2	38.6	36.3	28.6	23.6
13	Calcutta/Dum Dum	22.7	88.5	6	23.7	28.7	36.6	43.2	45.2	43.0	40.3	40.2	38.7	36.4	29.9	24.0
14	Cuttack	20.5	85.9	27	26.5	32.1	40.1	45.4	50.4	45.4	38.6	38.7	40.2	37.8	31.8	26.7
15	Belguam/Samra	15.9	74.6	747	26.6	29.0	34.1	37.9	36.3	30.6	27.3	28.1	28.7	30.4	28.5	26.7
16	Dibrugarh/Mohanbari	27.5	95.0	111	18.6	20.7	25.1	28.9	31.9	35.7	36.6	36.5	36.0	31.7	24.1	19.8
17	Masulipatam	16.2	81.1	3	28.8	31.8	35.9	40.4	47.6	45.3	38.5	38.3	38.3	36.4	32.4	29.0
18	Gauhti	26.1	91.6	54	19.8	22.5	28.2	33.8	34.5	38.1	40.2	40.1	38.1	33.7	25.8	21.1
19	Goa/Panjim	15.5	73.8	57	32.3	33.6	35.9	38.7	40.6	36.2	34.0	34.0	34.1	36.1	36.0	34.0
20	Begampet	17.5	78.5	545	25.5	29.8	36.2	42.6	47.7	40.2	33.8	32.5	32.3	31.7	26.9	24.9
21	Indore	22.7	75.8	567	20.1	24.1	30.5	40.4	47.8	42.6	34.1	31.8	31.7	30.5	25.4	21.4
22	Jogdalapur	19.1	82.0	553	23.8	28.1	34.4	40.8	45.3	38.4	32.2	32.0	32.5	31.8	26.5	23.4
23	Jaipur/Sanganer	26.8	75.8	390	17.8	21.4	29.9	40.6	48.3	50.5	40.6	37.9	36.6	33.6	24.0	20.0
24	Jodhpur	26.3	73.0	224	19.7	24.2	32.5	43.0	53.4	51.1	45.4	41.0	40.4	38.0	28.3	21.3
25	Kodaikanal	10.2	77.5	2343	14.9	15.5	16.9	17.4	17.9	17.7	16.3	16.9	16.8	16.3	15.0	14.6
26	Kota	25.2	75.9	257	19.9	25.4	34.1	47.7	56.5	53.6	42.4	37.8	38.0	36.2	28.3	22.0
27	Madras/Minambakkam	13.0	80.2	16	30.4	33.6	38.1	42.9	48.2	45.8	42.7	40.7	40.5	37.8	32.4	30.6
28	Minicoy	8.3	73.0	2	34.2	34.3	36.5	38.4	38.4	36.5	36.1	35.9	35.8	35.9	35.7	34.4
29	Nagpur/Sonegaon	21.1	79.1	310	23.9	28.5	36.0	45.6	56.3	47.7	36.4	35.7	35.8	33.6	27.1	23.5
30	New Dehli-Safarjung	28.6	77.2	216	16.1	19.8	27.0	38.3	47.8	53.4	44.9	40.4	38.5	32.5	23.5	17.1
31	Dwarka	22.4	69.1	11	24.2	27.1	31.9	35.8	40.3	40.9	38.4	36.6	36.2	36.0	32.1	26.6
32	Fort Cochin	10.0	76.2	3	35.8	36.2	38.2	38.7	37.9	34.1	33.6	33.6	33.8	34.3	35.8	35.7
33	Patna	25.6	85.2	53	21.0	22.7	32.2	45.4	50.5	50.7	42.6	40.5	40.4	36.2	27.0	21.1
34	Port Blair	11.7	92.7	79	34.2	34.4	36.0	38.4	36.4	34.4	34.1	34.0	33.7	34.1	34.5	34.0
35	Poona	18.5	73.9	559	25.1	27.1	33.9	40.5	40.9	36.3	31.7	30.2	30.6	31.9	27.3	25.3
36	Shillong	25.6	91.9	1500	12.4	14.0	17.9	23.4	23.9	24.1	25.2	25.2	23.6	19.9	15.3	13.2
37	Silchar	24.8	92.8	29	20.0	22.6	28.2	32.4	34.3	36.0	36.5	36.4	36.5	33.7	26.7	21.2
38	Srinagar	34.1	74.8	1587	6.6	8.4	11.1	14.9	18.8	25.6	30.0	28.8	23.8	16.3	10.7	7.8
39	Trivandrum	8.5	77.0	64	34.5	36.1	38.1	38.5	37.8	34.3	33.7	33.9	34.2	34.1	34.3	34.3
40	Panam	9.3	79.3	11	33.7	34.5	38.0	40.7	41.0	40.5	40.1	38.7	38.7	37.8	34.4	33.9
41	Veraval	20.9	70.4	8	25.6	28.1	30.7	34.5	38.5	40.4	36.6	36.0	36.0	36.2	33.7	28.4
42	Vishakhapatnam	17.7	83.2	3	28.5	32.0	37.9	42.9	47.8	45.4	40.3	40.3	38.7	36.5	32.5	28.8

Look-up Table for ea

Temp (C)	ea (mbar)
0	6.1
1	6.6
2	7.1
3	7.6
4	8.1
5	8.7
6	9.3
7	10.0
8	10.7
9	11.5
10	12.3
11	13.1
12	14.0
13	15.0
14	16.1
15	17.0
16	18.2
17	19.4
18	20.6
19	22.0
20	23.4
21	24.9
22	26.4
23	28.1
24	29.8
25	31.7
26	33.6
27	35.7
28	37.8
29	40.1
30	42.4
31	44.9
32	47.6
33	50.3
34	53.2
35	56.2
36	59.4
37	62.8
38	66.3
39	69.9

Temperature (degress C)

St# Eto	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Agra	27.2	78.0	169	14.6	18.6	23.9	29.8	33.6	35.3	31.2	29.2	28.7	26.2	20.8	15.7
2	Ahmadabad	23.1	72.6	55	20.2	23.0	27.2	31.3	34.1	32.8	29.4	28.4	28.4	28.0	24.9	21.6
3	Akola	20.7	77.0	282	21.8	24.2	28.2	32.5	34.9	32.1	28.0	27.0	27.4	26.9	23.9	21.5
4	Allahabad/Bamhrauli	25.5	81.7	98	16.2	19.8	25.3	31.0	34.3	35.3	30.7	29.3	29.1	26.9	21.8	16.6
5	Amini	11.1	72.7	4	28.4	29.3	30.3	31.0	31.1	28.8	28.0	27.9	28.0	28.7	28.4	28.2
6	Amritsar/Rajasansi	31.6	74.9	234	11.7	14.8	19.3	25.0	29.2	32.8	30.5	29.9	28.6	24.5	17.7	12.7
7	Bangalore	13.0	77.6	921	21.1	23.1	25.8	27.4	27.0	24.7	23.5	23.5	23.5	23.4	21.8	20.9
8	Sagar	23.9	78.8	551	17.7	21.0	25.2	29.9	33.2	31.2	26.6	25.3	25.5	25.2	22.1	18.8
9	Bikaner	28.0	73.3	224	13.8	18.0	23.5	29.2	33.4	35.2	33.0	31.8	30.3	27.3	20.4	14.9
10	Bombay/Colaba,India	18.9	72.8	11	24.7	25.5	27.0	28.7	30.3	29.1	27.4	27.2	27.6	28.5	28.2	26.4
11	Bombay/Santa Cruz	19.1	72.9	14	24.0	24.7	26.7	28.9	30.6	28.9	27.2	26.6	26.9	27.4	27.2	25.8
12	Calcutta/Alipore	22.5	88.3	6	20.1	22.5	27.1	30.8	31.2	30.6	28.9	29.1	28.8	27.6	23.5	20.2
13	Calcutta/Dum Dum	22.7	88.5	6	20.3	23.6	27.9	30.8	31.3	30.6	29.2	29.1	28.9	27.7	24.1	20.6
14	Cuttack	20.5	85.9	27	22.1	25.4	29.0	31.5	33.1	31.5	28.8	28.9	29.1	28.0	25.1	22.3
15	Belguam/Samra	15.9	74.6	747	22.2	23.9	26.5	28.1	27.6	24.8	22.9	23.0	23.6	24.6	23.4	22.3
16	Dibrugarh/Mohanbari	27.5	95.0	111	16.4	18.1	21.2	23.8	25.2	27.0	27.9	27.8	27.3	25.0	20.7	17.4
17	Masulipatam	16.2	81.1	3	23.7	25.1	27.2	29.3	32.0	31.4	28.7	28.5	28.5	27.7	25.7	23.9
18	Gauhti	26.1	91.6	54	17.4	19.5	23.1	26.2	26.9	28.3	29.1	29.0	28.3	26.1	21.9	18.5
19	Goa/Panjim	15.5	73.8	57	25.6	26.0	27.2	28.9	29.5	27.5	26.4	26.4	26.5	27.4	27.3	26.4
20	Begampet	17.5	78.5	545	21.6	24.0	27.5	30.2	32.1	29.1	26.2	25.8	25.6	25.0	22.5	21.0
21	Indore	22.7	75.8	567	17.7	20.7	24.7	29.3	32.2	30.2	26.5	25.1	25.0	24.7	21.5	18.8
22	Jogdalapur	19.1	82.0	553	20.4	23.0	26.8	29.7	31.4	28.6	25.5	25.3	25.8	25.1	22.1	20.0
23	Jaipur/Sanganer	26.8	75.8	390	15.8	18.8	24.1	29.5	32.7	33.2	29.5	28.1	27.9	26.0	20.6	17.6
24	Jodhpur	26.3	73.0	224	17.3	20.8	25.8	30.6	34.2	33.8	31.5	29.9	29.3	28.2	23.2	18.7
25	Kodaikanal	10.2	77.5	2343	12.9	13.5	14.8	15.4	15.9	15.7	14.2	14.8	14.7	14.2	13.0	12.6
26	Kota	25.2	75.9	257	17.5	21.5	26.5	32.1	35.3	34.4	30.0	28.0	28.2	27.5	23.2	19.0
27	Madras/Minambakkam	13.0	80.2	16	24.6	26.0	28.3	30.5	32.6	31.9	30.3	29.6	29.4	28.0	25.7	24.8
28	Minicoy	8.3	73.0	2	26.6	26.7	27.8	28.6	28.6	27.8	27.4	27.2	27.1	27.2	27.0	26.8
29	Nagpur/Sonegaon	21.1	79.1	310	20.5	23.4	27.3	31.7	35.1	32.1	27.7	27.0	27.1	26.0	22.7	20.1
30	New Dehli-Safarjung	28.6	77.2	216	14.0	17.4	22.6	28.5	32.2	34.2	31.0	29.3	28.7	25.8	20.1	15.1
31	Dwarka	22.4	69.1	11	20.8	22.7	25.2	27.1	29.2	29.8	28.6	27.9	27.5	27.3	25.4	22.2
32	Fort Cochin	10.0	76.2	3	27.1	27.5	28.4	28.9	28.1	26.5	26.0	26.0	26.2	26.7	27.1	27.0
33	Patna	25.6	85.2	53	18.4	19.7	25.5	31.5	33.2	33.4	30.2	29.4	29.3	27.5	22.6	18.5
34	Port Blair	11.7	92.7	79	26.6	26.8	27.3	28.6	27.7	26.8	26.5	26.4	26.1	26.5	26.9	26.4
35	Poona	18.5	73.9	559	21.2	22.7	26.3	29.4	29.8	27.6	25.0	24.4	24.8	25.2	22.9	21.4
36	Shillong	25.6	91.9	1500	9.9	11.9	15.9	20.0	20.5	20.7	21.3	21.3	20.2	17.5	13.3	10.9
37	Silchar	24.8	92.8	29	17.6	19.6	23.1	25.7	26.7	27.3	27.8	27.7	27.8	26.1	22.3	18.6
38	Srinagar	34.1	74.8	1587	0.5	3.8	8.4	12.9	16.6	21.7	24.2	23.7	20.4	14.2	7.7	2.7
39	Trivandrum	8.5	77.0	64	26.9	27.4	28.3	28.7	28.0	26.7	26.1	26.3	26.6	26.5	26.7	26.7
40	Panam	9.3	79.3	11	26.1	26.9	28.2	29.6	29.9	29.4	29.0	28.9	28.9	28.0	26.8	26.3
41	Veraval	20.9	70.4	8	21.7	23.0	24.9	26.9	28.7	29.3	27.9	27.3	27.3	27.5	26.1	23.3
42	Vishakhapatnam	17.7	83.2	3	23.4	25.3	28.1	30.5	32.2	31.5	29.2	29.2	28.9	27.8	25.8	23.7

APPENDIX J

EVAPOTRANSPIRATION
PENMAN METHOD

TOTAL NET RADIATION
(Rs)

Total Net Radiation. Rn = Rns - Rnl (mm/day)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	2.38	3.16	4.16	4.99	5.38	5.22	4.94	4.63	4.78	3.96	2.78	2.20
2	4	Ahmadabad	23.1	72.6	55	2.75	3.55	4.19	5.06	6.06	5.77	4.55	4.17	4.74	4.47	3.28	2.67
3	5	Akola	20.7	77.0	282	3.18	3.58	4.31	4.87	5.36	5.26	4.19	4.15	4.36	4.27	3.40	2.96
4	7	Allahabad	25.5	81.7	98	2.67	3.48	4.14	4.81	5.34	5.09	4.84	4.52	4.78	4.26	3.13	2.50
5	8	Amini Divi	11.1	72.7	4	4.65	5.36	6.09	6.09	5.17	4.19	4.06	4.47	4.97	4.68	4.54	4.31
6	9	Amritsar	31.6	74.9	234	1.85	2.72	3.73	4.85	5.51	5.66	5.58	5.39	4.75	3.64	2.36	1.65
7	14	Bangalor	13.0	77.6	897	4.04	4.71	5.05	5.34	5.16	4.32	3.78	4.11	4.27	4.20	4.07	3.77
8	21	Bhopal	23.3	77.4	503	2.85	3.51	4.12	4.76	5.37	5.20	4.15	3.84	4.37	4.18	3.21	2.57
9	24	Bikaner	28.0	73.3	224	2.19	3.05	4.17	5.27	6.00	6.67	6.27	5.73	5.41	3.81	2.54	1.99
10	26	Bombay	19.1	72.9	14	3.59	4.37	5.23	5.93	6.25	4.85	3.78	3.82	4.34	4.79	4.13	3.55
11	26	Bombay	19.1	72.9	14	3.59	4.33	5.18	5.93	6.26	4.82	3.78	3.79	4.30	4.73	4.07	3.51
12	27	Calcutta	22.7	88.5	6	3.10	3.91	4.78	5.69	5.93	4.49	4.35	4.21	4.15	4.11	3.45	2.89
13	27	Calcutta	22.7	88.5	6	3.11	3.96	4.80	5.69	5.93	4.49	4.38	4.21	4.15	4.11	3.49	2.89
14	34	Cuttack	20.5	85.9	24	3.52	4.27	4.95	5.53	6.06	4.66	4.13	4.27	4.30	4.37	3.74	3.27
15	36	Dharwar	15.4	75.1	679	4.12	4.79	5.45	5.61	5.42	4.22	3.55	3.91	4.27	4.41	4.07	3.85
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	2.39	2.98	3.93	4.12	4.62	4.30	4.48	4.77	3.99	3.80	2.98	2.35
17	39	Gannavaram	16.5	80.8	24	4.11	4.85	5.25	5.91	5.89	4.56	4.41	4.64	4.61	4.61	4.12	3.64
18	40	Gauhati	26.1	91.6	54	2.70	3.52	4.22	5.04	5.33	4.56	4.70	4.71	4.38	4.17	3.26	2.61
19	41	Goa	15.5	73.8	55	4.19	4.99	5.47	5.92	5.92	4.28	3.92	4.27	4.62	4.81	4.45	4.08
20	56	Hyderabad	17.5	78.5	545	3.74	4.30	4.75	5.30	5.45	4.81	4.25	4.46	4.49	4.58	3.92	3.45
21	59	Indore	22.7	75.8	567	2.84	3.39	4.17	4.72	5.41	5.17	4.09	3.76	4.28	3.99	3.03	2.55
22	61	Jagadalpur	19.1	82.0	553	3.60	4.28	5.01	5.57	5.56	4.79	3.97	3.94	4.14	4.39	3.77	3.37
23	62	Jaipur	26.8	75.8	390	2.34	3.07	3.86	4.52	4.93	4.92	4.45	4.30	4.73	3.87	2.69	2.13
24	69	Jodhpur	26.3	73.0	224	2.24	2.93	3.71	4.56	5.32	5.68	5.17	4.90	5.01	3.79	2.55	2.06
25	76	Kodaikanal	10.2	77.5	2345	3.89	4.41	4.76	4.74	4.35	3.74	3.41	3.72	3.79	3.61	3.42	3.43
26	79	Kota	25.2	75.5	257	2.55	3.28	4.03	4.71	5.29	5.61	4.70	4.35	4.77	3.95	2.90	2.43
27	86	Madras	13.0	80.2	16	4.38	5.31	5.88	6.23	5.84	4.96	4.56	4.84	4.93	4.65	4.19	3 88
28	89	Minicoy	8.3	73.0	2	5.08	5.59	5.84	5.71	5.09	4.37	4.38	5.00	4.96	5.03	4.94	4.58
29	92	Nagpur	21.2	79.1	311	3.25	3.82	4.42	4.96	5.33	4.98	4.11	4.07	4.40	4.49	3.60	3.08
30	97	New Dehli	28.6	77.2	216	2.22	3.04	3.85	4.64	5.00	4.78	4.97	4.86	4.61	3.86	2.71	2.04
31	99	Okha	22.5	69.1	7	3.23	4.38	5.24	6.08	6.48	5.46	4.49	4.37	5.14	5.12	3.79	2.84
32	100	Ollukara	10.5	76.3	22	4.76	5.25	5.70	5.52	4.67	3.88	3.51	3.81	4.25	4.41	4.50	4.24
33	105	Patna	25.5	85.3	52	2.78	3.46	4.36	5.17	6.07	5.65	5.19	5.07	4.88	4.42	3.32	2.62
34	107	Port Blair	11.7	92.7	79	4.63	5.43	5.86	5.95	4.67	4.00	4.02	4.11	4.15	4.58	4.63	4.41
35	108	Pune	18.5	73.9	563	3.49	4.04	4.70	5.32	5.86	4.94	3.97	4.03	4.37	4.47	3.82	3.34
36	123	Shillong	25.6	91.9	1598	2.31	3.16	3.95	4.64	4.83	3.94	3.92	3.79	3.66	3.33	2.55	2.14
37	124	Silicuri	24.8	92.9	40	2.76	3.48	4.38	4.98	5.09	4.45	4.59	4.50	4.36	3.92	3.16	2.59
38	127	Srinagar	34.1	74.8	1587	1.35	2.02	2.94	3.99	4.95	5.45	5.39	4.91	4.10	2.92	1.83	1.20
39	134	Trivandrum	8.5	77.0	64	4.77	5.25	5.56	5.22	4.79	4.00	4.07	4.61	4.78	4.50	4.28	4.33
40	135	Tuticorin	8.8	78.2	4	4.95	5.51	5.88	5.95	5.34	4.81	4.85	5.08	5.00	4.98	4.59	4.23
41	142	Veraval	20.9	70.4	8	3.29	4.35	5.54	5.97	6.68	5.89	4.44	4.33	5.18	4.91	3.84	3.13
42	144	Vishakhapatnam	17.7	83.2	3	4.07	4.91	5.46	6.04	6.23	4.64	4.26	4.71	4.68	4.71	4.12	3.66

Net Longwave Radiation. Rnl (mm/day)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	2.21	2.34	2.36	2.23	1.98	1.29	0.74	0.70	1.20	1.93	2.33	2.17
2	4	Ahmadabad	23.1	72.6	55	2.64	2.74	2.48	2.37	1.97	1.16	0.61	0.58	1.00	1.88	2.39	2.49
3	5	Akola	20.7	77.0	282	2.66	2.96	2.64	2.59	2.26	1.13	0.58	0.63	0.91	1.76	2.28	2.32
4	7	Allahabad	25.5	81.7	98	2.01	2.24	2.22	2.45	2.26	1.14	0.66	0.60	0.93	1.58	2.06	2.07
5	8	Amini Divi	11.1	72.7	4	1.37	1.34	1.31	1.06	0.77	0.60	0.56	0.70	0.91	0.91	1.08	1.18
6	9	Amritsar	31.6	74.9	234	1.83	1.90	1.71	1.93	2.13	1.58	0.93	0.93	1.20	1.80	2.10	1.92
7	14	Bangalor	13.0	77.6	897	1.85	1.88	1.98	1.73	1.33	0.87	0.65	0.79	0.91	1.06	1.33	1.54
8	21	Bhopal	23.3	77.4	503	2.52	2.72	2.62	2.61	2.52	1.28	0.60	0.55	1.02	1.99	2.45	2.40
9	24	Bikaner	28.0	73.3	224	2.47	2.53	2.49	2.65	2.69	1.92	1.24	1.21	1.69	2.49	2.53	2.43
10	26	Bombay	19.1	72.9	14	2.06	2.01	1.66	1.46	1.26	0.73	0.42	0.46	0.76	1.29	1.69	1.87
11	26	Bombay	19.1	72.9	14	2.06	2.05	1.70	1.46	1.26	0.76	0.42	0.49	0.80	1.36	1.76	1.92
12	27	Calcutta	22.7	88.5	6	1.83	1.81	1.47	1.25	0.98	0.51	0.53	0.50	0.63	1.00	1.62	1.80
13	27	Calcutta	22.7	88.5	6	1.82	1.77	1.46	1.25	0.98	0.51	0.50	0.50	0.62	1.00	1.58	1.79
14	34	Cuttack	20.5	85.9	24	1.93	1.84	1.51	1.28	1.14	0.67	0.50	0.57	0.67	1.08	1.68	1.97
15	36	Dharwar	15.4	75.1	679	2.10	2.09	1.79	1.40	1.25	0.80	0.52	0.66	0.91	1.23	1.69	1.96
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	1.52	1.34	1.35	0.90	0.77	0.53	0.56	0.73	0.68	1.10	1.59	1.68
17	39	Gannavaram	16.5	80.8	24	1.78	1.83	1.49	1.36	1.27	0.81	0.70	0.77	0.81	1.06	1.44	1.61
18	40	Gauhati	26.1	91.6	54	1.72	1.81	1.54	1.29	1.01	0.57	0.57	0.63	0.74	1.16	1.62	1.74
19	41	Goa	15.5	73.8	55	1.90	1.85	1.58	1.46	1.26	0.66	0.52	0.68	0.88	1.18	1.73	1.73
20	56	Hyderabad	17.5	78.5	545	2.19	2.44	2.20	2.01	1.98	1.08	0.75	0.87	1.01	1.43	1.85	2.05
21	59	Indore	22.7	75.8	567	2.63	2.93	2.65	2.80	2.61	1.25	0.60	0.53	1.07	2.27	2.64	2.51
22	61	Jagadalpur	19.1	82.0	553	2.13	2.18	2.24	1.82	1.49	0.88	0.55	0.57	0.78	1.27	1.74	2.02
23	62	Jaipur	26.8	75.8	390	2.38	2.57	2.44	2.53	2.34	1.31	0.68	0.67	1.22	2.20	2.59	2.48
24	69	Jodhpur	26.3	73.0	224	2.64	2.87	2.64	2.72	2.45	1.54	0.88	0.93	1.27	2.40	2.81	2.67
25	76	Kodaikanal	10.2	77.5	2345	1.77	1.94	1.82	1.50	1.24	0.90	0.69	0.83	0.92	0.92	1.10	1.42
26	79	Kota	25.2	75.5	257	2.53	2.74	2.60	2.70	2.64	1.53	0.75	0.69	1.17	2.11	2.45	2.43
27	86	Madras	13.0	80.2	16	1.54	1.64	1.43	1.22	1.11	1.01	0.83	0.86	0.90	0.92	1.12	1.25
28	89	Minicoy	8.3	73.0	2	1.51	1.52	1.34	1.23	1.01	0.78	0.78	0.97	0.99	1.06	1.21	1.24
29	92	Nagpur	21.2	79.1	311	2.28	2.56	2.37	2.34	2.24	0.99	0.58	0.56	0.86	1.60	2.14	2.19
30	97	New Dehli	28.6	77.2	216	2.02	2.23	1.93	2.14	1.89	1.15	0.76	0.77	1.13	1.89	2.28	2.10
31	99	Okha	22.5	69.1	7	2.15	1.93	1.51	1.27	1.13	0.78	0.57	0.62	1.11	1.37	1.89	1.94
32	100	Ollukara	10.5	76.3	22	1.43	1.40	1.25	1.05	0.74	0.54	0.42	0.51	0.69	0.84	1.06	1.17
33	105	Patna	25.5	85.3	52	2.07	2.27	2.12	2.00	1.71	0.94	0.67	0.74	0.87	1.34	1.93	2.05
34	107	Port Blair	11.7	92.7	79	1.39	1.51	1.38	1.19	0.73	0.57	0.57	0.59	0.63	0.88	1.13	1.29
35	108	Pune	18.5	73.9	563	2.36	2.63	2.44	2.16	1.73	1.03	0.59	0.67	0.96	1.52	1.98	2.13
36	123	Shillong	25.6	91.9	1598	1.63	1.94	1.84	1.48	1.19	0.64	0.61	0.66	0.82	1.23	1.51	1.62
37	124	Silicuri	24.8	92.9	40	1.93	1.83	1.71	1.35	0.99	0.59	0.63	0.68	0.81	1.08	1.60	1.86
38	127	Srinagar	34.1	74.8	1587	0.83	1.08	1.21	1.33	1.51	1.58	1.35	1.37	1.56	1.82	1.78	1.18
39	134	Trivandrum	8.5	77.0	64	1.45	1.44	1.23	0.95	0.81	0.62	0.63	0.81	0.89	0.84	0.93	1.18
40	135	Tuticorin	8.8	78.2	4	1.43	1.52	1.34	1.29	1.32	1.35	1.36	1.47	1.43	1.20	1.18	1.13
41	142	Veraval	20.9	70.4	8	2.34	2.13	1.88	1.48	1.26	0.91	0.57	0.59	1.08	1.53	1.97	2.24
42	144	Vishakhapatnam	17.7	83.2	3	1.85	1.81	1.39	1.17	1.02	0.67	0.56	0.72	0.81	1.16	1.58	1.81

Effect of the Ratio of Actual to Maximum Sunshine Hours on Longwave Radiation. f(n/N)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	0.807	0.822	0.807	0.783	0.723	0.582	0.469	0.464	0.661	0.816	0.869	0.816
2	4	Ahmadabad	23.1	72.6	55	0.890	0.899	0.790	0.804	0.828	0.658	0.403	0.372	0.598	0.842	0.901	0.898
3	5	Akola	20.7	77.0	282	0.921	0.900	0.813	0.799	0.772	0.585	0.351	0.374	0.510	0.747	0.842	0.854
4	7	Allahabad	25.5	81.7	98	0.783	0.834	0.759	0.786	0.762	0.546	0.446	0.432	0.605	0.783	0.845	0.816
5	8	Amini Divi	11.1	72.7	4	0.763	0.797	0.820	0.742	0.563	0.396	0.370	0.447	0.575	0.573	0.653	0.690
6	9	Amritsar	31.6	74.9	234	0.703	0.726	0.665	0.732	0.762	0.672	0.581	0.621	0.695	0.808	0.828	0.735
7	14	Bangalor	13.0	77.6	897	0.770	0.801	0.775	0.731	0.638	0.449	0.332	0.402	0.470	0.535	0.641	0.688
8	21	Bhopal	23.3	77.4	503	0.891	0.892	0.805	0.796	0.807	0.591	0.342	0.316	0.539	0.812	0.902	0.857
9	24	Bikaner	28.0	73.3	224	0.853	0.857	0.843	0.893	0.915	0.878	0.729	0.711	0.857	0.911	0.881	0.856
10	26	Bombay	19.1	72.9	14	0.841	0.842	0.790	0.787	0.762	0.474	0.271	0.297	0.474	0.737	0.837	0.848
11	26	Bombay	19.1	72.9	14	0.841	0.842	0.790	0.787	0.762	0.474	0.271	0.297	0.474	0.737	0.837	0.848
12	27	Calcutta	22.7	88.5	6	0.772	0.779	0.715	0.726	0.666	0.380	0.363	0.365	0.437	0.602	0.760	0.770
13	27	Calcutta	22.7	88.5	6	0.772	0.779	0.715	0.726	0.666	0.380	0.363	0.365	0.437	0.602	0.760	0.770
14	34	Cuttack	20.5	85.9	24	0.830	0.813	0.730	0.700	0.711	0.431	0.331	0.381	0.459	0.639	0.785	0.837
15	36	Dharwar	15.4	75.1	679	0.882	0.884	0.828	0.726	0.654	0.411	0.267	0.350	0.476	0.619	0.756	0.841
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	0.646	0.574	0.591	0.438	0.435	0.340	0.376	0.492	0.443	0.622	0.745	0.732
17	39	Gannavaram	16.5	80.8	24	0.839	0.862	0.753	0.768	0.721	0.457	0.419	0.477	0.519	0.635	0.735	0.748
18	40	Gauhati	26.1	91.6	54	0.735	0.764	0.660	0.644	0.578	0.388	0.411	0.466	0.509	0.691	0.789	0.776
19	41	Goa	15.5	73.8	55	0.859	0.877	0.798	0.783	0.731	0.397	0.323	0.407	0.528	0.680	0.835	0.841
20	56	Hyderabad	17.5	78.5	545	0.867	0.887	0.790	0.774	0.760	0.531	0.397	0.461	0.534	0.705	0.793	0.825
21	59	Indore	22.7	75.8	567	0.897	0.898	0.813	0.818	0.829	0.586	0.336	0.302	0.532	0.819	0.891	0.863
22	61	Jagadalpur	19.1	82.0	553	0.857	0.858	0.850	0.787	0.693	0.487	0.319	0.333	0.444	0.661	0.773	0.839
23	62	Jaipur	26.8	75.8	390	0.831	0.846	0.763	0.755	0.711	0.543	0.390	0.410	0.654	0.847	0.901	0.866
24	69	Jodhpur	26.3	73.0	224	0.854	0.868	0.765	0.792	0.786	0.688	0.523	0.541	0.706	0.862	0.907	0.880
25	76	Kodaikanal	10.2	77.5	2345	0.683	0.726	0.685	0.604	0.514	0.376	0.293	0.354	0.390	0.390	0.449	0.554
26	79	Kota	25.2	75.5	257	0.875	0.889	0.805	0.808	0.810	0.678	0.440	0.418	0.641	0.822	0.877	0.882
27	86	Madras	13.0	80.2	16	0.778	0.863	0.820	0.788	0.708	0.568	0.480	0.524	0.574	0.588	0.625	0.657
28	89	Minicoy	8.3	73.0	2	0.817	0.830	0.775	0.716	0.604	0.471	0.467	0.580	0.583	0.638	0.715	0.705
29	92	Nagpur	21.2	79.1	311	0.866	0.878	0.790	0.777	0.764	0.523	0.337	0.352	0.510	0.763	0.868	0.864
30	97	New Dehli	28.6	77.2	216	0.761	0.802	0.693	0.717	0.653	0.495	0.472	0.511	0.631	0.810	0.875	0.798
31	99	Okha	22.5	69.1	7	0.871	0.889	0.798	0.790	0.768	0.560	0.390	0.407	0.678	0.857	0.890	0.786
32	100	Ollukara	10.5	76.3	22	0.785	0.780	0.745	0.655	0.485	0.340	0.264	0.317	0.427	0.512	0.636	0.665
33	105	Patna	25.5	85.3	52	0.825	0.834	0.781	0.772	0.789	0.598	0.499	0.535	0.612	0.768	0.862	0.841
34	107	Port Blair	11.7	92.7	79	0.773	0.844	0.798	0.740	0.477	0.360	0.362	0.374	0.404	0.558	0.685	0.739
35	108	Pune	18.5	73.9	563	0.871	0.888	0.828	0.802	0.778	0.536	0.327	0.361	0.511	0.714	0.819	0.845
36	123	Shillong	25.6	91.9	1598	0.606	0.707	0.661	0.609	0.532	0.310	0.306	0.328	0.400	0.535	0.589	0.612
37	124	Silicuri	24.8	92.9	40	0.772	0.737	0.708	0.639	0.540	0.376	0.407	0.439	0.510	0.612	0.735	0.770
38	127	Srinagar	34.1	74.8	1587	0.313	0.410	0.454	0.513	0.591	0.637	0.612	0.622	0.666	0.703	0.674	0.446
39	134	Trivandrum	8.5	77.0	64	0.756	0.762	0.715	0.599	0.524	0.386	0.395	0.493	0.539	0.517	0.554	0.651
40	135	Tuticorin	8.8	78.2	4	0.788	0.823	0.783	0.760	0.689	0.627	0.632	0.667	0.658	0.655	0.655	0.629
41	142	Veraval	20.9	70.4	8	0.881	0.893	0.895	0.799	0.819	0.645	0.385	0.394	0.671	0.824	0.875	0.880
42	144	Vishakhapatnam	17.7	83.2	3	0.868	0.887	0.775	0.760	0.732	0.442	0.369	0.475	0.533	0.682	0.785	0.826

Effect of Vapour Pressure on Longwave Radiation, f(ed)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	0.201	0.199	0.190	0.171	0.156	0.123	0.093	0.091	0.110	0.149	0.182	0.194
2	4	Ahmadabad	23.1	72.6	55	0.203	0.201	0.194	0.173	0.134	0.101	0.091	0.096	0.102	0.137	0.170	0.186
3	5	Akola	20.7	77.0	282	0.193	0.213	0.199	0.187	0.164	0.113	0.102	0.105	0.111	0.147	0.176	0.183
4	7	Allahabad	25.5	81.7	98	0.185	0.185	0.186	0.184	0.167	0.116	0.087	0.085	0.093	0.126	0.163	0.183
5	8	Amini Divi	11.1	72.7	4	0.109	0.102	0.095	0.084	0.081	0.093	0.093	0.096	0.097	0.096	0.101	0.105
6	9	Amritsar	31.6	74.9	234	0.199	0.192	0.178	0.169	0.169	0.135	0.095	0.090	0.105	0.144	0.180	0.197
7	14	Bangalor	13.0	77.6	897	0.162	0.154	0.161	0.147	0.129	0.125	0.128	0.129	0.126	0.129	0.138	0.151
8	21	Bhopal	23.3	77.4	503	0.200	0.206	0.207	0.197	0.179	0.128	0.110	0.110	0.120	0.156	0.181	0.195
9	24	Bikaner	28.0	73.3	224	0.215	0.208	0.193	0.180	0.168	0.122	0.097	0.099	0.117	0.169	0.196	0.209
10	26	Bombay	19.1	72.9	14	0.157	0.151	0.130	0.113	0.099	0.093	0.095	0.096	0.098	0.107	0.124	0.138
11	26	Bombay	19.1	72.9	14	0.159	0.156	0.134	0.112	0.098	0.098	0.095	0.102	0.105	0.114	0.130	0.143
12	27	Calcutta	22.7	88.5	6	0.162	0.154	0.128	0.102	0.087	0.080	0.088	0.082	0.087	0.103	0.140	0.159
13	27	Calcutta	22.7	88.5	6	0.161	0.148	0.126	0.102	0.087	0.080	0.083	0.082	0.087	0.102	0.135	0.158
14	34	Cuttack	20.5	85.9	24	0.155	0.144	0.125	0.108	0.092	0.091	0.092	0.091	0.088	0.104	0.137	0.156
15	36	Dharwar	15.4	75.1	679	0.158	0.154	0.136	0.118	0.118	0.125	0.128	0.125	0.124	0.128	0.147	0.155
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	0.170	0.164	0.154	0.134	0.113	0.097	0.092	0.092	0.096	0.113	0.145	0.163
17	39	Gannavaram	16.5	80.8	24	0.138	0.135	0.123	0.107	0.102	0.103	0.101	0.099	0.095	0.103	0.123	0.140
18	40	Gauhati	26.1	91.6	54	0.166	0.163	0.153	0.126	0.109	0.091	0.083	0.082	0.089	0.105	0.137	0.157
19	41	Goa	15.5	73.8	55	0.140	0.132	0.123	0.113	0.104	0.102	0.101	0.104	0.104	0.107	0.128	0.129
20	56	Hyderabad	17.5	78.5	545	0.170	0.179	0.172	0.155	0.151	0.123	0.118	0.119	0.119	0.130	0.154	0.168
21	59	Indore	22.7	75.8	567	0.207	0.222	0.210	0.207	0.183	0.128	0.112	0.113	0.129	0.178	0.199	0.203
22	61	Jagadalpur	19.1	82.0	553	0.169	0.167	0.164	0.139	0.126	0.110	0.109	0.108	0.110	0.122	0.150	0.165
23	62	Jaipur	26.8	75.8	390	0.208	0.212	0.207	0.202	0.189	0.138	0.105	0.101	0.114	0.163	0.196	0.202
24	69	Jodhpur	26.3	73.0	224	0.220	0.224	0.218	0.204	0.176	0.127	0.099	0.103	0.109	0.170	0.204	0.212
25	76	Kodaikanal	10.2	77.5	2345	0.196	0.200	0.195	0.181	0.175	0.174	0.175	0.172	0.173	0.174	0.184	0.193
26	79	Kota	25.2	75.5	257	0.205	0.207	0.202	0.194	0.181	0.127	0.102	0.102	0.112	0.159	0.183	0.191
27	86	Madras	13.0	80.2	16	0.128	0.119	0.107	0.092	0.090	0.103	0.103	0.099	0.095	0.096	0.113	0.122
28	89	Minicoy	8.3	73.0	2	0.115	0.114	0.106	0.104	0.101	0.102	0.103	0.104	0.105	0.103	0.105	0.109
29	92	Nagpur	21.2	79.1	311	0.179	0.191	0.185	0.176	0.163	0.110	0.106	0.099	0.104	0.132	0.163	0.173
30	97	New Dehli	28.6	77.2	216	0.196	0.197	0.185	0.182	0.168	0.131	0.095	0.091	0.109	0.147	0.179	0.192
31	99	Okha	22.5	69.1	7	0.167	0.143	0.121	0.099	0.089	0.084	0.089	0.093	0.101	0.099	0.135	0.164
32	100	Ollukara	10.5	76.3	22	0.113	0.111	0.103	0.097	0.093	0.099	0.099	0.100	0.102	0.102	0.103	0.109
33	105	Patna	25.5	85.3	52	0.176	0.187	0.172	0.151	0.124	0.090	0.080	0.083	0.086	0.108	0.148	0.170
34	107	Port Blair	11.7	92.7	79	0.113	0.112	0.107	0.098	0.094	0.099	0.099	0.098	0.098	0.099	0.102	0.110
35	108	Pune	18.5	73.9	563	0.183	0.195	0.185	0.163	0.134	0.118	0.115	0.119	0.121	0.136	0.159	0.169
36	123	Shillong	25.6	91.9	1598	0.212	0.210	0.202	0.166	0.152	0.140	0.134	0.135	0.140	0.164	0.192	0.206
37	124	Silicuri	24.8	92.9	40	0.177	0.171	0.159	0.133	0.115	0.097	0.095	0.095	0.097	0.111	0.145	0.168
38	127	Srinagar	34.1	74.8	1587	0.238	0.226	0.214	0.196	0.184	0.166	0.142	0.143	0.160	0.191	0.214	0.229
39	134	Trivandrum	8.5	77.0	64	0.119	0.116	0.106	0.097	0.094	0.101	0.101	0.103	0.103	0.102	0.105	0.113
40	135	Tuticorin	8.8	78.2	4	0.114	0.115	0.105	0.102	0.115	0.130	0.131	0.133	0.132	0.112	0.112	0.112
41	142	Veraval	20.9	70.4	8	0.178	0.157	0.134	0.115	0.093	0.085	0.091	0.093	0.100	0.115	0.141	0.167
42	144	Vishakhapatnam	17.7	83.2	3	0.139	0.130	0.110	0.092	0.081	0.088	0.091	0.091	0.093	0.104	0.127	0.143

Effect of Temperature on Longwave Radiation, f(T)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	13.6	14.3	15.4	16.7	17.6	18.0	17.0	16.5	16.4	15.9	14.8	13.8
2	4	Ahmadabad	23.1	72.6	55	14.6	15.2	16.1	17.0	17.7	17.4	16.6	16.4	16.4	16.3	15.6	14.9
3	5	Akola	20.7	77.0	282	15.0	15.5	16.3	17.3	17.9	17.2	16.3	16.1	16.2	16.1	15.4	14.9
4	7	Allahabad	25.5	81.7	98	13.8	14.6	15.7	17.0	17.8	18.0	16.9	16.6	16.5	16.1	15.0	13.9
5	8	Amini Divi	11.1	72.7	4	16.4	16.6	16.8	17.0	17.0	16.5	16.3	16.3	16.3	16.4	16.4	16.3
6	9	Amritsar	31.6	74.9	234	13.0	13.6	14.5	15.7	16.5	17.4	16.8	16.7	16.4	15.5	14.1	13.2
7	14	Bangalor	13.0	77.6	897	14.8	15.2	15.9	16.2	16.1	15.6	15.3	15.3	15.3	15.3	15.0	14.8
8	21	Bhopal	23.3	77.4	503	14.1	14.8	15.7	16.7	17.5	17.0	16.0	15.7	15.8	15.7	15.0	14.4
9	24	Bikaner	28.0	73.3	224	13.5	14.2	15.3	16.5	17.6	17.9	17.5	17.2	16.8	16.2	14.7	13.6
10	26	Bombay	19.1	72.9	14	15.6	15.8	16.1	16.4	16.8	16.5	16.2	16.1	16.2	16.4	16.3	16.0
11	26	Bombay	19.1	72.9	14	15.4	15.6	16.0	16.5	16.9	16.5	16.1	16.0	16.1	16.2	16.1	15.9
12	27	Calcutta	22.7	88.5	6	14.6	15.1	16.1	16.9	17.0	16.9	16.5	16.5	16.5	16.2	15.3	14.6
13	27	Calcutta	22.7	88.5	6	14.7	15.3	16.3	16.9	17.0	16.9	16.5	16.5	16.5	16.2	15.4	14.7
14	34	Cuttack	20.5	85.9	24	15.0	15.8	16.5	17.1	17.5	17.1	16.5	16.5	16.5	16.3	15.7	15.1
15	36	Dharwar	15.4	75.1	679	15.0	15.4	16.0	16.3	16.2	15.6	15.2	15.2	15.3	15.6	15.3	15.1
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	13.9	14.2	14.8	15.4	15.7	16.1	16.3	16.3	16.2	15.7	14.7	14.1
17	39	Gannavaram	16.5	80.8	24	15.3	15.7	16.1	16.6	17.2	17.1	16.4	16.4	16.4	16.2	15.8	15.4
18	40	Gauhati	26.1	91.6	54	14.1	14.5	15.2	15.9	16.1	16.4	16.5	16.5	16.4	15.9	15.0	14.3
19	41	Goa	15.5	73.8	55	15.8	15.9	16.1	16.5	16.6	16.2	16.0	16.0	16.0	16.2	16.2	16.0
20	56	Hyderabad	17.5	78.5	545	14.9	15.4	16.2	16.8	17.2	16.5	15.9	15.9	15.8	15.7	15.1	14.8
21	59	Indore	22.7	75.8	567	14.1	14.7	15.6	16.6	17.3	16.8	16.0	15.7	15.7	15.6	14.9	14.4
22	61	Jagadalpur	19.1	82.0	553	14.7	15.2	16.1	16.6	17.1	16.4	15.8	15.7	15.9	15.7	15.0	14.6
23	62	Jaipur	26.8	75.8	390	13.8	14.4	15.4	16.6	17.4	17.5	16.6	16.3	16.3	15.9	14.7	14.1
24	69	Jodhpur	26.3	73.0	224	14.1	14.8	15.9	16.9	17.7	17.7	17.1	16.7	16.6	16.3	15.2	14.3
25	76	Kodaikanal	10.2	77.5	2345	13.3	13.4	13.6	13.7	13.8	13.8	13.5	13.6	13.6	13.5	13.3	13.2
26	79	Kota	25.2	75.5	257	14.1	14.9	16.0	17.2	18.0	17.8	16.7	16.3	16.3	16.2	15.2	14.4
27	86	Madras	13.0	80.2	16	15.6	15.9	16.4	16.8	17.4	17.2	16.8	16.6	16.6	16.3	15.8	15.6
28	89	Minicoy	8.3	73.0	2	16.0	16.0	16.3	16.4	16.4	16.3	16.2	16.1	16.1	16.1	16.1	16.1
29	92	Nagpur	21.2	79.1	311	14.7	15.3	16.2	17.1	17.9	17.2	16.2	16.1	16.1	15.9	15.1	14.6
30	97	New Dehli	28.6	77.2	216	13.5	14.1	15.1	16.4	17.3	17.7	17.0	16.6	16.4	15.9	14.6	13.7
31	99	Okha	22.5	69.1	7	14.8	15.1	15.7	16.1	16.5	16.7	16.4	16.3	16.2	16.2	15.8	15.0
32	100	Ollukara	10.5	76.3	22	16.1	16.2	16.4	16.5	16.3	16.0	15.9	15.9	15.9	16.0	16.1	16.1
33	105	Patna	25.5	85.3	52	14.3	14.5	15.8	17.1	17.5	17.6	16.8	16.6	16.6	16.2	15.1	14.3
34	107	Port Blair	11.7	92.7	79	16.0	16.1	16.2	16.4	16.2	16.1	16.0	16.0	15.9	16.0	16.1	16.0
35	108	Pune	18.5	73.9	563	14.8	15.1	16.0	16.6	16.7	16.2	15.7	15.5	15.6	15.7	15.2	14.9
36	123	Shillong	25.6	91.9	1598	12.7	13.1	13.8	14.6	14.7	14.7	14.9	14.9	14.6	14.1	13.4	12.9
37	124	Silicuri	24.8	92.9	40	14.1	14.5	15.2	15.8	16.0	16.2	16.3	16.2	16.3	15.9	15.1	14.3
38	127	Srinagar	34.1	74.8	1587	11.1	11.7	12.5	13.3	13.9	14.9	15.5	15.3	14.7	13.5	12.3	11.5
39	134	Trivandrum	8.5	77.0	64	16.1	16.2	16.4	16.4	16.3	16.0	15.9	16.0	16.0	16.0	16.0	16.0
40	135	Tuticorin	8.8	78.2	4	15.9	16.1	16.3	16.6	16.7	16.6	16.5	16.5	16.5	16.3	16.1	16.0
41	142	Veraval	20.9	70.4	8	14.9	15.2	15.6	16.1	16.4	16.6	16.3	16.2	16.2	16.2	15.9	15.3
42	144	Vishakhapatnam	17.7	83.2	3	15.3	15.7	16.3	16.8	17.3	17.1	16.5	16.5	16.5	16.3	15.9	15.3

Lookup Table

T(C)	f(T)
0	11.0
2	11.4
4	11.7
6	12.0
8	12.4
10	12.7
12	13.1
14	13.5
16	13.8
18	14.2
20	14.6
22	15.0
24	15.4
26	15.9
28	16.3
30	16.7
32	17.2
34	17.7
36	18.1

Net Shortwave Radiation. Rns (mm//day)
Reflectiveness of crop. a = 0.25

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	4.58	5.50	6.52	7.22	7.36	6.50	5.68	5.33	5.98	5.89	5.11	4.38
2	4	Ahmadabad	23.1	72.6	55	5.39	6.29	6.67	7.43	8.03	6.93	5.16	4.75	5.74	6.35	5.67	5.16
3	5	Akola	20.7	77.0	282	5.84	6.54	6.94	7.45	7.62	6.39	4.77	4.78	5.28	6.03	5.67	5.28
4	7	Allahabad	25.5	81.7	98	4.68	5.73	6.36	7.26	7.60	6.22	5.49	5.12	5.71	5.85	5.18	4.57
5	8	Amini Divi	11.1	72.7	4	6.02	6.70	7.40	7.14	5.94	4.79	4.62	5.17	5.88	5.59	5.61	5.50
6	9	Amritsar	31.6	74.9	234	3.68	4.61	5.44	6.78	7.65	7.24	6.52	6.32	5.95	5.44	4.46	3.57
7	14	Bangalor	13.0	77.6	897	5.88	6.60	7.03	7.07	6.48	5.19	4.43	4.90	5.18	5.26	5.39	5.30
8	21	Bhopal	23.3	77.4	503	5.37	6.23	6.74	7.37	7.89	6.48	4.75	4.38	5.38	6.17	5.66	4.97
9	24	Bikaner	28.0	73.3	224	4.66	5.58	6.66	7.93	8.69	8.60	7.51	6.94	7.09	6.31	5.08	4.42
10	26	Bombay	19.1	72.9	14	5.65	6.38	6.88	7.39	7.51	5.58	4.20	4.28	5.09	6.09	5.82	5.43
11	26	Bombay	19.1	72.9	14	5.65	6.38	6.88	7.39	7.51	5.58	4.20	4.28	5.09	6.09	5.82	5.43
12	27	Calcutta	22.7	88.5	6	4.93	5.73	6.26	6.93	6.91	5.01	4.88	4.71	4.77	5.11	5.07	4.69
13	27	Calcutta	22.7	88.5	6	4.93	5.73	6.26	6.93	6.91	5.01	4.88	4.71	4.77	5.11	5.07	4.69
14	34	Cuttack	20.5	85.9	24	5.45	6.11	6.46	6.81	7.20	5.33	4.63	4.83	4.97	5.45	5.43	5.23
15	36	Dharwar	15.4	75.1	679	6.22	6.88	7.24	7.01	6.67	5.02	4.07	4.58	5.17	5.64	5.77	5.81
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	3.91	4.31	5.28	5.02	5.39	4.83	5.04	5.51	4.67	4.89	4.56	4.02
17	39	Gannavaram	16.5	80.8	24	5.89	6.68	6.74	7.27	7.15	5.37	5.11	5.42	5.42	5.67	5.56	5.25
18	40	Gauhati	26.1	91.6	54	4.42	5.33	5.76	6.34	6.34	5.13	5.27	5.34	5.11	5.33	4.88	4.35
19	41	Goa	15.5	73.8	55	6.09	6.84	7.05	7.38	7.19	4.93	4.44	4.95	5.49	5.99	6.18	5.81
20	56	Hyderabad	17.5	78.5	545	5.94	6.74	6.95	7.31	7.44	5.89	4.99	5.33	5.50	6.01	5.77	5.50
21	59	Indore	22.7	75.8	567	5.47	6.32	6.83	7.53	8.03	6.42	4.70	4.29	5.35	6.26	5.67	5.06
22	61	Jagadalpur	19.1	82.0	553	5.73	6.46	7.25	7.39	7.05	5.67	4.52	4.51	4.91	5.66	5.51	5.39
23	62	Jaipur	26.8	75.8	390	4.72	5.65	6.30	7.05	7.27	6.23	5.13	4.97	5.95	6.07	5.28	4.61
24	69	Jodhpur	26.3	73.0	224	4.88	5.81	6.34	7.28	7.77	7.23	6.05	5.83	6.28	6.19	5.36	4.73
25	76	Kodaikanal	10.2	77.5	2345	5.66	6.35	6.59	6.24	5.59	4.64	4.10	4.55	4.71	4.52	4.52	4.84
26	79	Kota	25.2	75.5	257	5.08	6.02	6.63	7.40	7.93	7.13	5.45	5.04	5.94	6.07	5.35	4.86
27	86	Madras	13.0	80.2	16	5.92	6.95	7.31	7.45	6.95	5.97	5.40	5.70	5.83	5.57	5.30	5.14
28	89	Minicoy	8.3	73.0	2	6.59	7.11	7.17	6.94	6.09	5.15	5.15	5.98	5.95	6.09	6.15	5.82
29	92	Nagpur	21.2	79.1	311	5.53	6.38	6.79	7.30	7.57	5.97	4.69	4.64	5.26	6.09	5.74	5.27
30	97	New Dehli	28.6	77.2	216	4.24	5.27	5.78	6.79	6.89	5.93	5.73	5.63	5.74	5.75	4.99	4.14
31	99	Okha	22.5	69.1	7	5.38	6.30	6.75	7.35	7.61	6.24	5.06	4.98	6.24	6.49	5.68	4.77
32	100	Ollukara	10.5	76.3	22	6.19	6.65	6.96	6.58	5.41	4.42	3.93	4.32	4.94	5.25	5.56	5.41
33	105	Patna	25.5	85.3	52	4.85	5.72	6.48	7.17	7.78	6.59	5.86	5.80	5.75	5.76	5.25	4.67
34	107	Port Blair	11.7	92.7	79	6.02	6.94	7.24	7.13	5.40	4.58	4.59	4.70	4.78	5.46	5.76	5.70
35	108	Pune	18.5	73.9	563	5.85	6.67	7.14	7.49	7.59	5.97	4.55	4.69	5.33	5.99	5.80	5.48
36	123	Shillong	25.6	91.9	1598	3.94	5.10	5.79	6.12	6.03	4.58	4.53	4.44	4.48	4.56	4.06	3.76
37	124	Silicuri	24.8	92.9	40	4.69	5.31	6.09	6.33	6.08	5.04	5.22	5.18	5.16	5.00	4.76	4.45
38	127	Srinagar	34.1	74.8	1587	2.18	3.10	4.15	5.32	6.47	7.04	6.74	6.28	5.67	4.74	3.62	2.38
39	134	Trivandrum	8.5	77.0	64	6.22	6.68	6.79	6.18	5.59	4.62	4.70	5.42	5.67	5.34	5.21	5.51
40	135	Tuticorin	8.8	78.2	4	6.37	7.03	7.22	7.23	6.66	6.16	6.21	6.54	6.43	6.18	5.77	5.36
41	142	Veraval	20.9	70.4	8	5.63	6.48	7.42	7.45	7.94	6.80	5.01	4.92	6.26	6.44	5.81	5.37
42	144	Vishakhapatnam	17.7	83.2	3	5.91	6.72	6.85	7.21	7.25	5.30	4.81	5.43	5.49	5.87	5.70	5.47

Solar Radiation, Rs

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	6.11	7.34	8.70	9.63	9.81	8.67	7.58	7.10	7.97	7.86	6.82	5.84
2	4	Ahmadabad	23.1	72.6	55	7.19	8.39	8.89	9.90	10.71	9.24	6.88	6.33	7.66	8.47	7.56	6.89
3	5	Akola	20.7	77.0	282	7.79	8.72	9.25	9.94	10.16	8.52	6.37	6.38	7.04	8.04	7.57	7.04
4	7	Allahabad	25.5	81.7	98	6.24	7.64	8.47	9.68	10.13	8.30	7.33	6.83	7.61	7.80	6.91	6.09
5	8	Amini Divi	11.1	72.7	4	8.03	8.94	9.87	9.52	7.92	6.39	6.16	6.89	7.84	7.45	7.48	7.33
6	9	Amritsar	31.6	74.9	234	4.91	6.15	7.25	9.04	10.19	9.65	8.69	8.43	7.93	7.25	5.95	4.76
7	14	Bangalor	13.0	77.6	897	7.84	8.80	9.38	9.42	8.64	6.93	5.91	6.54	6.90	7.01	7.19	7.07
8	21	Bhopal	23.3	77.4	503	7.16	8.31	8.99	9.83	10.52	8.64	6.33	5.84	7.18	8.23	7.54	6.63
9	24	Bikaner	28.0	73.3	224	6.21	7.44	8.88	10.57	11.59	11.46	10.01	9.25	9.46	8.41	6.77	5.89
10	26	Bombay	19.1	72.9	14	7.53	8.50	9.18	9.85	10.02	7.44	5.59	5.70	6.79	8.12	7.77	7.24
11	26	Bombay	19.1	72.9	14	7.53	8.50	9.18	9.85	10.02	7.44	5.59	5.70	6.79	8.12	7.77	7.24
12	27	Calcutta	22.7	88.5	6	6.57	7.64	8.34	9.25	9.22	6.68	6.51	6.28	6.37	6.81	6.77	6.25
13	27	Calcutta	22.7	88.5	6	6.57	7.64	8.34	9.25	9.22	6.68	6.51	6.28	6.37	6.81	6.77	6.25
14	34	Cuttack	20.5	85.9	24	7.26	8.15	8.61	9.08	9.60	7.11	6.18	6.45	6.63	7.27	7.24	6.98
15	36	Dharwar	15.4	75.1	679	8.29	9.18	9.65	9.34	8.90	6.70	5.43	6.10	6.90	7.51	7.69	7.75
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	5.22	5.75	7.05	6.69	7.18	6.43	6.72	7.34	6.23	6.52	6.08	5.37
17	39	Gannavaram	16.5	80.8	24	7.85	8.90	8.99	9.69	9.54	7.16	6.81	7.22	7.23	7.56	7.41	7.00
18	40	Gauhati	26.1	91.6	54	5.89	7.10	7.68	8.45	8.46	6.85	7.02	7.11	6.82	7.10	6.51	5.80
19	41	Goa	15.5	73.8	55	8.13	9.12	9.40	9.84	9.58	6.58	5.92	6.60	7.33	7.98	8.23	7.75
20	56	Hyderabad	17.5	78.5	545	7.91	8.99	9.26	9.74	9.91	7.86	6.66	7.11	7.33	8.02	7.69	7.33
21	59	Indore	22.7	75.8	567	7.29	8.43	9.10	10.04	10.70	8.57	6.26	5.72	7.13	8.35	7.55	6.75
22	61	Jagadalpur	19.1	82.0	553	7.63	8.61	9.66	9.85	9.39	7.56	6.02	6.01	6.55	7.54	7.35	7.19
23	62	Jaipur	26.8	75.8	390	6.29	7.53	8.40	9.40	9.69	8.31	6.84	6.63	7.93	8.10	7.04	6.15
24	69	Jodhpur	26.3	73.0	224	6.51	7.74	8.46	9.70	10.36	9.64	8.06	7.77	8.37	8.25	7.15	6.31
25	76	Kodaikanal	10.2	77.5	2345	7.55	8.47	8.78	8.33	7.45	6.18	5.47	6.07	6.28	6.03	6.02	6.46
26	79	Kota	25.2	75.5	257	6.78	8.03	8.84	9.87	10.57	9.51	7.26	6.72	7.92	8.09	7.13	6.48
27	86	Madras	13.0	80.2	16	7.89	9.26	9.75	9.93	9.26	7.96	7.20	7.60	7.77	7.43	7.07	6.85
28	89	Minicoy	8.3	73.0	2	8.78	9.48	9.56	9.25	8.13	6.87	6.87	7.97	7.93	8.12	8.20	7.76
29	92	Nagpur	21.2	79.1	311	7.37	8.51	9.05	9.73	10.09	7.96	6.25	6.18	7.01	8.12	7.66	7.03
30	97	New Dehli	28.6	77.2	216	5.65	7.03	7.71	9.05	9.19	7.91	7.64	7.51	7.65	7.66	6.66	5.52
31	99	Okha	22.5	69.1	7	7.18	8.40	9.01	9.80	10.14	8.32	6.75	6.64	8.32	8.65	7.58	6.36
32	100	Ollukara	10.5	76.3	22	8.25	8.86	9.28	8.77	7.22	5.89	5.24	5.76	6.59	7.00	7.41	7.21
33	105	Patna	25.5	85.3	52	6.46	7.63	8.64	9.55	10.37	8.78	7.82	7.74	7.67	7.68	7.00	6.22
34	107	Port Blair	11.7	92.7	79	8.03	9.25	9.65	9.51	7.19	6.10	6.12	6.27	6.38	7.29	7.68	7.61
35	108	Pune	18.5	73.9	563	7.80	8.89	9.52	9.98	10.12	7.96	6.07	6.25	7.11	7.99	7.73	7.30
36	123	Shillong	25.6	91.9	1598	5.25	6.80	7.72	8.17	8.04	6.11	6.04	5.92	5.97	6.08	5.42	5.01
37	124	Silicuri	24.8	92.9	40	6.26	7.08	8.12	8.44	8.11	6.71	6.96	6.91	6.89	6.67	6.35	5.93
38	127	Srinagar	34.1	74.8	1587	2.90	4.13	5.53	7.10	8.62	9.38	8.98	8.37	7.56	6.32	4.82	3.17
39	134	Trivandrum	8.5	77.0	64	8.30	8.91	9.05	8.24	7.46	6.16	6.27	7.22	7.56	7.12	6.95	7.34
40	135	Tuticorin	8.8	78.2	4	8.49	9.37	9.63	9.64	8.88	8.21	8.28	8.73	8.57	8.24	7.70	7.15
41	142	Veraval	20.9	70.4	8	7.51	8.65	9.90	9.93	10.59	9.07	6.68	6.56	8.34	8.59	7.74	7.16
42	144	Vishakhapatnam	17.7	83.2	3	7.89	8.97	9.13	9.62	9.67	7.07	6.42	7.24	7.32	7.82	7.61	7.30

Mean Daily Duration of Maximum Possible Sunshine Hours. N (hrs)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	10.6	11.2	12.1	12.8	13.4	13.8	13.7	13.1	12.3	11.6	10.8	10.4
2	4	Ahmadabad	23.1	72.6	55	10.8	11.4	12.0	12.7	13.2	13.5	13.4	12.9	12.3	11.6	11.0	10.7
3	5	Akola	20.7	77.0	282	11.0	11.5	12.0	12.6	13.1	13.4	13.2	12.8	12.3	11.7	11.2	10.9
4	7	Allahabad	25.5	81.7	98	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
5	8	Amini Divi	11.1	72.7	4	11.5	11.8	12.0	12.3	12.6	12.8	12.7	12.4	12.1	11.8	11.6	11.4
6	9	Amritsar	31.6	74.9	234	10.3	11.1	12.1	13.0	13.7	14.2	14.0	13.3	12.4	11.4	10.5	10.1
7	14	Bangalor	13.0	77.6	897	11.4	11.7	12.0	12.4	12.7	12.9	12.8	12.5	12.2	11.8	11.5	11.3
8	21	Bhopal	23.3	77.4	503	10.8	11.4	12.0	12.7	13.2	13.6	13.4	12.9	12.3	11.6	11.0	10.7
9	24	Bikaner	28.0	73.3	224	10.5	11.2	12.1	12.8	13.5	13.9	13.7	13.1	12.4	11.5	10.7	10.4
10	26	Bombay	19.1	72.9	14	11.1	11.5	12.0	12.6	13.0	13.2	13.1	12.8	12.3	11.7	11.2	11.0
11	26	Bombay	19.1	72.9	14	11.1	11.5	12.0	12.6	13.0	13.2	13.1	12.8	12.3	11.7	11.2	11.0
12	27	Calcutta	22.7	88.5	6	10.8	11.4	12.0	12.7	13.2	13.5	13.4	12.9	12.3	11.6	11.0	10.7
13	27	Calcutta	22.7	88.5	6	10.8	11.4	12.0	12.7	13.2	13.5	13.4	12.9	12.3	11.6	11.0	10.7
14	34	Cuttack	20.5	85.9	24	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
15	36	Dharwar	15.4	75.1	679	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	10.6	11.2	12.1	12.8	13.4	13.8	13.7	13.1	12.3	11.6	10.8	10.4
17	39	Gannavaram	16.5	80.8	24	11.2	11.6	12.0	12.5	12.9	13.1	13.0	12.7	12.2	11.8	11.3	11.1
18	40	Gauhati	26.1	91.6	54	10.6	11.3	12.0	12.7	13.4	13.8	13.6	13.0	12.3	11.6	10.8	10.5
19	41	Goa	15.5	73.8	55	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
20	56	Hyderabad	17.5	78.5	545	11.2	11.6	12.0	12.5	12.9	13.1	13.0	12.7	12.2	11.8	11.3	11.1
21	59	Indore	22.7	75.8	567	10.8	11.4	12.0	12.7	13.2	13.5	13.4	12.9	12.3	11.6	11.0	10.7
22	61	Jagadalpur	19.1	82.0	553	11.1	11.5	12.0	12.6	13.0	13.2	13.1	12.8	12.3	11.7	11.2	11.0
23	62	Jaipur	26.8	75.8	390	10.6	11.2	12.1	12.8	13.4	13.8	13.6	13.1	12.3	11.6	10.8	10.5
24	69	Jodhpur	26.3	73.0	224	10.6	11.2	12.1	12.8	13.4	13.8	13.6	13.1	12.3	11.6	10.8	10.5
25	76	Kodaikanal	10.2	77.5	2345	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
26	79	Kota	25.2	75.5	257	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
27	86	Madras	13.0	80.2	16	11.4	11.7	12.0	12.4	12.7	12.9	12.8	12.5	12.2	11.8	11.5	11.3
28	89	Minicoy	8.3	73.0	2	11.7	11.8	12.0	12.3	12.5	12.6	12.5	12.4	12.1	11.9	11.7	11.6
29	92	Nagpur	21.2	79.1	311	10.9	11.5	12.0	12.6	13.1	13.4	13.3	12.8	12.3	11.7	11.1	10.8
30	97	New Dehli	28.6	77.2	216	10.5	11.2	12.1	12.8	13.5	13.9	13.8	13.1	12.4	11.5	10.7	10.3
31	99	Okha	22.5	69.1	7	10.9	11.4	12.0	12.6	13.2	13.5	13.3	12.9	12.3	11.7	11.1	10.8
32	100	Ollukara	10.5	76.3	22	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
33	105	Patna	25.5	85.3	52	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
34	107	Port Blair	11.7	92.7	79	11.5	11.7	12.0	12.4	12.7	12.8	12.7	12.5	12.1	11.8	11.5	11.4
35	108	Pune	18.5	73.9	563	11.1	11.5	12.0	12.6	13.0	13.2	13.1	12.7	12.3	11.7	11.3	11.0
36	123	Shillong	25.6	91.9	1598	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
37	124	Silicuri	24.8	92.9	40	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
38	127	Srinagar	34.1	74.8	1587	10.2	11.0	12.0	13.1	13.9	14.4	14.2	13.4	12.4	11.3	10.4	9.9
39	134	Trivandrum	8.5	77.0	64	11.7	11.8	12.0	12.3	12.5	12.6	12.5	12.4	12.1	11.9	11.7	11.6
40	135	Tuticorin	8.8	78.2	4	11.6	11.8	12.0	12.3	12.5	12.6	12.5	12.4	12.1	11.8	11.7	11.6
41	142	Veraval	20.9	70.4	8	10.9	11.5	12.0	12.6	13.1	13.4	13.3	12.8	12.3	11.7	11.1	10.8
42	144	Vishakhapatnam	17.7	83.2	3	11.1	11.5	12.0	12.6	13.0	13.2	13.1	12.7	12.3	11.7	11.3	11.0

Lookup Table for N (Northern Hemisphere), Given Latitude and Month

Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
10	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
15	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
20	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
25	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
30	10.4	11.1	12.2	12.9	13.6	14.0	13.9	13.2	12.4	11.5	10.6	10.2
35	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8

Actual Sunshine duration in a day in hours (n)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	8.3	9.0	9.5	9.7	9.3	7.4	5.6	5.3	7.7	9.2	9.2	8.3
2	4	Ahmadabad	23.1	72.6	55	9.5	10.1	9.2	9.9	10.7	8.4	4.5	3.9	6.8	9.6	9.8	9.5
3	5	Akola	20.7	77.0	282	10.0	10.2	9.5	9.8	9.8	7.2	3.7	3.9	5.6	8.4	9.2	9.1
4	7	Allahabad	25.5	81.7	98	8.1	9.2	8.8	9.7	9.8	6.8	5.2	4.8	6.9	8.8	9.0	8.4
5	8	Amini Divi	11.1	72.7	4	8.5	9.1	9.6	8.8	6.5	4.2	3.8	4.8	6.4	6.2	7.1	7.5
6	9	Amritsar	31.6	74.9	234	6.9	7.7	7.6	9.1	10.1	9.0	7.5	7.7	8.2	9.0	8.5	7.1
7	14	Bangalor	13.0	77.6	897	8.5	9.1	9.0	8.7	7.6	5.0	3.3	4.2	5.0	5.7	6.9	7.4
8	21	Bhopal	23.3	77.4	503	9.5	10.0	9.4	9.8	10.4	7.4	3.6	3.1	6.0	9.2	9.8	9.0
9	24	Bikaner	28.0	73.3	224	8.8	9.4	10.0	11.3	12.2	12.0	9.6	8.9	10.4	10.4	9.3	8.7
10	26	Bombay	19.1	72.9	14	9.1	9.5	9.2	9.6	9.6	5.5	2.5	2.8	5.1	8.3	9.2	9.1
11	26	Bombay	19.1	72.9	14	9.1	9.5	9.2	9.6	9.6	5.5	2.5	2.8	5.1	8.3	9.2	9.1
12	27	Calcutta	22.7	88.5	6	8.1	8.6	8.2	8.8	8.3	4.2	3.9	3.8	4.6	6.5	8.1	8.0
13	27	Calcutta	22.7	88.5	6	8.1	8.6	8.2	8.8	8.3	4.2	3.9	3.8	4.6	6.5	8.1	8.0
14	34	Cuttack	20.5	85.9	24	8.9	9.1	8.4	8.4	8.9	4.9	3.4	4.0	4.9	7.0	8.5	8.9
15	36	Dharwar	15.4	75.1	679	9.8	10.1	9.7	8.7	7.9	4.5	2.4	3.5	5.1	6.8	8.3	9.2
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	6.4	5.9	6.6	4.8	5.0	3.7	4.2	5.7	4.7	6.7	7.7	7.3
17	39	Gannavaram	16.5	80.8	24	9.2	9.8	8.7	9.3	8.9	5.2	4.6	5.3	5.7	7.0	8.0	8.0
18	40	Gauhati	26.1	91.6	54	7.5	8.3	7.5	7.7	7.1	4.4	4.7	5.3	5.6	7.6	8.3	7.9
19	41	Goa	15.5	73.8	55	9.5	10.0	9.3	9.5	9.0	4.3	3.2	4.3	5.8	7.6	9.3	9.2
20	56	Hyderabad	17.5	78.5	545	9.5	10.1	9.2	9.4	9.5	6.3	4.3	5.1	5.9	7.9	8.7	8.9
21	59	Indore	22.7	75.8	567	9.6	10.1	9.5	10.1	10.7	7.3	3.5	2.9	5.9	9.3	9.7	9.1
22	61	Jagadalpur	19.1	82.0	553	9.3	9.7	10.0	9.6	8.6	5.7	3.2	3.3	4.7	7.3	8.4	9.0
23	62	Jaipur	26.8	75.8	390	8.6	9.3	8.9	9.3	9.1	6.8	4.4	4.5	7.6	9.6	9.6	8.9
24	69	Jodhpur	26.3	73.0	224	8.9	9.6	8.9	9.8	10.2	9.0	6.4	6.4	8.3	9.8	9.7	9.1
25	76	Kodaikanal	10.2	77.5	2345	7.5	8.2	7.8	6.9	5.8	3.9	2.7	3.5	3.9	3.8	4.5	5.8
26	79	Kota	25.2	75.5	257	9.2	9.9	9.4	10.0	10.5	8.8	5.1	4.6	7.4	9.3	9.4	9.2
27	86	Madras	13.0	80.2	16	8.6	9.9	9.6	9.5	8.6	6.7	5.4	5.9	6.4	6.4	6.7	7.0
28	89	Minicoy	8.3	73.0	2	9.3	9.6	9.0	8.4	7.0	5.2	5.1	6.6	6.5	7.1	8.0	7.8
29	92	Nagpur	21.2	79.1	311	9.3	9.9	9.2	9.5	9.7	6.3	3.5	3.6	5.6	8.6	9.5	9.2
30	97	New Dehli	28.6	77.2	216	7.7	8.7	8.0	8.8	8.3	6.1	5.7	6.0	7.3	9.1	9.2	8.0
31	99	Okha	22.5	69.1	7	9.3	10.0	9.3	9.7	9.8	6.9	4.3	4.4	7.9	9.8	9.7	8.2
32	100	Ollukara	10.5	76.3	22	8.8	8.9	8.6	7.6	5.4	3.4	2.3	3.0	4.4	5.4	6.9	7.2
33	105	Patna	25.5	85.3	52	8.6	9.2	9.1	9.5	10.2	7.6	6.0	6.3	7.0	8.6	9.2	8.7
34	107	Port Blair	11.7	92.7	79	8.6	9.7	9.3	8.8	5.3	3.7	3.7	3.8	4.1	6 0	7.5	8.1
35	108	Pune	18.5	73.9	563	9.5	10.1	9.7	9.8	9.8	6.4	3.3	3.7	5.6	8.0	9.0	9.1
36	123	Shillong	25.6	91.9	1598	6.0	7.6	7.5	7.2	6.4	3.2	3.1	3.3	4.1	5.6	5.9	6.0
37	124	Silicuri	24.8	92.9	40	8.0	8.0	8.1	7.6	6.5	4.2	4.6	4.9	5.6	6.6	7.7	7.9
38	127	Srinagar	34.1	74.8	1587	2.4	3.8	4.7	6.0	7.6	8.6	8.1	7.8	7.8	7.6	6.6	3.8
39	134	Trivandrum	8.5	77.0	64	8.5	8.7	8.2	6.8	5.9	4.0	4.1	5.4	5.9	5.5	5.9	7.1
40	135	Tuticorin	8.8	78.2	4	8.9	9.5	9.1	9.0	8.2	7.4	7.4	7.8	7.5	7.3	7.2	6.8
41	142	Veraval	20.9	70.4	8	9.5	10.1	10.6	9.8	10.5	8.1	4.2	4.2	7.8	9.4	9.6	9.4
42	144	Vishakhapatnam	17.7	83.2	3	9.5	10.1	9.0	9.2	9.1	5.0	3.9	5.3	5.9	7.6	8.6	8.9

Radiation Received at the Top of the Atmosphere, Ra (mm/day)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	9.5	11.3	13.5	15.3	16.5	16.8	16.7	15.7	14.2	12.1	10.1	9.0
2	4	Ahmadabad	23.1	72.6	55	10.4	12.1	14.0	15.4	16.4	16.5	16.5	15.8	14.5	12.8	10.9	9.9
3	5	Akola	20.7	77.0	282	11.0	12.6	14.3	15.6	16.3	16.4	16.3	15.9	14.7	13.2	11.4	10.5
4	7	Allahabad	25.5	81.7	98	9.9	11.6	13.8	15.3	16.4	16.7	16.6	15.7	14.4	12.4	10.4	9.4
5	8	Amini Divi	11.1	72.7	4	13.0	14.0	15.2	15.7	15.6	15.4	15.4	15.6	15.2	14.5	13.4	12.7
6	9	Amritsar	31.6	74.9	234	8.4	10.3	12.9	15.0	16.5	17.0	16.8	15.6	13.7	11.3	9.1	7.9
7	14	Bangalor	13.0	77.6	897	12.6	13.8	15.0	15.7	15.7	15.6	15.6	15.6	15.2	14.3	13.1	12.3
8	21	Bhopal	23.3	77.4	503	10.4	12.0	14.0	15.4	16.4	16.5	16.5	15.8	14.5	12.7	10.8	9.9
9	24	Bikaner	28.0	73.3	224	9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8
10	26	Bombay	19.1	72.9	14	11.4	12.8	14.5	15.6	16.2	16.3	16.2	15.9	14.8	13.4	11.8	10.9
11	26	Bombay	19.1	72.9	14	11.4	12.8	14.5	15.6	16.2	16.3	16.2	15.9	14.8	13.4	11.8	10.9
12	27	Calcutta	22.7	88.5	6	10.5	12.2	14.1	15.5	16.3	16.5	16.4	15.8	14.6	12.9	11.0	10.0
13	27	Calcutta	22.7	88.5	6	10.5	12.2	14.1	15.5	16.3	16.5	16.4	15.8	14.6	12.9	11.0	10.0
14	34	Cuttack	20.5	85.9	24	11.1	12.6	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.2	11.5	10.6
15	36	Dharwar	15.4	75.1	679	12.1	13.4	14.8	15.6	15.9	15.8	15.8	15.7	15.0	14.0	12.5	11.7
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	9.4	11.2	13.5	15.3	16.5	16.8	16.7	15.7	14.2	12.1	10.0	8.9
17	39	Gannavaram	16.5	80.8	24	11.9	13.2	14.7	15.6	16.0	16.0	16.0	15.7	15.0	13.8	12.3	11.5
18	40	Gauhati	26.1	91.6	54	9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3
19	41	Goa	15.5	73.8	55	12.1	13.4	14.8	15.6	15.9	15.8	15.8	15.7	15.0	14.0	12.5	11.7
20	56	Hyderabad	17.5	78.5	545	11.7	13.1	14.6	15.6	16.1	16.0	16.0	15.8	14.9	13.7	12.1	11.2
21	59	Indore	22.7	75.8	567	10.5	12.2	14.1	15.5	16.3	16.5	16.4	15.8	14.6	12.9	11.0	10.0
22	61	Jagadalpur	19.1	82.0	553	11.4	12.8	14.5	15.6	16.2	16.3	16.2	15.9	14.8	13.4	11.8	10.9
23	62	Jaipur	26.8	75.8	390	9.6	11.3	13.6	15.3	16.4	16.7	16.6	15.7	14.2	12.2	10.1	9.1
24	69	Jodhpur	26.3	73.0	224	9.7	11.4	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.2	9.2
25	76	Kodaikanal	10.2	77.5	2345	13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9
26	79	Kota	25.2	75.5	257	10.0	11.7	13.8	15.3	16.4	16.7	16.6	15.7	14.4	12.4	10.5	9.5
27	86	Madras	13.0	80.2	16	12.6	13.8	15.0	15.7	15.8	15.6	15.6	15.7	15.2	14.3	13.1	12.3
28	89	Minicoy	8.3	73.0	2	13.5	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.2
29	92	Nagpur	21.2	79.1	311	10.9	12.5	14.3	15.5	16.3	16.4	16.4	15.8	14.7	13.1	11.3	10.4
30	97	New Dehli	28.6	77.2	216	9.2	11.0	13.3	15.3	16.5	16.9	16.7	15.7	14.0	11.9	9.8	8.7
31	99	Okha	22.5	69.1	7	10.6	12.2	14.1	15.5	16.3	16.4	16.4	15.8	14.6	12.9	11.0	10.1
32	100	Ollukara	10.5	76.3	22	13.1	14.1	15.2	15.7	15.6	15.4	15.4	15.5	15.3	14.6	13.5	12.8
33	105	Patna	25.5	85.3	52	9.9	11.6	13.8	15.3	16.4	16.7	16.6	15.7	14.4	12.4	10.4	9.4
34	107	Port Blair	11.7	92.7	79	12.9	14.0	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.5	13.4	12.6
35	108	Pune	18.5	73.9	563	11.5	12.9	14.5	15.6	16.2	16.2	16.2	15.8	14.9	13.5	11.9	11.0
36	123	Shillong	25.6	91.9	1598	9.9	11.6	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.4	10.4	9.4
37	124	Silicuri	24.8	92.9	40	10.0	11.7	13.8	15.4	16.4	16.6	16.5	15.8	14.4	12.5	10.5	9.5
38	127	Srinagar	34.1	74.8	1587	7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2
39	134	Trivandrum	8.5	77.0	64	13.5	14.4	15.3	15.6	15.3	15.1	15.1	15.4	15.3	14.8	13.8	13.2
40	135	Tuticorin	8.8	78.2	4	13.4	14.4	15.3	15.6	15.4	15.1	15.2	15.4	15.3	14.8	13.8	13.1
41	142	Veraval	20.9	70.4	8	11.0	12.5	14.3	15.6	16.3	16.4	16.3	15.9	14.7	13.2	11.4	10.5
42	144	Vishakhapatnam	17.7	83.2	3	11.7	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.1	11.2

Lookup Table for Extraterrestrial Radiation, Ra (mm/day), Northern Hemisphere

Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
8	13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3
10	13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9
12	12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5
14	12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0
16	12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6
18	11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1
20	11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7
22	10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2
24	10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7
26	9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3
28	9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8
30	8.8	10.7	13.1	15.2	16.5	17.0	16.8	15.7	13.9	11.6	9.5	8.3
32	8.3	10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8
34	7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2
36	7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6

APPENDIX K

EVAPOTRANSPIRATION
PENMAN METHOD

WIND FUNCTION
(F(u))

Wind Function, f(u)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Height (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	2.0	0.555	0.649	0.692	0.759	0.846	1.011	0.939	0.774	0.713	0.547	0.483	0.505
2	5	Ahmadabad Airport	23.1	72.6	55	2.0	0.587	0.565	0.592	0.630	0.742	0.802	0.726	0.603	0.560	0.474	0.512	0.560
3	9	Akola Airport	20.7	77.1	309	2.0	0.721	0.716	0.660	0.762	0.977	1.085	0.911	0.788	0.747	0.665	0.680	0.562
4	13	Allahabad Airport	25.5	81.7	98	2.0	0.443	0.486	0.529	0.599	0.620	0.691	0.691	0.588	0.572	0.453	0.405	0.410
5	19	Amini Divi	11.1	72.7	4	2.0	0.591	0.691	0.726	0.776	1.002	1.508	1.693	1.558	1.292	0.811	0.566	0.541
6	21	Amritsar Airport	31.6	74.9	234	2.0	0.562	0.662	0.742	0.763	0.827	0.848	0.869	0.715	0.631	0.578	0.535	0.546
7	37	Bangalore Airport	13.0	77.6	897	2.0	0.746	0.716	0.709	0.700	0.897	1.225	1.311	1.140	0.981	0.681	0.718	0.717
8	59	Bhopal Airport	23.3	77.4	523	2.0	0.698	0.733	0.793	0.874	1.100	1.277	1.171	1.090	0.889	0.647	0.607	0.582
9	64	Bikaner	28.0	73.3	224	2.0	0.450	0.504	0.597	0.635	0.760	0.994	0.918	0.814	0.711	0.531	0.471	0.466
10	69	Bombay-Colaba	18.9	72.8	11	2.0	0.665	0.660	0.728	0.753	0.738	0.836	0.977	0.889	0.758	0.616	0.597	0.616
11	70	Bombay-Santacruz	19.1	72.9	14	2.0	0.680	0.717	0.764	0.822	0.938	1.132	1.395	1.211	0.869	0.643	0.638	0.649
12	75	Calcutta-Alipore	22.5	88.3	6	2.0	0.439	0.507	0.575	0.691	0.773	0.676	0.628	0.584	0.551	0.483	0.439	0.439
13	76	Calcutta-Dum Dum	22.7	88.5	6	2.0	0.438	0.501	0.611	0.811	0.926	0.821	0.785	0.711	0.611	0.522	0.422	0.412
14	97	Cuttack	20.5	85.9	27	2.0	0.425	0.506	0.586	0.706	0.767	0.676	0.621	0.581	0.541	0.466	0.415	0.395
15	48	Belgaum Airport	15.9	74.6	747	2.0	0.541	0.629	0.728	0.780	0.962	1.175	1.175	1.066	0.816	0.598	0.587	0.587
16	112	Dibrugarh Airport	27.5	95.0	111	2.0	0.423	0.516	0.582	0.622	0.589	0.589	0.522	0.482	0.462	0.416	0.396	0.396
17	126	Gannavaram Airport	16.5	80.8	24	2.0	0.771	0.745	0.812	0.884	1.008	1.158	1.065	0.972	0.812	0.724	0.807	0.765
18	127	Gauhati Airport	26.1	91.6	54	2.0	0.419	0.483	0.563	0.590	0.606	0.563	0.531	0.526	0.505	0.451	0.425	0.403
19	131	Gao-Panjim	15.5	73.8	60	2.0	0.737	0.771	0.800	0.819	0.906	0.925	1.190	1.094	0.757	0.665	0.699	0.728
20	153	Hyderabad-Begumpet	17.5	78.5	545	2.0	0.676	0.686	0.723	0.771	0.971	1.414	1.525	1.287	0.971	0.650	0.618	0.618
21	156	Indore Airport	22.7	75.8	567	2.0	0.699	0.775	0.881	1.002	1.280	1.533	1.432	1.316	1.103	0.699	0.613	0.634
22	158	Jagdalpur	19.1	82.0	553	2.0	0.406	0.462	0.497	0.543	0.563	0.598	0.639	0.593	0.523	0.457	0.416	0.391
23	159	Jaipur Airport	26.8	75.8	390	2.0	0.577	0.575	0.608	0.641	0.732	0.808	0.723	0.620	0.593	0.516	0.527	0.511
24	172	Jodhpur	26.3	73.0	217	2.0	0.641	0.636	0.730	0.761	0.970	1.210	1.048	0.918	0.761	0.594	0.636	0.636
25	194	Kodaikanal	10.2	77.5	2343	2.0	0.871	0.926	0.921	0.856	0.876	0.956	1.150	0.991	0.871	0.842	0.911	0.956
26	200	Kota Airport	25.2	75.9	274	2.0	0.589	0.671	0.677	0.874	1.105	1.237	1.155	1.001	0.814	0.633	0.583	0.572
27	209	Madras- Minambakkam	13.0	80.2	16	2.0	0.727	0.707	0.757	0.825	0.909	0.988	0.909	0.855	0.796	0.678	0.737	0.737
28	231	Minicoy	8.3	73.0	2	2.0	0.560	0.565	0.589	0.614	0.884	1.032	1.071	1.002	0.904	0.727	0.604	0.521
29	239	Nagpur Airport	21.1	79.1	310	2.0	0.632	0.687	0.712	0.772	0.968	1.014	0.928	0.868	0.813	0.677	0.637	0.607
30	250	New Dehli - Safderjung	28.6	77.2	216	2.0	0.693	0.800	0.810	0.849	0.932	1.063	0.771	0.703	0.713	0.577	0.577	0.664
31	256	Okha	22.5	69.1	7	2.0	1.292	1.271	1.329	1.398	1.567	1.567	1.673	1.641	1.207	1.069	1.144	1.186
32	122	Fort Cochin	10.0	76.2	3	2.0	0.695	0.741	0.792	0.751	0.782	0.705	0.736	0.757	0.751	0.685	0.649	0.639
33	271	Patna Airport	25.6	85.1	60	2.0	0.463	0.516	0.578	0.680	0.718	0.708	0.680	0.602	0.578	0.463	0.400	0.429
34	278	Port Blair	11.7	92.7	79	2.0	0.761	0.670	0.590	0.585	0.921	1.241	1.257	1.214	1.070	0.734	0.686	0.777
35	281	Pune Airport	18.6	73.9	593	2.0	0.677	0.744	0.870	0.995	1.355	1.465	1.394	1.336	1.095	0.749	0.692	0.632
36	314	Shillong	25.6	91.9	1600	2.0	0.386	0.421	0.522	0.637	0.647	0.547	0.441	0.411	0.396	0.416	0.371	0.351
37	320	Silchar - Khumbhigram	24.9	93.0	97	2.0	0.667	0.692	0.728	0.692	0.646	0.590	0.555	0.534	0.545	0.570	0.565	0.616
38	325	Srinagar Airport	34.0	74.8	1666	2.0	0.389	0.415	0.523	0.530	0.538	0.556	0.542	0.509	0.480	0.455	0.394	0.372
39	340	Trivandrum Airport	8.5	77.0	8	2.0	0.582	0.603	0.663	0.636	0.770	0.738	0.765	0.851	0.754	0.636	0.550	0.544
40	342	Tuticorin	8.8	78.2	4	2.0	1.356	1.383	1.193	0.987	1.003	1.193	1.269	1.253	1.150	0.922	1.123	1.334
41	352	Veraval	20.9	70.4	8	2.0	0.978	1.034	1.140	1.247	1.312	1.601	1.986	1.641	1.307	0.984	0.908	0.958
42	353	Vishakhapatnam	17.7	83.2	3	2.0	0.698	0.693	0.786	1.013	1.060	1.049	1.127	0.956	0.750	0.626	0.719	0.678

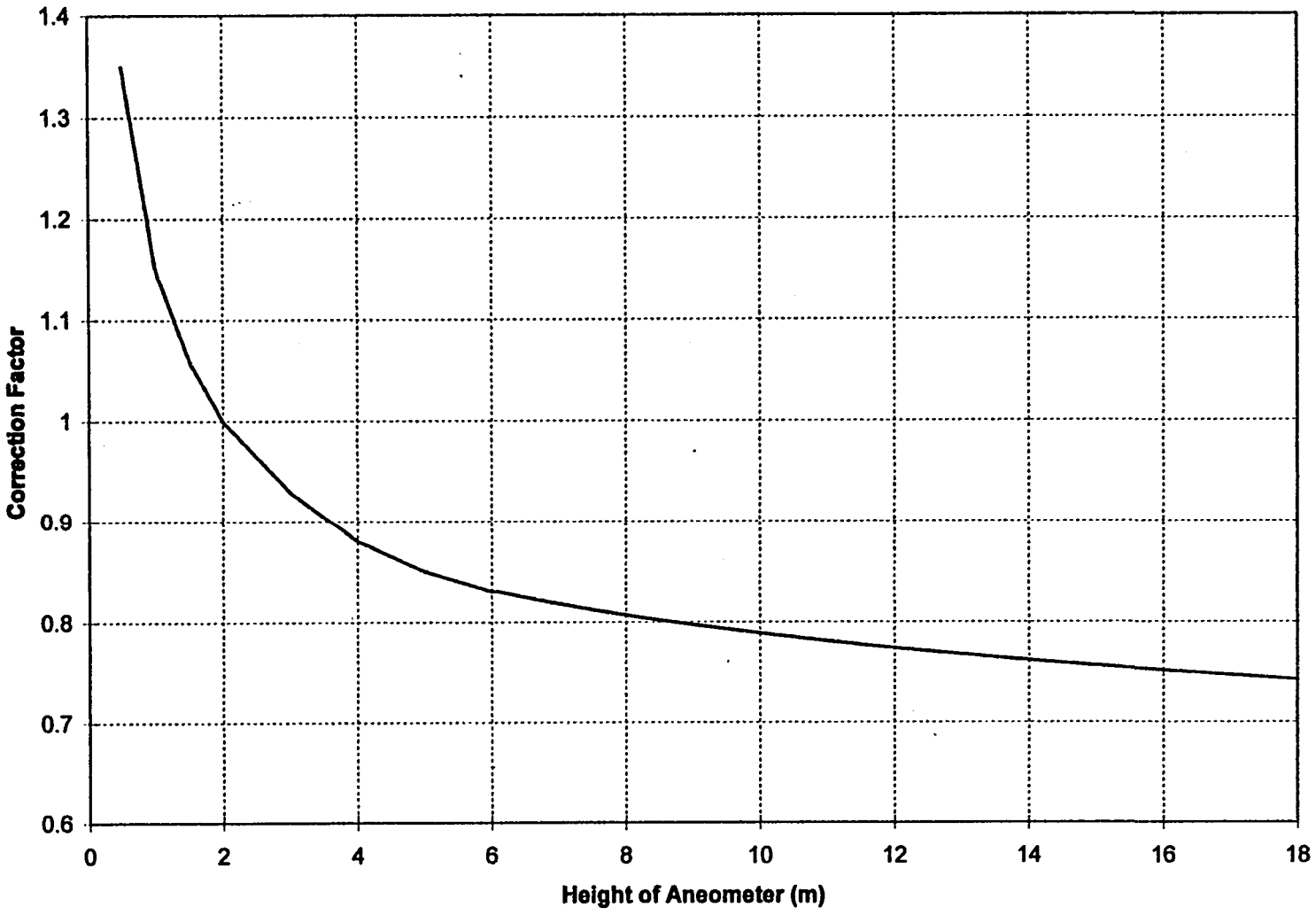
Mean Daily Wind Speed Corrected to 2 m Height, u (km/day)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Height (m)	Factor CF	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	13.7	0.76	105.5	140.4	156.1	181.0	213.3	274.5	247.7	186.5	164.2	102.6	78.8	86.9
2	5	Ahmadabad Airport	23.1	72.6	55	6.2	0.83	117.3	109.4	119.3	133.2	175.0	196.9	169.0	123.3	107.4	75.6	89.5	107.4
3	9	Akola Airport	20.7	77.1	309	9.7	0.79	167.1	165.2	144.3	182.3	262.0	301.9	237.3	191.8	176.6	146.2	151.9	168.2
4	13	Allahabad Airport	25.5	81.7	98	5.9	0.83	63.9	79.9	95.8	121.8	129.8	155.8	155.8	117.8	111.8	67.9	49.9	51.9
5	19	Amini Divi	11.1	72.7	4	12.1	0.77	118.8	155.9	168.9	187.5	271.0	458.4	527.1	477.0	378.6	200.4	109.5	100.2
6	21	Amritsar Airport	31.6	74.9	234	7.0	0.82	108.0	145.3	174.8	182.6	206.2	214.0	221.9	164.9	133.5	113.9	98.2	102.1
7	37	Bangalore Airport	13.0	77.6	897	14.9	0.76	176.2	165.3	162.8	159.1	232.2	353.9	385.5	322.3	263.4	152.2	166.0	165.7
8	59	Bhopal Airport	23.3	77.4	523	11.6	0.78	158.4	171.5	193.9	223.7	307.6	372.8	333.7	303.8	229.3	139.8	124.9	115.6
9	64	Bikaner	28.0	73.3	224	5.5	0.84	66.5	86.7	121.0	135.1	181.4	268.1	239.9	201.6	163.3	96.8	74.6	72.6
10	69	Bombay-Colaba	18.9	72.8	11	15.8	0.75	146.3	144.4	169.7	178.8	173.3	209.4	261.8	229.3	180.6	128.2	121.0	128.2
11	70	Bombay-Santacruz	19.1	72.9	14	7.6	0.81	151.9	165.5	183.0	204.4	247.3	319.3	416.7	348.5	222.0	138.2	136.3	140.2
12	75	Calcutta-Alipore	22.5	88.3	6	17.0	0.75	62.7	87.8	112.9	155.9	186.4	150.5	132.6	116.5	103.9	78.8	62.7	62.7
13	76	Calcutta-Dum Dum	22.7	88.5	6	7.7	0.81	62.2	85.6	126.4	200.3	243.1	204.2	190.6	163.3	126.4	93.3	56.4	52.5
14	97	Cuttack	20.5	85.9	27	12.0	0.77	57.6	87.3	117.0	161.6	183.9	150.5	130.0	115.2	100.3	72.4	53.9	46.4
15	48	Belgaum Airport	15.9	74.6	747	8.4	0.80	100.2	133.0	169.6	188.9	256.3	335.3	335.3	294.8	202.3	121.4	117.6	117.6
16	112	Dibrugarh Airport	27.5	95.0	111	1.8	1.02	56.5	90.9	115.5	130.3	118.0	118.0	93.4	78.6	71.3	54.1	46.7	46.7
17	126	Dennaverem Airport	16.5	80.8	24	9.1	0.80	185.4	175.8	200.7	227.4	273.3	328.7	294.3	259.9	200.7	168.2	198.8	183.5
18	127	Gauhati Airport	26.1	91.6	54	6.6	0.82	55.3	79.0	108.7	118.5	124.5	108.7	96.8	94.8	86.9	67.2	57.3	49.4
19	131	Goa-Panjim	15.5	73.8	60	17.7	0.74	173.1	185.6	196.3	203.4	235.6	242.7	340.9	305.2	180.2	146.3	158.8	169.5
20	153	Hyderabad-Begumpet	17.5	78.5	545	7.4	0.81	150.3	154.2	167.9	185.5	259.7	423.7	464.7	376.8	259.7	140.6	128.9	128.9
21	156	Indore Airport	22.7	75.8	567	11.2	0.78	159.0	187.1	226.4	271.3	374.2	467.7	430.3	387.3	308.7	159.0	127.2	134.7
22	158	Jagdalpur	19.1	82.0	553	11.2	0.78	50.5	71.1	84.2	101.0	108.5	121.6	136.6	119.7	93.5	69.2	54.3	44.9
23	159	Jaipur Airport	26.8	75.8	390	9.8	0.79	113.6	113.1	125.2	137.5	170.9	199.2	167.9	129.7	119.7	91.3	95.1	89.1
24	172	Jodhpur	26.3	73.0	217	8.1	0.81	137.3	135.4	170.2	181.8	259.2	348.2	288.2	239.9	181.8	119.9	135.4	135.4
25	194	Kodaikanal	10.2	77.5	2343	13.1	0.77	222.7	243.0	241.1	217.2	224.6	254.0	325.8	266.9	222.7	211.7	237.5	254.0
26	200	Kota Airport	25.2	75.9	274	5.1	0.85	118.0	148.6	150.6	223.9	309.4	358.2	327.7	270.7	201.5	134.3	116.0	111.9
27	209	Madras- Minambakkam	13.0	80.2	16	14.6	0.76	169.3	162.0	180.2	205.7	236.6	265.8	236.6	216.6	194.8	151.1	172.9	172.9
28	231	Minicoy	8.3	73.0	2	14.6	0.76	107.4	109.2	118.3	127.4	227.5	282.2	296.7	271.2	234.8	169.3	123.8	92.8
29	239	Nagpur Airport	21.1	79.1	310	11.8	0.78	134.0	154.4	163.7	186.1	258.6	275.4	243.8	221.4	201.0	150.7	135.8	124.7
30	250	New Dehli - Safdarjung	28.6	77.2	216	16.1	0.75	156.8	196.4	200.0	214.4	245.1	293.7	185.6	160.4	164.0	113.5	113.5	146.0
31	256	Okha	22.5	69.1	7	7.1	0.82	378.4	370.6	392.2	417.7	480.4	480.4	519.6	507.9	347.1	296.1	323.5	339.2
32	122	Fort Cochin	10.0	76.2	3	9.8	0.79	157.4	174.5	193.5	178.3	189.7	161.2	172.6	160.2	178.3	153.6	140.4	136.6
33	271	Patna Airport	25.6	85.1	60	17.7	0.74	71.4	91.0	114.2	151.7	166.0	162.4	151.7	123.1	114.2	71.4	48.2	58.9
34	278	Port Blair	11.7	92.7	79	6.6	0.82	181.8	148.2	118.5	116.6	241.0	359.6	365.5	349.7	296.3	171.9	154.1	187.7
35	281	Pune Airport	18.6	73.9	593	3.0	0.93	150.7	175.6	222.1	268.6	401.8	442.7	416.3	394.7	305.4	177.4	156.2	133.9
36	314	Shillong	25.6	91.9	1600	11.6	0.78	42.9	55.9	93.2	136.1	139.8	102.5	63.4	52.2	46.6	54.1	37.3	29.8
37	320	Silchar - Khumbhigram	24.9	93.0	97	10.5	0.78	146.9	156.3	169.5	156.3	139.4	118.6	105.5	97.9	101.7	111.1	109.2	128.1
38	325	Srinagar Airport	34.0	74.8	1666	18.0	0.74	44.2	53.8	93.7	96.2	99.4	105.8	100.8	88.4	77.7	68.4	46.0	37.8
39	340	Trivandrum Airport	8.5	77.0	8	6.0	0.83	115.5	123.5	145.4	135.5	185.3	173.3	183.3	215.1	179.3	135.5	103.6	101.6
40	342	Tuticorin	8.8	78.2	4	5.6	0.84	402.2	412.3	341.9	265.5	271.5	341.9	370.1	364.0	325.8	241.3	315.8	394.2
41	352	Veraval	20.9	70.4	8	11.0	0.78	262.4	283.0	322.4	361.7	386.1	492.9	635.4	507.9	384.2	264.3	236.2	254.9
42	353	Vishakhapatnam	17.7	83.2	3	9.1	0.80	158.6	156.7	191.1	275.2	292.4	288.6	317.3	254.2	177.7	131.9	166.3	151.0

Lookup Table for Wind Correction Factor

Height (m)	Correction Factor CF	Height (m)	Correction Factor CF	Height (m)	Correction Factor CF
0.5	1.35	6.4	0.83	12.3	0.77
0.6	1.31	6.5	0.82	12.4	0.77
0.7	1.27	6.6	0.82	12.5	0.77
0.8	1.23	6.7	0.82	12.6	0.77
0.9	1.19	6.8	0.82	12.7	0.77
1.0	1.15	6.9	0.82	12.8	0.77
1.1	1.13	7.0	0.82	12.9	0.77
1.2	1.11	7.1	0.82	13.0	0.77
1.3	1.10	7.2	0.82	13.1	0.77
1.4	1.08	7.3	0.81	13.2	0.77
1.5	1.06	7.4	0.81	13.3	0.77
1.6	1.05	7.5	0.81	13.4	0.77
1.7	1.04	7.6	0.81	13.5	0.76
1.8	1.02	7.7	0.81	13.6	0.76
1.9	1.01	7.8	0.81	13.7	0.76
2.0	1.00	7.9	0.81	13.8	0.76
2.1	0.99	8.0	0.81	13.9	0.76
2.2	0.99	8.1	0.81	14.0	0.76
2.3	0.98	8.2	0.80	14.1	0.76
2.4	0.97	8.3	0.80	14.2	0.76
2.5	0.97	8.4	0.80	14.3	0.76
2.6	0.96	8.5	0.80	14.4	0.76
2.7	0.95	8.6	0.80	14.5	0.76
2.8	0.94	8.7	0.80	14.6	0.76
2.9	0.94	8.8	0.80	14.7	0.76
3.0	0.93	8.9	0.80	14.8	0.76
3.1	0.93	9.0	0.80	14.9	0.76
3.2	0.92	9.1	0.80	15.0	0.76
3.3	0.92	9.2	0.80	15.1	0.76
3.4	0.91	9.3	0.79	15.2	0.76
3.5	0.91	9.4	0.79	15.3	0.75
3.6	0.90	9.5	0.79	15.4	0.75
3.7	0.90	9.6	0.79	15.5	0.75
3.8	0.89	9.7	0.79	15.6	0.75
3.9	0.89	9.8	0.79	15.7	0.75
4.0	0.88	9.9	0.79	15.8	0.75
4.1	0.88	10.0	0.79	15.9	0.75
4.2	0.87	10.1	0.79	16.0	0.75
4.3	0.87	10.2	0.79	16.1	0.75
4.4	0.87	10.3	0.79	16.2	0.75
4.5	0.87	10.4	0.79	16.3	0.75
4.6	0.86	10.5	0.78	16.4	0.75
4.7	0.86	10.6	0.78	16.5	0.75
4.8	0.86	10.7	0.78	16.6	0.75
4.9	0.85	10.8	0.78	16.7	0.75
5.0	0.85	10.9	0.78	16.8	0.75
5.1	0.85	11.0	0.78	16.9	0.75
5.2	0.85	11.1	0.78	17.0	0.75
5.3	0.84	11.2	0.78	17.1	0.75
5.4	0.84	11.3	0.78	17.2	0.75
5.5	0.84	11.4	0.78	17.3	0.75
5.6	0.84	11.5	0.78	17.4	0.74
5.7	0.84	11.6	0.78	17.5	0.74
5.8	0.83	11.7	0.78	17.6	0.74
5.9	0.83	11.8	0.78	17.7	0.74
6.0	0.83	11.9	0.77	17.8	0.74
6.1	0.83	12.0	0.77	17.9	0.74
6.2	0.83	12.1	0.77	18.0	0.74
6.3	0.83	12.2	0.77		

Wind Correction for Height



Wind Correction for Height

Height H (m)	Log(H)	Correction Factor CF	Log(CF)	Regress Log(CF)	Regress CF	Using CF
0.5	-0.3010	1.35	0.1303	0.0310	1.07	1.35
1.0	0.0000	1.15	0.0607	0.0000	1.00	1.15
1.5	0.1761	1.06	0.0253	-0.0182	0.96	1.06
2.0	0.3010	1.00	0.0000	-0.0310	0.93	1.00
3.0	0.4771	0.93	-0.0315	-0.0492	0.89	0.93
4.0	0.6021	0.88	-0.0555	-0.0621	0.87	0.88
5.0	0.6990	0.85	-0.0706	-0.0721	0.85	0.85
6.0	0.7782	0.83	-0.0809	-0.0802	0.83	0.83
7.0	0.8451			-0.0871	0.82	0.82
8.0	0.9031			-0.0931	0.81	0.81
9.0	0.9542			-0.0984	0.80	0.80
10.0	1.0000			-0.1031	0.79	0.79
11.0	1.0414			-0.1074	0.78	0.78
12.0	1.0792			-0.1113	0.77	0.77
13.0	1.1139			-0.1149	0.77	0.77
14.0	1.1461			-0.1182	0.76	0.76
15.0	1.1761			-0.1213	0.76	0.76
16.0	1.2041			-0.1242	0.75	0.75
17.0	1.2304			-0.1269	0.75	0.75
18.0	1.2553			-0.1294	0.74	0.74

Regression on Log(H) vs Log(CF)

Regression Output:	
Constant	0
Std Err of Y Est	0.048923197
R Squared	0.545403531
No. of Observations	8
Degrees of Freedom	7
X Coefficient(s)	-0.10311078
Std Err of Coef.	0.035525863

Mean Daily Wind Speed (kmph)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Height (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	13.7	5.8	7.7	8.5	9.9	11.6	15.0	13.5	10.2	9.0	5.6	4.3	4.7
2	5	Ahmadabad Airport	23.1	72.6	55	6.2	5.9	5.5	6.0	6.7	8.8	9.9	8.5	6.2	5.4	3.8	4.5	5.4
3	9	Akola Airport	20.7	77.1	309	9.7	8.8	8.7	7.6	9.6	13.8	15.9	12.5	10.1	9.3	7.7	8.0	5.7
4	13	Allahabad Airport	25.5	81.7	98	5.9	3.2	4.0	4.8	6.1	6.5	7.8	7.8	5.9	5.6	3.4	2.5	2.6
5	19	Amini Divi	11.1	72.7	4	12.1	6.4	8.4	9.1	10.1	14.6	24.7	28.4	25.7	20.4	10.8	5.9	5.4
6	21	Amritsar Airport	31.6	74.9	234	7.0	5.5	7.4	8.9	9.3	10.5	10.9	11.3	8.4	6.8	5.8	5.0	5.2
7	37	Bangalore Airport	13.0	77.6	897	14.9	9.7	9.1	9.0	8.8	12.8	19.5	21.2	17.7	14.5	8.4	9.1	9.1
8	59	Bhopal Airport	23.3	77.4	523	11.6	8.5	9.2	10.4	12.0	16.5	20.0	17.9	16.3	12.3	7.5	6.7	6.2
9	64	Bikaner	28.0	73.3	224	5.5	3.3	4.3	6.0	6.7	9.0	13.3	11.9	10.0	8.1	4.8	3.7	3.6
10	69	Bombay-Colaba	18.9	72.8	11	15.8	8.1	8.0	9.4	9.9	9.6	11.6	14.5	12.7	10.0	7.1	6.7	7.1
11	70	Bombay-Santacruz	19.1	72.9	14	7.6	7.8	8.5	9.4	10.5	12.7	16.4	21.4	17.9	11.4	7.1	7.0	7.2
12	75	Calcutta-Alipore	22.5	88.3	6	17.0	3.5	4.9	6.3	8.7	10.4	8.4	7.4	6.5	5.8	4.4	3.5	3.5
13	76	Calcutta-Dum Dum	22.7	88.5	6	7.7	3.2	4.4	6.5	10.3	12.5	10.5	9.8	8.4	6.5	4.8	2.9	2.7
14	97	Cuttack	20.5	85.9	27	12.0	3.1	4.7	6.3	8.7	9.9	8.1	7.0	6.2	5.4	3.9	2.9	2.5
15	48	Belgaum Airport	15.9	74.6	747	8.4	5.2	6.9	8.8	9.8	13.3	17.4	17.4	15.3	10.5	6.3	6.1	6.1
16	112	Dibrugarh Airport	27.5	95.0	111	1.8	2.3	3.7	4.7	5.3	4.8	4.8	3.8	3.2	2.9	2.2	1.9	1.9
17	126	Gannavaram Airport	16.5	80.8	24	9.1	9.7	9.2	10.5	11.9	14.3	17.2	15.4	13.6	10.5	8.8	10.4	9.6
18	127	Gauhati Airport	26.1	91.6	54	6.6	2.8	4.0	5.5	6.0	6.3	5.5	4.9	4.8	4.4	3.4	2.9	2.5
19	131	Gao-Panjim	15.5	73.8	60	17.7	9.7	10.4	11.0	11.4	13.2	13.6	19.1	17.1	10.1	8.2	8.9	9.5
20	153	Hyderabad-Begumpet	17.5	78.5	545	7.4	7.7	7.9	8.6	9.5	13.3	21.7	23.8	19.3	13.3	7.2	6.6	6.6
21	156	Indore Airport	22.7	75.8	567	11.2	8.5	10.0	12.1	14.5	20.0	25.0	23.0	20.7	16.5	8.5	6.8	7.2
22	158	Jagdalpur	19.1	82.0	553	11.2	2.7	3.8	4.5	5.4	5.8	6.5	7.3	6.4	5.0	3.7	2.9	2.4
23	159	Jaipur Airport	26.8	75.8	390	9.8	6.0	6.0	6.6	7.3	9.0	10.5	8.9	6.8	6.3	4.8	5.0	4.7
24	172	Jodhpur	26.3	73.0	217	8.1	7.1	7.0	8.8	9.4	13.4	18.0	14.9	12.4	9.4	6.2	7.0	7.0
25	194	Kodaikanal	10.2	77.5	2343	13.1	12.1	13.2	13.1	11.8	12.2	13.8	17.7	14.5	12.1	11.5	12.9	13.8
26	200	Kota Airport	25.2	75.9	274	5.1	5.8	7.3	7.4	11.0	15.2	17.6	16.1	13.3	9.9	6.6	5.7	5.5
27	209	Madras- Minambakkam	13.0	80.2	16	14.6	9.3	8.9	9.9	11.3	13.0	14.6	13.0	11.9	10.7	8.3	9.5	9.5
28	231	Minicoy	8.3	73.0	2	14.6	5.9	6.0	6.5	7.0	12.5	15.5	16.3	14.9	12.9	9.3	6.8	5.1
29	239	Nagpur Airport	21.1	79.1	310	11.8	7.2	8.3	8.8	10.0	13.9	14.8	13.1	11.9	10.8	8.1	7.3	6.7
30	250	New Dehli - Safdarjung	28.6	77.2	216	16.1	8.7	10.9	11.1	11.9	13.6	16.3	10.3	8.9	9.1	6.3	6.3	8.1
31	256	Okha	22.5	69.1	7	7.1	19.3	18.9	20.0	21.3	24.5	24.5	26.5	25.9	17.7	15.1	16.5	17.3
32	122	Fort Cochin	10.0	76.2	3	9.8	8.3	9.2	10.2	9.4	10.0	8.5	9.1	9.5	9.4	8.1	7.4	7.2
33	271	Patna Airport	25.6	85.1	60	17.7	4.0	5.1	6.4	8.5	9.3	9.1	8.5	6.9	6.4	4.0	2.7	3.3
34	278	Port Blair	11.7	92.7	79	6.6	9.2	7.5	6.0	5.9	12.2	18.2	18.5	17.7	15.0	8.7	7.8	9.5
35	281	Pune Airport	18.6	73.9	593	3.0	6.8	7.9	10.0	12.0	18.0	19.8	18.7	17.7	13.7	8.0	7.0	6.0
36	314	Shillong	25.6	91.9	1500	11.6	2.3	3.0	5.0	7.3	7.5	5.5	3.4	2.8	2.5	2.9	2.0	1.6
37	320	Silchar - Khumbhigram	24.9	93.0	97	10.5	7.8	8.3	9.0	8.3	7.4	6.3	5.6	5.2	5.4	5.9	5.8	6.8
38	325	Srinagar Airport	34.0	74.8	1666	18.0	2.5	3.0	5.3	5.4	5.6	5.9	5.7	5.0	4.4	3.8	2.6	2.1
39	340	Trivandrum Airport	8.5	77.0	8	6.0	5.8	6.2	7.3	6.8	9.3	8.7	9.2	10.8	9.0	6.8	5.2	5.1
40	342	Tuticorin	8.8	78.2	4	5.6	20.0	20.5	17.0	13.2	13.5	17.0	18.4	18.1	16.2	12.0	15.7	19.6
41	352	Veraval	20.9	70.4	8	11.0	14.0	15.1	17.2	19.3	20.6	26.3	33.9	27.1	20.5	14.1	12.6	13.6
42	353	Vishakhapatnam	17.7	83.2	3	9.1	8.3	8.2	10.0	14.4	15.3	15.1	16.6	13.3	9.3	6.9	8.7	7.9

APPENDIX L

EVAPOTRANSPIRATION
PENMAN METHOD

WEIGHTING FACTOR
(W)

Weighing Factor. W

St# Eto	St# Sun	Station	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	0.624	0.673	0.733	0.783	0.818	0.833	0.806	0.771	0.777	0.756	0.702	0.646
2	4	Ahmadat	23.1	72.6	55	0.696	0.725	0.764	0.796	0.820	0.806	0.777	0.773	0.772	0.771	0.739	0.708
3	5	Akola	20.7	77.0	282	0.711	0.736	0.776	0.807	0.825	0.803	0.776	0.764	0.766	0.760	0.733	0.707
4	7	Allahat	25.5	81.7	98	0.647	0.690	0.747	0.795	0.823	0.825	0.785	0.777	0.776	0.765	0.708	0.652
5	8	Amini I	11.1	72.7	4	0.762	0.769	0.774	0.779	0.779	0.772	0.768	0.769	0.768	0.770	0.767	0.765
6	9	Amritsa	31.6	74.9	234	0.589	0.628	0.689	0.747	0.782	0.812	0.790	0.783	0.777	0.741	0.662	0.598
7	14	Bangalc	13.0	77.6	897	0.719	0.740	0.766	0.784	0.774	0.748	0.739	0.738	0.741	0.738	0.729	0.717
8	21	Bhopal	23.3	77.4	503	0.671	0.710	0.758	0.792	0.814	0.802	0.768	0.757	0.756	0.752	0.721	0.686
9	24	Bikaner	28.0	73.3	224	0.613	0.665	0.729	0.780	0.815	0.829	0.812	0.802	0.790	0.767	0.699	0.627
10	26	Bombay	19.1	72.9	14	0.730	0.739	0.756	0.772	0.779	0.775	0.764	0.760	0.761	0.769	0.762	0.743
11	26	Bombay	19.1	72.9	14	0.730	0.739	0.756	0.772	0.779	0.775	0.764	0.760	0.761	0.769	0.762	0.743
12	27	Calcutt	22.7	88.5	6	0.678	0.716	0.759	0.781	0.789	0.779	0.773	0.773	0.772	0.762	0.722	0.684
13	27	Calcutt	22.7	88.5	6	0.678	0.716	0.759	0.781	0.789	0.779	0.773	0.773	0.772	0.762	0.722	0.684
14	34	Cuttack	20.5	85.9	24	0.712	0.744	0.775	0.798	0.813	0.793	0.774	0.775	0.776	0.771	0.741	0.714
15	36	Dharwar	15.4	75.1	679	0.739	0.762	0.787	0.793	0.790	0.768	0.750	0.752	0.756	0.763	0.748	0.736
16	38	Dibruga	27.5	95.0	111	0.633	0.660	0.704	0.726	0.739	0.761	0.772	0.767	0.762	0.737	0.692	0.649
17	39	Gannava	16.5	80.8	24	0.733	0.754	0.774	0.788	0.818	0.800	0.776	0.775	0.773	0.766	0.750	0.731
18	40	Gauhati	26.1	91.6	54	0.746	0.678	0.721	0.752	0.758	0.768	0.774	0.774	0.772	0.750	0.710	0.663
19	41	Goa	15.5	73.8	55	0.748	0.753	0.764	0.775	0.778	0.765	0.756	0.757	0.756	0.767	0.763	0.755
20	56	Hyderat	17.5	78.5	545	0.721	0.745	0.779	0.793	0.811	0.785	0.759	0.756	0.756	0.751	0.727	0.712
21	59	Indore	22.7	75.8	567	0.673	0.713	0.745	0.787	0.806	0.794	0.767	0.750	0.755	0.757	0.720	0.688
22	61	Jagadal	19.1	82.0	553	0.705	0.731	0.769	0.788	0.800	0.781	0.751	0.751	0.756	0.750	0.717	0.692
23	62	Jaipur	26.8	75.8	390	0.643	0.687	0.739	0.785	0.811	0.817	0.787	0.779	0.776	0.760	0.711	0.657
24	69	Jodhpur	26.3	73.0	224	0.662	0.702	0.756	0.793	0.818	0.820	0.797	0.784	0.781	0.775	0.725	0.683
25	76	Kodaika	10.2	77.5	2345	0.654	0.661	0.678	0.691	0.701	0.688	0.675	0.678	0.678	0.669	0.659	0.654
26	79	Kota	25.2	75.5	257	0.657	0.707	0.759	0.800	0.830	0.827	0.790	0.779	0.778	0.770	0.719	0.673
27	86	Madras	13.0	80.2	16	0.738	0.750	0.771	0.783	0.803	0.797	0.783	0.778	0.777	0.767	0.747	0.738
28	89	Minicoy	8.3	73.0	2	0.758	0.760	0.770	0.773	0.775	0.771	0.766	0.766	0.765	0.764	0.762	0.759
29	92	Nagpur	21.2	79.1	311	0.701	0.732	0.771	0.804	0.826	0.801	0.769	0.762	0.764	0.754	0.722	0.696
30	97	New Del	28.6	77.2	216	0.617	0.664	0.722	0.779	0.808	0.820	0.795	0.781	0.778	0.755	0.698	0.632
31	99	Okha	22.5	69.1	7	0.704	0.718	0.738	0.756	0.773	0.778	0.775	0.770	0.767	0.763	0.751	0.717
32	100	Ollukar	10.5	76.3	22	0.760	0.766	0.774	0.776	0.773	0.761	0.754	0.754	0.756	0.760	0.763	0.760
33	105	Patna	25.5	85.3	52	0.645	0.687	0.737	0.780	0.802	0.800	0.779	0.775	0.775	0.753	0.707	0.655
34	107	Port Bl	11.7	92.7	79	0.757	0.760	0.766	0.774	0.767	0.761	0.759	0.756	0.753	0.756	0.761	0.757
35	108	Pune	18.5	73.9	563	0.715	0.734	0.768	0.790	0.791	0.775	0.750	0.746	0.750	0.757	0.735	0.719
36	123	Shillor	25.6	91.9	1598	0.604	0.630	0.677	0.709	0.716	0.721	0.728	0.726	0.719	0.697	0.654	0.620
37	124	Silicur	24.8	92.9	40	0.668	0.696	0.729	0.752	0.760	0.765	0.771	0.771	0.771	0.754	0.719	0.687
38	127	Srinaga	34.1	74.8	1587	0.458	0.502	0.577	0.639	0.687	0.740	0.767	0.760	0.726	0.653	0.561	0.493
39	134	Trivanc	8.5	77.0	64	0.758	0.763	0.772	0.774	0.769	0.755	0.751	0.751	0.754	0.755	0.756	0.757
40	135	Tuticor	8.8	78.2	4	0.738	0.746	0.764	0.775	0.785	0.784	0.782	0.783	0.779	0.770	0.753	0.740
41	142	Veraval	20.9	70.4	8	0.706	0.712	0.733	0.752	0.772	0.778	0.771	0.765	0.763	0.762	0.751	0.722
42	144	Vishakt	17.7	83.2	3	0.726	0.744	0.770	0.783	0.800	0.792	0.775	0.775	0.774	0.766	0.747	0.728

Weighing Factor, 1-W

St# Eto	St# Sun	Station	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	0.376	0.327	0.267	0.217	0.182	0.167	0.194	0.229	0.223	0.244	0.298	0.354
2	4	Ahmadal	23.1	72.6	55	0.304	0.275	0.236	0.204	0.180	0.194	0.223	0.227	0.228	0.229	0.261	0.292
3	5	Akola	20.7	77.0	282	0.289	0.264	0.224	0.193	0.175	0.197	0.224	0.236	0.234	0.240	0.267	0.293
4	7	Allahal	25.5	81.7	98	0.353	0.310	0.253	0.205	0.177	0.175	0.215	0.223	0.224	0.235	0.292	0.348
5	8	Amini I	11.1	72.7	4	0.238	0.231	0.226	0.221	0.221	0.228	0.232	0.231	0.232	0.230	0.233	0.235
6	9	Amritsa	31.6	74.9	234	0.411	0.372	0.311	0.253	0.218	0.188	0.210	0.217	0.223	0.259	0.338	0.402
7	14	Bangalc	13.0	77.6	897	0.281	0.260	0.234	0.216	0.226	0.252	0.261	0.262	0.259	0.262	0.271	0.283
8	21	Bhopal	23.3	77.4	503	0.329	0.290	0.242	0.208	0.186	0.198	0.232	0.243	0.244	0.248	0.279	0.314
9	24	Bikaner	28.0	73.3	224	0.387	0.335	0.271	0.220	0.185	0.171	0.188	0.198	0.210	0.233	0.301	0.373
10	26	Bombay	19.1	72.9	14	0.270	0.261	0.244	0.228	0.221	0.225	0.236	0.240	0.239	0.231	0.238	0.257
11	26	Bombay	19.1	72.9	14	0.270	0.261	0.244	0.228	0.221	0.225	0.236	0.240	0.239	0.231	0.238	0.257
12	27	Calcuti	22.7	88.5	6	0.322	0.284	0.241	0.219	0.211	0.221	0.227	0.227	0.228	0.238	0.278	0.316
13	27	Calcuti	22.7	88.5	6	0.322	0.284	0.241	0.219	0.211	0.221	0.227	0.227	0.228	0.238	0.278	0.316
14	34	Cuttacl	20.5	85.9	24	0.288	0.256	0.225	0.202	0.187	0.207	0.226	0.225	0.224	0.229	0.259	0.286
15	36	Dharwai	15.4	75.1	679	0.261	0.238	0.213	0.207	0.210	0.232	0.250	0.248	0.244	0.237	0.252	0.264
16	38	Dibrugi	27.5	95.0	111	0.367	0.340	0.296	0.274	0.261	0.239	0.228	0.233	0.238	0.263	0.308	0.351
17	39	Gannavi	16.5	80.8	24	0.267	0.246	0.226	0.212	0.182	0.200	0.224	0.225	0.227	0.234	0.250	0.269
18	40	Gauhati	26.1	91.6	54	0.254	0.322	0.279	0.248	0.242	0.232	0.226	0.226	0.228	0.250	0.290	0.337
19	41	Goa	15.5	73.8	55	0.252	0.247	0.236	0.225	0.222	0.235	0.244	0.243	0.244	0.233	0.237	0.245
20	56	Hyderal	17.5	78.5	545	0.279	0.255	0.221	0.207	0.189	0.215	0.241	0.244	0.244	0.249	0.273	0.288
21	59	Indore	22.7	75.8	567	0.327	0.287	0.255	0.213	0.194	0.206	0.233	0.250	0.245	0.243	0.280	0.312
22	61	Jagadal	19.1	82.0	553	0.295	0.269	0.231	0.212	0.200	0.219	0.249	0.249	0.244	0.250	0.283	0.308
23	62	Jaipur	26.8	75.8	390	0.357	0.313	0.261	0.215	0.189	0.183	0.213	0.221	0.224	0.240	0.289	0.343
24	69	Jodhpui	26.3	73.0	224	0.338	0.298	0.244	0.207	0.182	0.180	0.203	0.216	0.219	0.225	0.275	0.317
25	76	Kodaika	10.2	77.5	2345	0.346	0.339	0.322	0.309	0.299	0.312	0.325	0.322	0.322	0.331	0.341	0.346
26	79	Kota	25.2	75.5	257	0.343	0.293	0.241	0.200	0.170	0.173	0.210	0.221	0.222	0.230	0.281	0.327
27	86	Madras	13.0	80.2	16	0.262	0.250	0.229	0.217	0.197	0.203	0.217	0.222	0.223	0.233	0.253	0.262
28	89	Minicoy	8.3	73.0	2	0.242	0.240	0.230	0.227	0.225	0.229	0.234	0.234	0.235	0.236	0.238	0.241
29	92	Nagpur	21.2	79.1	311	0.299	0.268	0.229	0.196	0.174	0.199	0.231	0.238	0.236	0.246	0.278	0.304
30	97	New Del	28.6	77.2	216	0.383	0.336	0.278	0.221	0.192	0.180	0.205	0.219	0.222	0.245	0.302	0.368
31	99	Okha	22.5	69.1	7	0.296	0.282	0.262	0.244	0.227	0.222	0.225	0.230	0.233	0.237	0.249	0.283
32	100	Ollukai	10.5	76.3	22	0.240	0.234	0.226	0.224	0.227	0.239	0.246	0.246	0.244	0.240	0.237	0.240
33	105	Patna	25.5	85.3	52	0.355	0.313	0.263	0.220	0.198	0.200	0.221	0.225	0.225	0.247	0.293	0.345
34	107	Port Bl	11.7	92.7	79	0.243	0.240	0.234	0.226	0.233	0.239	0.241	0.244	0.247	0.244	0.239	0.243
35	108	Pune	18.5	73.9	563	0.285	0.266	0.232	0.210	0.209	0.225	0.250	0.254	0.250	0.243	0.265	0.281
36	123	Shillor	25.6	91.9	1598	0.396	0.370	0.323	0.291	0.284	0.279	0.272	0.274	0.281	0.303	0.346	0.380
37	124	Silicui	24.8	92.9	40	0.332	0.304	0.271	0.248	0.240	0.235	0.229	0.229	0.229	0.246	0.281	0.313
38	127	Srinagi	34.1	74.8	1587	0.542	0.498	0.423	0.361	0.313	0.260	0.233	0.240	0.274	0.347	0.439	0.507
39	134	Trivanc	8.5	77.0	64	0.242	0.237	0.228	0.226	0.231	0.245	0.249	0.249	0.246	0.245	0.244	0.243
40	135	Tuticoi	8.8	78.2	4	0.262	0.254	0.236	0.225	0.215	0.216	0.218	0.217	0.221	0.230	0.247	0.260
41	142	Veraval	20.9	70.4	8	0.294	0.288	0.267	0.248	0.228	0.222	0.229	0.235	0.237	0.238	0.249	0.278
42	144	Vishakl	17.7	83.2	3	0.274	0.256	0.230	0.217	0.200	0.208	0.225	0.225	0.226	0.234	0.253	0.272

Lookup Table for W

Temp (C)	Elev (m) 0	500	1000	2000	3000	4000
2	0.43	0.44	0.46	0.49	0.52	0.54
4	0.46	0.48	0.49	0.52	0.55	0.58
6	0.49	0.51	0.52	0.55	0.58	0.61
8	0.52	0.54	0.55	0.58	0.61	0.64
10	0.55	0.57	0.58	0.61	0.64	0.66
12	0.58	0.60	0.61	0.64	0.66	0.69
14	0.61	0.62	0.64	0.66	0.69	0.71
16	0.64	0.65	0.66	0.69	0.71	0.73
18	0.66	0.67	0.69	0.71	0.73	0.75
20	0.69	0.70	0.71	0.73	0.75	0.77
22	0.71	0.72	0.73	0.75	0.77	0.79
24	0.73	0.74	0.75	0.77	0.79	0.81
26	0.75	0.76	0.77	0.79	0.81	0.82
28	0.77	0.78	0.79	0.81	0.82	0.84
30	0.78	0.79	0.80	0.82	0.84	0.85
32	0.80	0.81	0.82	0.84	0.85	0.86
34	0.82	0.82	0.83	0.85	0.86	0.87
36	0.83	0.84	0.85	0.86	0.87	0.89
38	0.84	0.85	0.86	0.87	0.88	0.90
40	0.85	0.86	0.87	0.88	0.89	0.90

Median Temperature (C)

St# Eto	St# Sun	Station	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	14.7	18.7	24.0	29.9	33.8	36.0	32.3	27.8	28.8	26.3	20.9	16.3
2	4	Ahmadal	23.1	72.6	55	20.5	23.4	27.3	31.5	34.1	32.5	29.1	28.3	28.3	28.1	24.8	21.7
3	5	Akola	20.7	77.0	282	21.5	24.1	28.1	32.2	34.7	31.8	28.1	26.8	27.1	26.5	23.7	21.2
4	7	Allahal	25.5	81.7	98	16.6	19.9	25.5	31.3	34.5	34.9	30.3	29.1	28.9	27.4	21.7	17.0
5	8	Amini I	11.1	72.7	4	27.2	27.9	28.7	29.7	29.9	28.5	27.8	27.9	27.8	28.0	27.7	27.5
6	9	Amritsa	31.6	74.9	234	12.0	14.9	19.7	25.3	29.5	33.0	30.6	29.7	28.5	24.6	17.7	12.7
7	14	Bangalo	13.0	77.6	897	21.2	23.3	25.8	27.6	26.7	24.0	23.1	23.1	23.3	23.0	22.1	21.0
8	21	Bhopal	23.3	77.4	503	18.1	21.0	25.8	30.2	32.8	31.2	26.8	25.7	25.6	25.2	22.1	19.1
9	24	Bikaner	28.0	73.3	224	13.9	18.1	23.5	29.2	33.4	35.3	33.0	31.8	30.6	27.3	20.5	14.9
10	26	Bombay	19.1	72.9	14	24.0	24.9	26.6	28.3	29.8	28.9	27.4	27.0	27.1	27.9	27.2	25.3
11	26	Bombay	19.1	72.9	14	24.0	24.9	26.6	28.3	29.8	28.9	27.4	27.0	27.1	27.9	27.2	25.3
12	27	Calcutt	22.7	88.5	6	19.2	22.6	26.9	30.1	30.9	29.8	28.6	28.7	28.3	27.2	23.2	19.6
13	27	Calcutt	22.7	88.5	6	19.2	22.6	26.9	30.1	30.9	29.8	28.6	28.7	28.3	27.2	23.2	19.6
14	34	Cuttack	20.5	85.9	24	22.2	25.4	29.0	31.8	33.3	31.3	28.8	29.0	29.1	28.1	25.1	22.4
15	36	Dharwa	15.4	75.1	679	23.5	25.9	28.8	30.0	29.2	26.4	24.7	24.9	25.3	25.9	24.5	23.3
16	38	Dibrug	27.5	95.0	111	15.4	17.8	21.2	23.4	24.7	26.9	28.0	27.5	27.0	24.5	20.0	16.7
17	39	Gannav	16.5	80.8	24	24.3	26.4	28.7	30.8	33.8	32.0	29.2	28.9	28.6	27.6	26.0	24.1
18	40	Gauhati	26.1	91.6	54	25.5	19.2	23.0	26.1	26.7	27.7	28.6	28.5	28.1	25.9	21.9	18.1
19	41	Goa	15.5	73.8	55	25.7	26.2	27.3	28.8	29.3	27.4	26.5	26.6	26.5	27.6	27.2	26.4
20	56	Hyderal	17.5	78.5	545	22.1	24.5	27.8	30.2	32.0	28.8	25.9	25.5	25.5	25.1	22.7	21.1
21	59	Indore	22.7	75.8	567	18.1	21.2	24.4	29.1	31.5	30.3	26.6	24.9	25.4	25.6	21.9	19.1
22	61	Jagadal	19.1	82.0	553	20.4	23.0	26.8	29.4	30.9	28.1	25.0	25.0	25.5	24.9	21.6	19.4
23	62	Jaipur	26.8	75.8	390	15.7	19.3	24.1	29.5	32.6	33.6	29.9	28.3	27.8	26.3	21.4	16.9
24	69	Jodhpu	26.3	73.0	224	17.8	20.8	26.2	30.9	33.8	34.1	31.3	30.0	29.3	28.1	23.1	19.3
25	76	Kodaik	10.2	77.5	2345	12.6	13.2	14.6	15.6	16.4	15.4	14.4	14.6	14.6	13.9	13.0	12.6
26	79	Kota	25.2	75.5	257	17.2	21.2	26.4	31.5	35.4	35.0	30.5	28.7	28.6	27.5	22.4	18.5
27	86	Madras	13.0	80.2	16	24.8	26.0	28.1	30.3	32.3	31.7	30.3	29.6	29.3	27.7	25.7	24.8
28	89	Minico	8.3	73.0	2	26.8	27.0	28.0	28.7	29.0	28.1	27.6	27.6	27.5	27.4	27.2	26.9
29	92	Nagpur	21.2	79.1	311	20.5	23.6	27.5	31.8	34.8	31.5	27.3	26.6	26.8	25.8	22.6	20.0
30	97	New Del	28.6	77.2	216	14.2	18.0	22.8	28.9	32.5	34.1	31.1	29.4	28.8	26.1	20.4	15.2
31	99	Okha	22.5	69.1	7	21.4	22.8	24.8	26.6	28.7	29.6	29.0	28.0	27.7	27.3	26.1	22.7
32	100	Ollukka	10.5	76.3	22	27.0	27.6	28.7	29.1	28.6	27.1	26.4	26.4	26.6	27.0	27.3	27.0
33	105	Patna	25.5	85.3	52	16.4	19.7	24.6	29.9	32.1	31.9	29.5	28.8	28.8	26.2	21.6	17.4
34	107	Port Bl	11.7	92.7	79	26.6	26.9	27.4	28.5	27.6	27.0	26.7	26.5	26.1	26.5	26.9	26.5
35	108	Pune	18.5	73.9	563	21.4	23.3	26.7	29.8	29.9	27.4	24.9	24.5	24.9	25.6	23.4	21.8
36	123	Shillo	25.6	91.9	1598	10.4	12.2	15.9	18.7	19.5	19.9	20.7	20.5	19.7	17.6	14.2	11.5
37	124	Silicu	24.8	92.9	40	18.5	20.6	23.8	26.2	27.0	27.5	28.1	28.1	28.1	26.4	22.8	19.8
38	127	Srinag	34.1	74.8	1587	0.7	3.6	8.6	13.0	16.8	21.8	24.5	23.8	20.4	14.1	7.6	3.1
39	134	Trivan	8.5	77.0	64	26.7	27.2	28.2	28.6	27.8	26.4	26.0	26.0	26.3	26.4	26.5	26.6
40	135	Tutico	8.8	78.2	4	24.8	25.6	27.4	28.9	30.5	30.4	30.2	30.3	29.9	28.1	26.3	25.0
41	142	Veraval	20.9	70.4	8	21.6	22.2	24.3	26.2	28.4	29.6	28.2	27.5	27.3	27.2	26.1	23.2
42	144	Vishakl	17.7	83.2	3	23.6	25.4	28.0	30.3	32.0	31.2	29.0	29.0	28.8	27.6	25.7	23.8

Maximum Temperature (C)

St# Eto	St# Sun	Station	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	22.5	26.5	32.2	38.0	41.5	42.4	35.6	32.8	33.1	33.2	29.1	24.5
2	4	Ahmadat	23.1	72.6	55	28.0	31.6	35.1	38.8	40.9	37.1	31.7	30.8	31.6	34.6	32.2	28.9
3	5	Akola	20.7	77.0	282	30.1	33.6	37.0	40.9	42.3	38.1	32.9	30.8	31.9	33.8	31.7	29.3
4	7	Allahat	25.5	81.7	98	22.5	26.6	32.6	38.2	40.9	39.3	32.7	31.2	31.7	32.7	27.8	23.2
5	8	Amini I	11.1	72.7	4	29.6	30.3	30.9	31.6	31.4	29.0	28.2	28.6	28.7	29.5	29.7	29.5
6	9	Amritsa	31.6	74.9	234	18.0	21.1	26.1	32.0	36.6	39.1	33.9	32.6	32.5	31.0	24.5	19.3
7	14	Bangalc	13.0	77.6	897	27.0	28.8	31.7	33.1	31.5	27.6	26.3	26.2	26.6	26.6	25.5	25.3
8	21	Bhopal	23.3	77.4	503	23.9	27.9	32.5	36.9	39.1	35 6	29.2	27.7	28.7	30.4	27.6	24.9
9	24	Bikaner	28.0	73.3	224	23.3	27.4	32.3	37.6	41.5	41.7	38.2	36.7	36.3	36.0	30.2	24.2
10	26	Bombay	19.1	72.9	14	29.6	30.7	31.3	31.9	32.4	30.5	28.3	27.9	28.8	31.6	32.1	30.5
11	26	Bombay	19.1	72.9	14	29.6	30.7	31.3	31.9	32.4	30.5	28.3	27.9	28.8	31.6	32.1	30.5
12	27	Calcuti	22.7	88.5	6	25.1	28.8	32.8	35.2	34.7	32.4	30.5	30.6	30.2	30.0	28.0	25.3
13	27	Calcuti	22.7	88.5	6	25.1	28.8	32.8	35.2	34.7	32.4	30.5	30.6	30.2	30.0	28.0	25.3
14	34	Cuttacl	20.5	85.9	24	28.6	32.2	35.8	38.5	39.5	35.9	31.9	32.1	32.5	32.4	30.9	28.9
15	36	Dharwai	15.4	75.1	679	30.1	33.2	36.2	37.4	36.1	31.2	28.1	28.8	30.0	31.3	30.3	29.3
16	38	Dibruga	27.5	95.0	111	21.7	22.5	26.3	27.2	27.4	29.3	29.9	29.8	29.5	27.8	25.1	22.4
17	39	Gannava	16.5	80.8	24	28.7	32.1	33.8	35.4	39.1	35.6	31.6	31.3	31.1	30.5	29.5	28.6
18	40	Gauhati	26.1	91.6	54	34.0	25.0	29.1	30.5	29.6	29.5	30.4	30.3	30.3	28.9	26.3	23.3
19	41	Goa	15.5	73.8	55	30.6	31.0	30.8	31.8	31.8	29.1	27.4	27.9	28.3	30.7	31.5	30.8
20	56	Hyderat	17.5	78.5	545	27.6	30.6	33.6	35.6	37.0	32.6	28.5	28.0	28.4	29.2	27.7	26.9
21	59	Indore	22.7	75.8	567	25.1	28.9	31.7	36.2	38.1	35.1	29.3	27.3	29.1	31.8	28.6	25.5
22	61	Jagadal	19.1	82.0	553	27.4	30.3	33.7	35.5	36.5	31.4	26.8	26.9	28.0	28.7	27.4	26.4
23	62	Jaipur	26.8	75.8	390	21.8	25.6	30.5	35.6	38.8	38.0	32.3	30.8	31.4	32.4	27.9	23.3
24	69	Jodhpui	26.3	73.0	224	24.2	27.7	33.2	37.8	40.4	38.9	34.6	33.1	33.4	34.8	29.8	25.6
25	76	Kodaika	10.2	77.5	2345	15.7	16.6	18.1	18.5	18.8	17.2	16.0	16.4	16.5	15.6	14.9	15.1
26	79	Kota	25.2	75.5	257	24.2	28.9	33.9	38.7	42.1	40.7	34.6	32.0	32.8	34.3	29.3	25.6
27	86	Madras	13.0	80.2	16	27.7	29.8	32.0	34.0	36.1	35.3	33.5	32.8	32.4	30.3	27.9	27.3
28	89	Minicoy	8.3	73.0	2	29.5	29.7	30.2	30.7	30.5	29.2	28.5	28.7	28.8	29.1	29.4	29.3
29	92	Nagpur	21.2	79.1	311	27.2	31.3	34.6	38.4	40.5	35.4	29.5	28.7	29.7	31.0	29.1	26.6
30	97	New Del	28.6	77.2	216	19.7	23.9	28.9	35.1	38.7	38.5	33.7	31.6	32.0	31.3	26.4	20.9
31	99	Okha	22.5	69.1	7	22.7	24.2	26.3	28.0	30.1	30.7	29.8	28.8	28.9	28.6	27.2	23.9
32	100	Ollukai	10.5	76.3	22	31.6	32.0	32.5	32.9	31.8	30.0	29.1	29.1	29.5	30.1	31.1	31.3
33	105	Patna	25.5	85.3	52	22.2	26.3	31.3	36.1	37.9	35.7	31.7	30.6	31.3	30.2	27.2	23.1
34	107	Port Bl	11.7	92.7	79	29.4	30.4	31.3	32.0	29.5	28.4	28.0	27.7	27.5	28.5	29.3	28.9
35	108	Pune	18.5	73.9	563	29.7	32.5	35.2	37.4	35.9	30.8	26.8	26.5	28.0	31.2	29.9	29.0
36	123	Shillor	25.6	91.9	1598	13.7	15.7	19.5	22.1	21.9	21.6	22.5	22.4	21.7	19.8	17.0	14.5
37	124	Silicui	24.8	92.9	40	25.2	27.2	30.5	31.9	31.7	31.2	32.0	31.9	32.3	31.0	29.0	26.5
38	127	Srinaga	34.1	74.8	1587	2.5	6.2	11.9	16.5	21.2	27.3	28.9	28.3	25.8	20.0	11.7	5.7
39	134	Trivanc	8.5	77.0	64	30.1	30.5	31.4	31.4	30.0	28.2	27.8	27.9	28.5	28.7	29.0	29.6
40	135	Tuticoi	8.8	78.2	4	27.7	28.4	30.2	31.9	34.4	34.9	34.5	34.7	34.3	31.7	29.2	28.0
41	142	Veraval	20.9	70.4	8	26.8	27.3	28.5	29.3	30.3	30.6	28.6	27.9	28.2	30.7	30.7	27.9
42	144	Vishakl	17.7	83.2	3	28.0	30.4	32.6	34.1	35.4	33.9	31.3	31.2	31.1	30.2	29.2	27.8

Minimum Temperature (C)

St# Eto	St# Sun	Station	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	6.9	10.8	15.8	21.7	26.0	29.5	29.0	22.7	24.4	19.3	12.6	8.1
2	4	Ahmadat	23.1	72.6	55	13.0	15.1	19.5	24.1	27.2	27.9	26.5	25.8	24.9	21.5	17.3	14.5
3	5	Akola	20.7	77.0	282	12.9	14.5	19.1	23.4	27.0	25.4	23.2	22.8	22.2	19.1	15.7	13.0
4	7	Allahat	25.5	81.7	98	10.6	13.1	18.4	24.4	28.0	30.5	27.9	27.0	26.1	22.0	15.5	10.8
5	8	Amini I	11.1	72.7	4	24.7	25.5	26.5	27.8	28.3	27.9	27.4	27.2	26.8	26.5	25.6	25.4
6	9	Amritsa	31.6	74.9	234	5.9	8.7	13.2	18.5	22.4	26.8	27.2	26.8	24.4	18.2	10.9	6.1
7	14	Bangalo	13.0	77.6	897	15.3	17.7	19.9	22.1	21.8	20.4	19.9	19.9	20.0	19.4	18.7	16.6
8	21	Bhopal	23.3	77.4	503	12.2	14.1	19.0	23.4	26.5	26.7	24.4	23.6	22.5	19.9	16.5	13.2
9	24	Bikaner	28.0	73.3	224	4.4	8.7	14.6	20.8	25.3	28.9	27.8	26.8	24.8	18.6	10.7	5.5
10	26	Bombay	19.1	72.9	14	18.3	19.1	21.9	24.6	27.2	27.2	26.5	26.0	25.3	24.2	22.2	20.1
11	26	Bombay	19.1	72.9	14	18.3	19.1	21.9	24.6	27.2	27.2	26.5	26.0	25.3	24.2	22.2	20.1
12	27	Calcutt	22.7	88.5	6	13.3	16.3	21.0	25.0	27.0	27.2	26.6	26.7	26.4	24.3	18.3	13.9
13	27	Calcutt	22.7	88.5	6	13.3	16.3	21.0	25.0	27.0	27.2	26.6	26.7	26.4	24.3	18.3	13.9
14	34	Cuttack	20.5	85.9	24	15.7	18.5	22.2	25.0	27.0	26.7	25.7	25.8	25.6	23.7	19.3	15.8
15	36	Dharwar	15.4	75.1	679	16.9	18.5	21.3	22.5	22.3	21.6	21.2	20.9	20.5	20.5	18.6	17.2
16	38	Dibruga	27.5	95.0	111	9.1	13.1	16.1	19.5	22.0	24.4	26.1	25.1	24.5	21.2	14.9	10.9
17	39	Gannava	16.5	80.8	24	19.8	20.7	23.5	26.1	28.4	28.3	26.7	26.5	26.1	24.7	22.4	19.6
18	40	Gauhati	26.1	91.6	54	17.0	13.3	16.8	21.6	23.7	25.8	26.8	26.7	25.9	22.8	17.4	12.9
19	41	Goa	15.5	73.8	55	20.8	21.4	23.7	25.7	26.8	25.7	25.5	25.3	24.7	24.4	22.8	21.9
20	56	Hyderat	17.5	78.5	545	16.5	18.3	22.0	24.8	27.0	25.0	23.2	23.0	22.6	20.9	17.6	15.3
21	59	Indore	22.7	75.8	567	11.0	13.4	17.1	22.0	24.8	25.5	23.9	22.5	21.6	19.4	15.2	12.6
22	61	Jagadal	19.1	82.0	553	13.3	15.6	19.9	23.3	25.2	24.7	23.2	23.1	22.9	21.1	15.8	12.4
23	62	Jaipur	26.8	75.8	390	9.5	13.0	17.7	23.3	26.4	29.1	27.4	25.7	24.2	20.1	14.8	10.5
24	69	Jodhpur	26.3	73.0	224	11.4	13.9	19.1	24.0	27.1	29.2	28.0	26.8	25.1	21.4	16.3	12.9
25	76	Kodaika	10.2	77.5	2345	9.5	9.8	11.1	12.6	14.0	13.5	12.7	12.8	12.6	12.1	11.1	10.1
26	79	Kota	25.2	75.5	257	10.1	13.5	18.8	24.2	28.6	29.2	26.3	25.4	24.3	20.7	15.4	11.4
27	86	Madras	13.0	80.2	16	21.8	22.2	24.2	26.6	28.5	28.1	27.1	26.3	26.1	25.1	23.5	22.3
28	89	Minicoy	8.3	73.0	2	24.0	24.3	25.7	26.6	27.5	27.0	26.7	26.5	26.2	25.6	24.9	24.5
29	92	Nagpur	21.2	79.1	311	13.7	15.9	20.4	25.2	29.1	27.5	25.0	24.4	23.8	20.6	16.1	13.4
30	97	New Del	28.6	77.2	216	8.6	12.0	16.6	22.6	26.3	29.6	28.4	27.1	25.5	20.8	14.3	9.5
31	99	Okha	22.5	69.1	7	20.1	21.3	23.3	25.1	27.2	28.5	28.1	27.1	26.4	25.9	24.9	21.5
32	100	Ollukar	10.5	76.3	22	22.3	23.2	24.9	25.3	25.3	24.2	23.6	23.7	23.6	23.9	23.5	22.7
33	105	Patna	25.5	85.3	52	10.6	13.1	17.8	23.6	26.3	28.1	27.3	27.0	26.3	22.1	16.0	11.6
34	107	Port Bl	11.7	92.7	79	23.7	23.3	23.5	24.9	25.6	25.5	25.4	25.2	24.7	24.4	24.5	24.1
35	108	Pune	18.5	73.9	563	13.1	14.0	18.1	22.1	23.9	23.9	23.0	22.4	21.7	20.0	16.8	14.6
36	123	Shillor	25.6	91.9	1598	7.1	8.7	12.3	15.3	17.0	18.2	18.8	18.5	17.7	15.4	11.3	8.5
37	124	Silicur	24.8	92.9	40	11.7	13.9	17.1	20.4	22.2	23.7	24.2	24.2	23.9	21.7	16.6	13.0
38	127	Srinaga	34.1	74.8	1587	-1.1	1.0	5.3	9.4	12.3	16.3	20.1	19.3	15.0	8.2	3.4	0.4
39	134	Trivanc	8.5	77.0	64	23.3	23.8	25.0	25.8	25.6	24.6	24.1	24.1	24.1	24.1	23.9	23.5
40	135	Tuticor	8.8	78.2	4	21.9	22.7	24.5	25.9	26.5	25.9	25.8	25.9	25.4	24.4	23.4	22.0
41	142	Veraval	20.9	70.4	8	16.4	17.1	20.0	23.0	26.5	28.5	27.7	27.0	26.3	23.6	21.5	18.5
42	144	Vishakh	17.7	83.2	3	19.1	20.3	23.4	26.5	28.6	28.5	26.7	26.7	26.4	24.9	22.1	19.7

APPENDIX M

EVAPOTRANSPIRATION
PENMAN METHOD

ADJUSTMENT FACTOR
(c)

Adjustment Factor, C

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	0.992	0.977	0.961	0.941	0.906	0.886	0.963	0.993	1.010	1.000	0.983	0.976
2	4	Ahmadabad	23.1	72.6	55	1.007	1.019	0.987	0.997	1.013	1.014	0.992	1.007	1.051	1.093	1.055	1.017
3	5	Akola	20.7	77.0	282	0.939	0.887	0.905	0.887	0.874	0.930	0.940	0.975	1.001	0.997	0.961	1.000
4	7	Allahabad	25.5	81.7	98	1.070	1.090	1.069	0.979	0.979	0.977	1.013	1.036	1.056	1.094	1.068	1.062
5	8	Amini Divi	11.1	72.7	4	1.041	1.031	1.032	1.033	0.965	0.837	0.801	0.854	0.925	0.977	1.029	1.044
6	9	Amritsar	31.6	74.9	234	0.987	0.980	0.993	1.007	0.974	0.979	1.013	1.046	1.048	1.041	1.009	0.988
7	14	Bangalor	13.0	77.6	897	1.028	1.063	1.037	1.043	1.008	0.932	0.894	0.932	0.970	1.035	1.040	1.025
8	21	Bhopal	23.3	77.4	503	0.959	0.960	0.915	0.892	0.884	0.915	0.912	0.913	0.990	1.038	0.991	0.971
9	24	Bikaner	28.0	73.3	224	0.986	0.990	0.987	0.981	0.969	0.979	0.997	1.015	1.025	1.015	0.980	0.980
10	26	Bombay	19.1	72.9	14	0.983	1.019	1.052	1.073	1.055	0.973	0.907	0.923	0.978	1.037	1.012	0.990
11	26	Bombay	19.1	72.9	14	0.993	1.036	1.109	1.151	1.079	0.942	0.842	0.872	0.977	1.066	1.027	0.998
12	27	Calcutta	22.7	88.5	6	1.080	1.104	1.154	1.086	1.079	1.014	1.026	1.029	1.036	1.065	1.089	1.069
13	27	Calcutta	22.7	88.5	6	1.095	1.081	1.065	1.037	1.032	0.974	0.982	0.992	1.027	1.052	1.099	1.103
14	34	Cuttack	20.5	85.9	24	1.051	1.033	1.028	1.008	1.008	0.973	0.984	1.000	1.010	1.030	1.027	1.030
15	36	Dharwar	15.4	75.1	679	1.192	1.048	1.025	1.025	1.015	0.932	0.891	0.931	1.011	1.057	1.116	1.075
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	1.070	1.037	1.045	1.012	1.045	1.021	1.039	1.065	1.046	1.078	1.092	1.085
17	39	Gannavaram	16.5	80.8	24	1.055	1.113	1.103	1.072	1.026	0.914	0.950	0.982	1.019	1.051	1.024	1.003
18	40	Gauhati	26.1	91.6	54	1.075	1.071	1.071	1.061	1.072	1.039	1.052	1.063	1.059	1.114	1.088	1.087
19	41	Goa	15.5	73.8	55	1.009	1.037	1.060	1.069	1.037	0.946	0.886	0.918	1.015	1.047	1.023	1.001
20	56	Hyderabad	17.5	78.5	545	1.054	1.051	1.013	1.003	0.950	0.890	0.861	0.921	0.989	1.112	1.098	1.074
21	59	Indore	22.7	75.8	567	0.941	0.881	0.874	0.838	0.857	0.890	0.866	0.877	0.938	0.977	0.940	0.951
22	61	Jagadalpur	19.1	82.0	553	1.105	1.139	1.087	1.072	1.065	1.036	0.995	1.011	1.048	1.101	1.148	1.119
23	62	Jaipur	26.8	75.8	390	0.963	0.967	0.947	0.930	0.918	0.961	1.007	1.036	1.094	1.026	0.973	0.964
24	69	Jodhpur	26.3	73.0	224	0.904	0.902	0.878	0.894	0.896	0.939	0.955	0.980	1.075	0.977	0.900	0.905
25	76	Kodaikanal	10.2	77.5	2345	0.976	0.980	0.993	1.022	0.977	0.930	0.889	0.935	0.961	0.958	0.934	0.923
26	79	Kota	25.2	75.5	257	0.952	0.922	0.910	0.858	0.832	0.885	0.904	0.931	0.994	0.985	0.960	0.956
27	86	Madras	13.0	80.2	16	1.095	1.131	1.125	1.102	1.014	0.956	0.951	0.988	1.012	1.049	1.049	1.025
28	89	Minicoy	8.3	73.0	2	1.077	1.100	1.101	1.074	0.993	0.925	0.920	0.966	0.979	1.018	1.043	1.061
29	92	Nagpur	21.2	79.1	311	1.003	0.984	0.963	0.937	0.890	0.936	0.957	0.966	1.007	1.045	1.028	1.014
30	97	New Dehli	28.6	77.2	216	0.971	0.974	0.972	0.935	0.892	0.873	0.992	1.021	1.030	1.043	1.010	0.972
31	99	Okha	22.5	69.1	7	0.870	0.936	0.959	0.985	0.966	0.922	0.835	0.843	0.961	0.981	0.916	0.854
32	100	Ollukara	10.5	76.3	22	1.054	1.085	1.093	1.075	1.005	0.980	0.961	0.971	0.997	1.020	1.037	1.029
33	105	Patna	25.5	85.3	52	1.096	1.099	1.064	1.034	1.034	1.030	1.043	1.053	1.066	1.113	1.189	1.118
34	107	Port Blair	11.7	92.7	79	1.016	1.085	1.116	1.113	0.997	0.905	0.903	0.918	0.953	1.028	1.031	1.003
35	108	Pune	18.5	73.9	563	1.031	1.009	0.982	0.971	0.967	0.931	0.887	0.921	0.998	1.086	1.068	1.041
36	123	Shillong	25.6	91.9	1598	1.015	1.008	0.992	1.008	1.020	1.010	1.036	1.037	1.037	1.035	1.031	1.027
37	124	Silicuri	24.8	92.9	40	0.992	0.996	0.998	1.024	1.032	1.023	1.039	1.041	1.037	1.025	1.014	0.997
38	127	Srinagar	34.1	74.8	1587	0.995	1.014	1.017	1.049	1.080	1.080	1.079	1.081	1.071	1.049	1.034	1.007
39	134	Trivandrum	8.5	77.0	64	1.040	1.050	1.048	1.047	1.031	0.978	0.990	1.012	1.050	1.030	1.030	1.036
40	135	Tuticorin	8.8	78.2	4	0.926	0.943	0.969	1.006	0.963	0.885	0.869	0.885	0.905	0.974	0.934	0.883
41	142	Veraval	20.9	70.4	8	0.903	0.963	1.002	0.993	1.003	0.939	0.803	0.844	0.946	0.992	0.949	0.898
42	144	Vishakhapatnam	17.7	83.2	3	1.211	1.313	1.188	1.131	1.074	0.947	0.928	1.002	1.047	1.114	1.109	1.117

Look-up Table for Adjustment Factor, c

Ud(m/s)	0																			
RHmax(%)	30					60					90					120				
Rs(mm/d)	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
Ud/Un																				
0	0.82	0.86	0.90	1.00	1.00	0.94	0.96	0.98	1.05	1.05	0.98	1.02	1.06	1.10	1.10	1.02	1.08	1.14	1.15	1.15
1	0.82	0.86	0.90	1.00	1.00	0.94	0.96	0.98	1.05	1.05	0.98	1.02	1.06	1.10	1.10	1.02	1.08	1.14	1.15	1.15
2	0.82	0.86	0.90	1.00	1.00	0.94	0.96	0.98	1.05	1.05	0.98	1.02	1.06	1.10	1.10	1.02	1.08	1.14	1.15	1.15
3	0.82	0.86	0.90	1.00	1.00	0.94	0.96	0.98	1.05	1.05	0.98	1.02	1.06	1.10	1.10	1.02	1.08	1.14	1.15	1.15
4	0.82	0.86	0.90	1.00	1.00	0.94	0.96	0.98	1.05	1.05	0.98	1.02	1.06	1.10	1.10	1.02	1.08	1.14	1.15	1.15
5	0.82	0.86	0.90	1.00	1.00	0.94	0.96	0.98	1.05	1.05	0.98	1.02	1.06	1.10	1.10	1.02	1.08	1.14	1.15	1.15
6	0.82	0.86	0.90	1.00	1.00	0.94	0.96	0.98	1.05	1.05	0.98	1.02	1.06	1.10	1.10	1.02	1.08	1.14	1.15	1.15
7	0.82	0.86	0.90	1.00	1.00	0.94	0.96	0.98	1.05	1.05	0.98	1.02	1.06	1.10	1.10	1.02	1.08	1.14	1.15	1.15
Ud(m/s)	3																			
RHmax(%)	30					60					90					120				
Rs(mm/d)	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
Ud/Un																				
0	0.52	0.59	0.66	0.79	0.86	0.65	0.73	0.81	0.89	0.93	0.76	0.81	0.86	0.92	0.96	0.87	0.89	0.91	0.95	0.99
1	0.57	0.64	0.71	0.82	0.89	0.70	0.78	0.86	0.94	0.99	0.78	0.85	0.92	1.01	1.05	0.86	0.92	0.98	1.08	1.11
2	0.62	0.69	0.76	0.85	0.92	0.75	0.83	0.91	0.99	1.05	0.80	0.89	0.98	1.10	1.14	0.85	0.95	1.05	1.21	1.23
3	0.71	0.76	0.81	0.88	0.94	0.78	0.87	0.96	1.06	1.12	0.84	0.94	1.04	1.18	1.28	0.90	1.01	1.12	1.30	1.44
4	0.74	0.79	0.84	0.92	0.97	0.84	0.92	1.00	1.11	1.19	0.88	0.99	1.10	1.27	1.32	0.92	1.06	1.20	1.43	1.45
5	0.77	0.82	0.87	0.96	1.00	0.90	0.97	1.04	1.16	1.26	0.92	1.04	1.16	1.36	1.36	0.94	1.11	1.28	1.56	1.46
6	0.80	0.85	0.90	1.00	1.03	0.96	1.02	1.08	1.21	1.33	0.96	1.09	1.22	1.45	1.40	0.96	1.16	1.36	1.69	1.47
7	0.83	0.88	0.93	1.04	1.06	1.02	1.07	1.12	1.26	1.40	1.00	1.14	1.28	1.54	1.44	0.98	1.21	1.44	1.82	1.48
Ud(m/s)	6																			
RHmax(%)	30					60					90					120				
Rs(mm/d)	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
Ud/Un																				
0	0.21	0.33	0.45	0.62	0.74	0.48	0.54	0.60	0.74	0.84	0.58	0.65	0.72	0.85	0.88	0.68	0.76	0.84	0.96	0.92
1	0.33	0.43	0.53	0.68	0.79	0.54	0.62	0.70	0.84	0.93	0.62	0.72	0.82	0.95	1.00	0.70	0.82	0.94	1.06	1.07
2	0.45	0.53	0.61	0.74	0.84	0.60	0.70	0.80	0.94	1.02	0.66	0.79	0.92	1.05	1.12	0.72	0.88	1.04	1.16	1.22
3	0.54	0.61	0.68	0.81	0.88	0.66	0.77	0.88	1.02	1.10	0.71	0.86	1.01	1.15	1.22	0.76	0.95	1.14	1.28	1.34
4	0.59	0.68	0.77	0.87	0.93	0.74	0.85	0.96	1.11	1.19	0.78	0.94	1.10	1.26	1.33	0.82	1.03	1.24	1.41	1.47
5	0.64	0.75	0.86	0.93	0.98	0.82	0.93	1.04	1.20	1.28	0.85	1.02	1.19	1.37	1.44	0.88	1.11	1.34	1.54	1.60
6	0.69	0.82	0.95	0.99	1.03	0.90	1.01	1.12	1.29	1.37	0.92	1.10	1.28	1.48	1.55	0.94	1.19	1.44	1.67	1.73
7	0.74	0.89	1.04	1.05	1.08	0.98	1.09	1.20	1.38	1.46	0.99	1.18	1.37	1.59	1.66	1.00	1.27	1.54	1.80	1.86
Ud(m/s)	9																			
RHmax(%)	30					60					90					120				
Rs(mm/d)	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
Ud/Un																				
0	0.00	0.17	0.34	0.53	0.64	0.32	0.41	0.50	0.66	0.79	0.43	0.53	0.63	0.78	0.86	0.54	0.65	0.76	0.90	0.93
1	0.13	0.27	0.41	0.59	0.70	0.40	0.50	0.60	0.75	0.87	0.52	0.62	0.72	0.87	0.96	0.64	0.74	0.84	0.99	1.05
2	0.26	0.37	0.48	0.65	0.76	0.48	0.59	0.70	0.84	0.95	0.61	0.71	0.81	0.96	1.06	0.74	0.83	0.92	1.08	1.17
3	0.36	0.46	0.56	0.72	0.82	0.55	0.67	0.79	0.88	1.05	0.64	0.78	0.92	1.06	1.18	0.73	0.89	1.05	1.24	1.31
4	0.45	0.55	0.65	0.78	0.90	0.64	0.76	0.88	1.02	1.14	0.75	0.88	1.01	1.16	1.27	0.86	1.00	1.14	1.30	1.40
5	0.54	0.64	0.74	0.84	0.98	0.73	0.85	0.97	1.16	1.23	0.86	0.98	1.10	1.26	1.36	0.99	1.11	1.23	1.36	1.49
6	0.63	0.73	0.83	0.90	1.06	0.82	0.94	1.06	1.30	1.32	0.97	1.08	1.19	1.36	1.45	1.12	1.22	1.32	1.42	1.58
7	0.72	0.82	0.92	0.96	1.14	0.91	1.03	1.15	1.44	1.41	1.08	1.18	1.28	1.46	1.54	1.25	1.33	1.41	1.48	1.67

Relative Humidity (%) -Maximum for Month

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	73	62	50	43	40	49	75	84	77	63	59	70
2	4	Ahmadabad	23.1	72.6	55	60	57	52	57	66	79	91	93	93	81	69	67
3	5	Akola	20.7	77.0	282	58	37	35	33	39	68	87	90	88	74	65	66
4	7	Allahabad	25.5	81.7	98	91	82	63	47	46	61	89	93	92	91	90	92
5	8	Amini Divi	11.1	72.7	4	82	82	81	84	83	84	85	85	84	84	85	84
6	9	Amritsar	31.6	74.9	234	93	87	82	70	57	63	85	91	91	90	91	93
7	14	Bangalor	13.0	77.6	897	92	90	77	78	85	93	94	94	95	95	95	95
8	21	Bhopal	23.3	77.4	503	70	60	47	41	44	70	91	93	93	79	71	73
9	24	Bikaner	28.0	73.3	224	70	63	56	50	47	59	74	80	76	63	65	73
10	26	Bombay	19.1	72.9	14	74	75	81	86	81	84	89	88	88	85	79	77
11	26	Bombay	19.1	72.9	14	74	75	81	86	81	84	89	88	88	85	79	77
12	27	Calcutta	22.7	88.5	6	90	89	89	87	87	91	92	93	93	92	91	91
13	27	Calcutta	22.7	88.5	6	90	89	89	87	87	91	92	93	93	92	91	91
14	34	Cuttack	20.5	85.9	24	81	77	74	71	71	75	85	85	84	80	75	76
15	36	Dharwar	15.4	75.1	679	74	64	73	82	89	92	94	94	95	88	81	80
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	95	92	87	88	92	93	94	95	95	94	95	95
17	39	Gannavaram	16.5	80.8	24	91	93	92	90	85	79	87	89	92	93	91	89
18	40	Gauhati	26.1	91.6	54	96	93	88	88	91	93	92	94	95	96	96	96
19	41	Goa	15.5	73.8	55	82	82	83	80	81	88	90	88	91	90	85	84
20	56	Hyderabad	17.5	78.5	545	87	72	66	66	58	78	88	89	92	94	92	90
21	59	Indore	22.7	75.8	567	60	42	41	32	43	74	90	94	87	61	53	64
22	61	Jagadalpur	19.1	82.0	553	93	88	78	80	79	86	92	94	95	96	96	95
23	62	Jaipur	26.8	75.8	390	72	60	48	38	38	56	82	89	87	70	65	69
24	69	Jodhpur	26.3	73.0	224	54	44	38	36	43	67	81	86	87	59	48	55
25	76	Kodaikanal	10.2	77.5	2345	87	81	82	91	89	89	92	95	95	94	90	83
26	79	Kota	25.2	75.5	257	62	49	40	33	32	54	78	85	83	65	61	66
27	86	Madras	13.0	80.2	16	93	94	93	91	81	76	78	85	89	94	94	93
28	89	Minicoy	8.3	73.0	2	88	90	89	85	84	84	84	84	84	87	88	89
29	92	Nagpur	21.2	79.1	311	81	65	55	48	43	71	91	94	94	90	86	87
30	97	New Dehli	28.6	77.2	216	87	76	69	52	46	56	82	90	87	80	80	86
31	99	Okha	22.5	69.1	7	71	81	84	87	85	87	86	88	85	87	76	67
32	100	Ollukara	10.5	76.3	22	86	88	89	89	91	94	95	94	94	94	92	89
33	105	Patna	25.5	85.3	52	88	78	65	60	72	82	93	95	94	96	95	94
34	107	Port Blair	11.7	92.7	79	89	94	96	95	94	93	93	94	95	96	94	90
35	108	Pune	18.5	73.9	563	80	67	59	60	73	83	90	92	93	93	89	87
36	123	Shillong	25.6	91.9	1598	86	75	66	77	84	91	93	92	91	91	90	89
37	124	Silicuri	24.8	92.9	40	88	86	79	86	90	95	97	97	96	94	91	90
38	127	Srinagar	34.1	74.8	1587	91	94	93	93	92	89	89	92	95	97	96	94
39	134	Trivandrum	8.5	77.0	64	87	86	90	93	93	94	95	95	95	95	93	91
40	135	Tuticorin	8.8	78.2	4	79	77	76	73	65	61	60	59	60	73	80	81
41	142	Veraval	20.9	70.4	8	63	73	79	80	85	85	89	89	85	80	71	64
42	144	Vishakhapatnam	17.7	83.2	3	90	91	89	89	86	81	89	89	91	90	87	86

Shortwave Radiation. Rs (mm/day)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra	27.2	78.1	169	6.11	7.34	8.70	9.63	9.81	8.67	7.58	7.10	7.97	7.86	6.82	5.84
2	4	Ahmadabad	23.1	72.6	55	7.19	8.39	8.89	9.90	10.71	9.24	6.88	6.33	7.66	8.47	7.56	6.89
3	5	Akola	20.7	77.0	282	7.79	8.72	9.25	9.94	10.16	8.52	6.37	6.38	7.04	8.04	7.57	7.04
4	7	Allahabad	25.5	81.7	98	6.24	7.64	8.47	9.68	10.13	8.30	7.33	6.83	7.61	7.80	6.91	6.09
5	8	Amini Divi	11.1	72.7	4	8.03	8.94	9.87	9.52	7.92	6.39	6.16	6.89	7.84	7.45	7.48	7.33
6	9	Amritsar	31.6	74.9	234	4.91	6.15	7.25	9.04	10.19	9.65	8.69	8.43	7.93	7.25	5.95	4.76
7	14	Bangalor	13.0	77.6	897	7.84	8.80	9.38	9.42	8.64	6.93	5.91	6.54	6.90	7.01	7.19	7.07
8	21	Bhopal	23.3	77.4	503	7.16	8.31	8.99	9.83	10.52	8.64	6.33	5.84	7.18	8.23	7.54	6.63
9	24	Bikaner	28.0	73.3	224	6.21	7.44	8.88	10.57	11.59	11.46	10.01	9.25	9.46	8.41	6.77	5.89
10	26	Bombay	19.1	72.9	14	7.53	8.50	9.18	9.85	10.02	7.44	5.59	5.70	6.79	8.12	7.77	7.24
11	26	Bombay	19.1	72.9	14	7.53	8.50	9.18	9.85	10.02	7.44	5.59	5.70	6.79	8.12	7.77	7.24
12	27	Calcutta	22.7	88.5	6	6.57	7.64	8.34	9.25	9.22	6.68	6.51	6.28	6.37	6.81	6.77	6.25
13	27	Calcutta	22.7	88.5	6	6.57	7.64	8.34	9.25	9.22	6.68	6.51	6.28	6.37	6.81	6.77	6.25
14	34	Cuttack	20.5	85.9	24	7.26	8.15	8.61	9.08	9.60	7.11	6.18	6.45	6.63	7.27	7.24	6.98
15	36	Dharwar	15.4	75.1	679	8.29	9.18	9.65	9.34	8.90	6.70	5.43	6.10	6.90	7.51	7.69	7.75
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	5.22	5.75	7.05	6.69	7.18	6.43	6.72	7.34	6.23	6.52	6.08	5.37
17	39	Gannavaram	16.5	80.8	24	7.85	8.90	8.99	9.69	9.54	7.16	6.81	7.22	7.23	7.56	7.41	7.00
18	40	Gauhati	26.1	91.6	54	5.89	7.10	7.68	8.45	8.46	6.85	7.02	7.11	6.82	7.10	6.51	5.80
19	41	Goa	15.5	73.8	55	8.13	9.12	9.40	9.84	9.58	6.58	5.92	6.60	7.33	7.98	8.23	7.75
20	56	Hyderabad	17.5	78.5	545	7.91	8.99	9.26	9.74	9.91	7.86	6.66	7.11	7.33	8.02	7.69	7.33
21	59	Indore	22.7	75.8	567	7.29	8.43	9.10	10.04	10.70	8.57	6.26	5.72	7.13	8.35	7.55	6.75
22	61	Jagadalpur	19.1	82.0	553	7.63	8.61	9.66	9.85	9.39	7.56	6.02	6.01	6.55	7.54	7.35	7.19
23	62	Jaipur	26.8	75.8	390	6.29	7.53	8.40	9.40	9.69	8.31	6.84	6.63	7.93	8.10	7.04	6.15
24	69	Jodhpur	26.3	73.0	224	6.51	7.74	8.46	9.70	10.36	9.64	8.06	7.77	8.37	8.25	7.15	6.31
25	76	Kodaikanal	10.2	77.5	2345	7.55	8.47	8.78	8.33	7.45	6.18	5.47	6.07	6.28	6.03	6.02	6.46
26	79	Kota	25.2	75.5	257	6.78	8.03	8.84	9.87	10.57	9.51	7.26	6.72	7.92	8.09	7.13	6.48
27	86	Madras	13.0	80.2	16	7.89	9.26	9.75	9.93	9.26	7.96	7.20	7.60	7.77	7.43	7.07	6.85
28	89	Minicoy	8.3	73.0	2	8.78	9.48	9.56	9.25	8.13	6.87	6.87	7.97	7.93	8.12	8.20	7.76
29	92	Nagpur	21.2	79.1	311	7.37	8.51	9.05	9.73	10.09	7.96	6.25	6.18	7.01	8.12	7.66	7.03
30	97	New Dehli	28.6	77.2	216	5.65	7.03	7.71	9.05	9.19	7.91	7.64	7.51	7.65	7.66	6.66	5.52
31	99	Okha	22.5	69.1	7	7.18	8.40	9.01	9.80	10.14	8.32	6.75	6.64	8.32	8.65	7.58	6.36
32	100	Ollukara	10.5	76.3	22	8.25	8.86	9.28	8.77	7.22	5.89	5.24	5.76	6.59	7.00	7.41	7.21
33	105	Patna	25.5	85.3	52	6.46	7.63	8.64	9.55	10.37	8.78	7.82	7.74	7.67	7.68	7.00	6.22
34	107	Port Blair	11.7	92.7	79	8.03	9.25	9.65	9.51	7.19	6.10	6.12	6.27	6.38	7.29	7.68	7.61
35	108	Pune	18.5	73.9	563	7.80	8.89	9.52	9.98	10.12	7.96	6.07	6.25	7.11	7.99	7.73	7.30
36	123	Shillong	25.6	91.9	1598	5.25	6.80	7.72	8.17	8.04	6.11	6.04	5.92	5.97	6.08	5.42	5.01
37	124	Silicuri	24.8	92.9	40	6.26	7.08	8.12	8.44	8.11	6.71	6.96	6.91	6.89	6.67	6.35	5.93
38	127	Srinagar	34.1	74.8	1587	2.90	4.13	5.53	7.10	8.62	9.38	8.98	8.37	7.56	6.32	4.82	3.17
39	134	Trivandrum	8.5	77.0	64	8.30	8.91	9.05	8.24	7.46	6.16	6.27	7.22	7.56	7.12	6.95	7.34
40	135	Tuticorin	8.8	78.2	4	8.49	9.37	9.63	9.64	8.88	8.21	8.28	8.73	8.57	8.24	7.70	7.15
41	142	Veraval	20.9	70.4	8	7.51	8.65	9.90	9.93	10.59	9.07	6.68	6.56	8.34	8.59	7.74	7.16
42	144	Vishakhapatnam	17.7	83.2	3	7.89	8.97	9.13	9.62	9.67	7.07	6.42	7.24	7.32	7.82	7.61	7.30

Uday/Unight

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	2.48	2.14	2.12	2.12	1.76	1.51	1.62	1.61	1.65	2.00	2.67	2.15
2	5	Ahmadabad Airport	23.1	72.6	55	3.16	2.89	2.31	1.58	1.33	1.17	1.16	1.29	1.53	2.86	3.46	3.13
3	9	Akola Airport	20.7	77.1	309	1.33	1.40	1.59	1.38	1.21	1.17	1.41	1.65	1.69	1.38	1.42	2.63
4	13	Allahabad Airport	25.5	81.7	98	3.35	3.32	3.54	2.34	2.33	1.84	1.48	1.86	1.82	2.69	2.66	3.08
5	19	Amini Divi	11.1	72.7	4	1.86	1.18	1.07	1.19	1.27	1.05	1.12	1.13	1.14	1.03	1.60	2.20
6	21	Amritsar Airport	31.6	74.9	234	1.61	1.55	1.68	1.59	1.51	1.37	1.28	1.44	1.61	1.83	1.54	1.56
7	37	Bangalore Airport	13.0	77.6	897	1.35	1.53	1.50	1.53	1.21	1.19	1.33	1.21	1.29	1.72	1.79	1.55
8	59	Bhopal Airport	23.3	77.4	523	1.36	1.45	1.54	1.47	1.36	1.23	1.40	1.42	1.48	1.96	1.65	1.11
9	64	Bikaner	28.0	73.3	224	2.09	2.03	1.80	1.55	1.46	1.17	1.11	1.17	1.31	2.14	1.86	1.81
10	69	Bombay-Colaba	18.9	72.8	11	1.36	1.62	1.71	1.69	1.59	1.15	1.07	1.12	1.13	1.54	1.38	1.33
11	70	Bombay-Santacruz	19.1	72.9	14	1.80	2.09	2.57	2.69	2.16	1.48	1.20	1.30	1.73	2.21	2.01	1.85
12	75	Calcutta-Alipore	22.5	88.3	6	3.46	3.10	3.33	1.91	1.85	1.89	2.10	2.17	2.14	2.55	3.46	3.30
13	76	Calcutta-Dum Dum	22.7	88.5	6	3.95	2.55	1.80	1.27	1.40	1.42	1.58	1.67	2.12	2.21	3.86	4.65
14	97	Cuttack	20.5	85.9	27	2.55	1.58	1.59	1.28	1.31	1.38	1.52	1.64	1.67	1.87	2.09	2.35
15	48	Belgaum Airport	15.9	74.6	747	5.20	2.53	1.52	1.17	1.18	1.45	1.45	1.51	1.82	2.22	3.58	2.88
16	112	Dibrugarh Airport	27.5	95.0	111	3.91	2.70	2.32	1.78	1.89	1.77	1.62	1.77	1.98	3.06	4.09	4.51
17	126	Gannavaram Airport	16.5	80.8	24	2.00	2.07	2.04	1.67	1.44	1.56	1.76	1.70	1.84	1.97	1.85	1.77
18	127	Gauhati Airport	26.1	91.6	54	3.38	2.40	2.36	1.67	1.75	1.84	2.05	2.14	2.14	3.43	3.23	3.98
19	131	Gao-Panjim	15.5	73.8	60	1.38	1.49	1.77	1.98	1.65	1.35	1.14	1.17	1.65	1.69	1.35	1.28
20	153	Hyderabad-Begumpet	17.5	78.5	545	2.04	2.21	1.86	1.52	1.32	1.19	1.27	1.38	1.59	2.54	2.65	2.58
21	156	Indore Airport	22.7	75.8	567	1.57	1.52	1.50	1.20	1.22	1.14	1.28	1.29	1.35	1.81	1.92	1.77
22	158	Jagdalpur	19.1	82.0	553	3.13	3.40	2.33	1.81	1.83	1.80	1.66	1.77	2.08	2.70	4.38	3.95
23	159	Jaipur Airport	26.8	75.8	390	1.24	1.41	1.72	1.91	2.12	2.19	2.13	2.32	2.74	2.03	1.23	1.20
24	172	Jodhpur	26.3	73.0	217	1.22	1.65	1.42	1.37	1.23	1.14	1.16	1.29	2.18	1.42	1.49	1.09
25	194	Kodaikanal	10.2	77.5	2343	0.99	1.00	1.04	1.35	0.96	0.88	0.86	0.82	0.89	0.88	0.94	0.95
26	200	Kota Airport	25.2	75.9	274	1.70	1.62	1.90	1.44	1.25	1.08	1.08	1.29	1.37	1.59	1.71	1.61
27	209	Madras- Minambakkam	13.0	80.2	16	2.43	2.16	2.06	1.91	1.35	1.46	1.57	1.48	1.48	1.90	2.23	2.03
28	231	Minicoy	8.3	73.0	2	1.77	1.94	1.97	1.76	1.35	1.13	1.10	1.15	1.21	1.24	1.38	1.93
29	239	Nagpur Airport	21.1	79.1	310	1.44	1.37	1.45	1.41	1.34	1.43	1.73	1.65	1.69	1.58	1.66	1.55
30	250	New Dehli - Safdarjun	28.6	77.2	216	1.95	1.98	1.93	1.85	1.66	1.49	1.45	1.54	1.83	2.28	2.22	2.01
31	256	Okha	22.5	69.1	7	0.80	0.87	0.92	1.19	1.09	1.12	1.09	1.08	1.26	0.94	0.79	0.80
32	122	Fort Cochin	10.0	76.2	3	1.90	1.97	1.96	1.85	1.59	1.49	1.58	1.73	1.63	1.61	1.71	1.81
33	271	Patna Airport	25.6	85.1	60	4.13	3.73	3.02	2.45	1.54	1.36	1.57	1.53	1.90	2.93	6.33	4.71
34	278	Port Blair	11.7	92.7	79	1.27	1.57	1.89	1.91	1.61	1.50	1.49	1.48	1.68	1.61	1.32	1.22
35	281	Pune Airport	18.6	73.9	593	2.02	1.83	1.84	1.59	1.41	1.63	1.63	1.79	1.94	2.22	2.28	2.08
36	314	Shillong	25.6	91.9	1600	1.49	1.23	1.17	1.16	1.21	0.97	1.64	1.73	1.54	0.95	1.47	1.77
37	320	Silchar - Khumbhigram	24.9	93.0	97	0.64	0.77	0.82	0.91	1.02	1.25	1.22	1.16	1.19	0.80	0.80	0.71
38	325	Srinagar Airport	34.0	74.8	1666	2.29	1.85	1.80	1.67	1.60	1.53	1.55	1.76	1.72	1.43	1.66	1.86
39	340	Trivandrum Airport	8.5	77.0	8	0.73	0.59	0.84	1.23	1.78	1.31	1.76	1.67	1.90	1.47	1.03	0.77
40	342	Tuticorin	8.8	78.2	4	1.11	1.10	1.19	1.67	1.74	1.43	1.30	1.34	1.52	1.67	1.29	1.16
41	352	Veraval	20.9	70.4	8	1.36	1.43	1.46	1.42	1.23	0.99	0.99	0.98	1.16	1.50	1.55	1.35
42	353	Vishakhapatnam	17.7	83.2	3	4.07	4.44	3.18	2.60	2.09	1.83	1.68	1.99	2.20	2.91	3.11	3.45

Mean Wind Speed for the Period 17:30 - 8:30 Corrected to 2m Height. Unight (m/s)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Height (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	2.0	0.65	0.96	1.08	1.25	1.70	2.43	2.09	1.58	1.37	0.74	0.46	0.59
2	5	Ahmadabad Airport	23.1	72.6	55	2.0	0.75	0.74	0.93	1.27	1.80	2.14	1.85	1.29	1.04	0.52	0.54	0.69
3	9	Akola Airport	20.7	77.1	309	2.0	1.72	1.66	1.37	1.85	2.81	3.28	2.38	1.78	1.62	1.48	1.52	0.78
4	13	Allahabad Airport	25.5	81.7	98	2.0	0.39	0.49	0.57	0.94	1.00	1.37	1.53	1.03	0.99	0.48	0.36	0.34
5	19	Amini Divi	11.1	72.7	4	2.0	1.04	1.69	1.90	2.03	2.85	5.20	5.84	5.26	4.16	2.29	1.04	0.80
6	21	Amritsar Airport	31.6	74.9	234	2.0	1.02	1.40	1.61	1.73	2.00	2.18	2.32	1.64	1.26	1.00	0.95	0.98
7	37	Bangalore Airport	13.0	77.6	897	2.0	1.68	1.45	1.45	1.40	2.39	3.68	3.72	3.31	2.60	1.23	1.30	1.44
8	59	Bhopal Airport	23.3	77.4	523	2.0	1.61	1.70	1.87	2.20	3.13	3.98	3.36	3.04	2.25	1.19	1.16	1.29
9	64	Bikaner	28.0	73.3	224	2.0	0.55	0.72	1.08	1.30	1.79	2.92	2.66	2.19	1.69	0.78	0.65	0.64
10	69	Bombay-Colaba	18.9	72.8	11	2.0	1.49	1.36	1.55	1.64	1.64	2.30	2.95	2.54	1.99	1.23	1.22	1.32
11	70	Bombay-Santacruz	19.1	72.9	14	2.0	1.35	1.36	1.33	1.45	2.00	3.13	4.48	3.63	2.01	1.10	1.14	1.23
12	75	Calcutta-Alipore	22.5	88.3	6	2.0	0.38	0.57	0.70	1.34	1.63	1.31	1.09	0.94	0.84	0.58	0.38	0.39
13	76	Calcutta-Dum Dum	22.7	88.5	6	2.0	0.34	0.63	1.13	2.10	2.45	2.04	1.81	1.51	1.03	0.74	0.32	0.26
14	97	Cuttack	20.5	85.9	27	2.0	0.42	0.83	1.11	1.69	1.91	1.52	1.26	1.07	0.93	0.63	0.44	0.36
15	48	Belgaum Airport	15.9	74.6	747	2.0	0.45	0.98	1.64	2.05	2.78	3.32	3.32	2.86	1.79	0.96	0.69	0.80
16	112	Dibrugarh Airport	27.5	95.0	111	2.0	0.31	0.64	0.89	1.17	1.02	1.06	0.88	0.71	0.60	0.35	0.25	0.23
17	126	Gannavaram Airport	16.5	80.8	24	2.0	1.56	1.45	1.67	2.10	2.71	3.14	2.65	2.38	1.77	1.43	1.74	1.65
18	127	Gauhati Airport	26.1	91.6	54	2.0	0.34	0.60	0.83	1.10	1.13	0.96	0.80	0.77	0.70	0.41	0.36	0.27
19	131	Gao-Panjim	15.5	73.8	60	2.0	1.76	1.81	1.76	1.72	2.19	2.49	3.75	3.32	1.68	1.35	1.63	1.78
20	153	Hyderabad-Begumpet	17.5	78.5	545	2.0	1.25	1.23	1.47	1.79	2.68	4.58	4.89	3.82	2.46	1.03	0.92	0.94
21	156	Indore Airport	22.7	75.8	567	2.0	1.52	1.81	2.20	2.92	4.01	5.14	4.51	4.04	3.16	1.41	1.10	1.21
22	158	Jagdalpur	19.1	82.0	553	2.0	0.32	0.43	0.65	0.90	0.96	1.08	1.27	1.07	0.77	0.49	0.28	0.25
23	159	Jaipur Airport	26.8	75.8	390	2.0	1.17	1.09	1.06	1.09	1.27	1.44	1.24	0.91	0.74	0.70	0.99	0.94
24	172	Jodhpur	26.3	73.0	217	2.0	1.47	1.26	1.70	1.85	2.76	3.83	3.15	2.51	1.46	1.20	1.33	1.51
25	194	Kodaikanal	10.2	77.5	2343	2.0	2.59	2.81	2.75	2.22	2.64	3.08	3.98	3.31	2.69	2.57	2.81	2.99
26	200	Kota Airport	25.2	75.9	274	2.0	1.08	1.39	1.30	2.22	3.27	4.02	3.68	2.82	2.05	1.27	1.06	1.06
27	209	Madras- Minambakkam	13.0	80.2	16	2.0	1.28	1.31	1.49	1.77	2.42	2.62	2.26	2.13	1.91	1.31	1.37	1.45
28	231	Minicoy	8.3	73.0	2	2.0	0.96	0.94	1.00	1.15	2.33	3.11	3.31	2.97	2.52	1.80	1.26	0.80
29	239	Nagpur Airport	21.1	79.1	310	2.0	1.33	1.57	1.62	1.87	2.66	2.75	2.21	2.06	1.85	1.43	1.26	1.20
30	250	New Dehli - Safdarjung	28.6	77.2	216	2.0	1.34	1.66	1.71	1.88	2.27	2.87	1.84	1.54	1.45	0.89	0.90	1.23
31	256	Okha	22.5	69.1	7	2.0	4.73	4.51	4.68	4.51	5.37	5.32	5.81	5.71	3.66	3.51	4.06	4.25
32	122	Fort Cochin	10.0	76.2	3	2.0	1.36	1.48	1.65	1.56	1.80	1.58	1.64	1.64	1.67	1.45	1.28	1.21
33	271	Patna Airport	25.6	85.1	60	2.0	0.38	0.52	0.75	1.14	1.60	1.66	1.45	1.19	0.99	0.48	0.19	0.29
34	278	Port Blair	11.7	92.7	79	2.0	1.91	1.41	1.03	1.01	2.27	3.50	3.57	3.43	2.73	1.62	1.59	2.01
35	281	Pune Airport	18.6	73.9	593	2.0	1.15	1.44	1.81	2.40	3.87	3.89	3.66	3.27	2.40	1.27	1.10	1.01
36	314	Shillong	25.6	91.9	1600	2.0	0.42	0.60	1.01	1.48	1.50	1.20	0.59	0.47	0.45	0.64	0.37	0.27
37	320	Silchar - Khumbhigram	24.9	93.0	97	2.0	1.96	1.98	2.11	1.87	1.60	1.26	1.13	1.07	1.10	1.39	1.37	1.67
38	325	Srinagar Airport	34.0	74.8	1666	2.0	0.29	0.41	0.73	0.79	0.85	0.93	0.88	0.70	0.63	0.63	0.38	0.29
39	340	Trivandrum Airport	8.5	77.0	8	2.0	1.49	1.69	1.79	1.44	1.66	1.80	1.65	1.99	1.55	1.33	1.19	1.29
40	342	Tuticorin	8.8	78.2	4	2.0	4.47	4.60	3.69	2.46	2.46	3.41	3.85	3.74	3.16	2.23	3.29	4.30
41	352	Veraval	20.9	70.4	8	2.0	2.67	2.82	3.18	3.61	4.12	5.73	7.38	5.92	4.20	2.58	2.26	2.61
42	353	Vishakhapatnam	17.7	83.2	3	2.0	0.85	0.79	1.22	1.99	2.40	2.54	2.93	2.15	1.42	0.89	1.08	0.91

Mean Daily Wind Speed Corrected to 2m Height. U (m/s)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Height (m)	CF	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	13.7	0.76	1.22	1.62	1.81	2.10	2.47	3.18	2.87	2.16	1.90	1.19	0.91	1.01
2	5	Ahmadabad Airport	23.1	72.6	55	6.2	0.83	1.36	1.27	1.38	1.54	2.03	2.28	1.96	1.43	1.24	0.87	1.04	1.24
3	9	Akola Airport	20.7	77.1	309	9.7	0.79	1.93	1.91	1.67	2.11	3.03	3.49	2.75	2.22	2.04	1.69	1.76	1.25
4	13	Allahabad Airport	25.5	81.7	98	5.9	0.83	0.74	0.92	1.11	1.41	1.50	1.80	1.80	1.36	1.29	0.79	0.58	0.60
5	19	Amini Divi	11.1	72.7	4	12.1	0.77	1.37	1.80	1.95	2.17	3.14	5.31	6.10	5.52	4.38	2.32	1.27	1.16
6	21	Amritsar Airport	31.6	74.9	234	7.0	0.82	1.25	1.68	2.02	2.11	2.39	2.48	2.57	1.91	1.55	1.32	1.14	1.18
7	37	Bangalore Airport	13.0	77.6	897	14.9	0.76	2.04	1.91	1.88	1.84	2.69	4.10	4.46	3.73	3.05	1.76	1.92	1.92
8	59	Bhopal Airport	23.3	77.4	523	11.6	0.78	1.83	1.98	2.24	2.59	3.56	4.31	3.86	3.52	2.65	1.62	1.45	1.34
9	64	Bikaner	28.0	73.3	224	5.5	0.84	0.77	1.00	1.40	1.56	2.10	3.10	2.78	2.33	1.89	1.12	0.86	0.84
10	69	Bombay-Colaba	18.9	72.8	11	15.8	0.75	1.69	1.67	1.96	2.07	2.01	2.42	3.03	2.65	2.09	1.48	1.40	1.48
11	70	Bombay-Santacruz	19.1	72.9	14	7.6	0.81	1.76	1.92	2.12	2.37	2.86	3.70	4.82	4.03	2.57	1.60	1.58	1.62
12	75	Calcutta-Alipore	22.5	88.3	6	17.0	0.75	0.73	1.02	1.31	1.80	2.16	1.74	1.53	1.35	1.20	0.91	0.73	0.73
13	76	Calcutta-Dum Dum	22.7	88.5	6	7.7	0.81	0.72	0.99	1.46	2.32	2.81	2.36	2.21	1.89	1.46	1.08	0.65	0.61
14	97	Cuttack	20.5	85.9	27	12.0	0.77	0.67	1.01	1.35	1.87	2.13	1.74	1.50	1.33	1.16	0.84	0.62	0.54
15	48	Belgaum Airport	15.9	74.6	747	8.4	0.80	1.16	1.54	1.96	2.19	2.97	3.88	3.88	3.41	2.34	1.41	1.36	1.36
16	112	Dibrugarh Airport	27.5	95.0	111	1.8	1.02	0.65	1.05	1.34	1.51	1.37	1.37	1.08	0.91	0.82	0.63	0.54	0.54
17	126	Gannavaram Airport	16.5	80.8	24	9.1	0.80	2.15	2.04	2.32	2.63	3.16	3.80	3.41	3.01	2.32	1.95	2.30	2.12
18	127	Gauhati Airport	26.1	91.6	54	6.6	0.82	0.64	0.91	1.26	1.37	1.44	1.26	1.12	1.10	1.01	0.78	0.66	0.57
19	131	Gao-Panjim	15.5	73.8	60	17.7	0.74	2.00	2.15	2.27	2.35	2.73	2.81	3.95	3.53	2.09	1.69	1.84	1.96
20	153	Hyderabad-Begumpet	17.5	78.5	545	7.4	0.81	1.74	1.79	1.94	2.15	3.01	4.90	5.38	4.36	3.01	1.63	1.49	1.49
21	156	Indore Airport	22.7	75.8	567	11.2	0.78	1.84	2.17	2.62	3.14	4.33	5.41	4.98	4.48	3.57	1.84	1.47	1.56
22	158	Jagdalpur	19.1	82.0	553	11.2	0.78	0.58	0.82	0.97	1.17	1.26	1.41	1.58	1.39	1.08	0.80	0.63	0.52
23	159	Jaipur Airport	26.8	75.8	390	9.8	0.79	1.31	1.31	1.45	1.59	1.98	2.31	1.94	1.50	1.39	1.06	1.10	1.03
24	172	Jodhpur	26.3	73.0	217	8.1	0.81	1.59	1.57	1.97	2.10	3.00	4.03	3.34	2.78	2.10	1.39	1.57	1.57
25	194	Kodaikanal	10.2	77.5	2343	13.1	0.77	2.58	2.81	2.79	2.51	2.60	2.94	3.77	3.09	2.58	2.45	2.75	2.94
26	200	Kota Airport	25.2	75.9	274	5.1	0.85	1.37	1.72	1.74	2.59	3.58	4.15	3.79	3.13	2.33	1.55	1.34	1.30
27	209	Madras- Minambakkam	13.0	80.2	16	14.6	0.76	1.96	1.88	2.09	2.38	2.74	3.08	2.74	2.51	2.25	1.75	2.00	2.00
28	231	Minicoy	8.3	73.0	2	14.6	0.76	1.24	1.26	1.37	1.47	2.63	3.27	3.43	3.14	2.72	1.96	1.43	1.07
29	239	Nagpur Airport	21.1	79.1	310	11.8	0.78	1.55	1.79	1.90	2.15	2.99	3.19	2.82	2.56	2.33	1.74	1.57	1.44
30	250	New Dehli - Safdarjung	28.6	77.2	216	16.1	0.75	1.81	2.27	2.32	2.48	2.84	3.40	2.15	1.86	1.90	1.31	1.31	1.69
31	256	Okha	22.5	69.1	7	7.1	0.82	4.38	4.29	4.54	4.83	5.56	5.56	6.01	5.88	4.02	3.43	3.74	3.93
32	122	Fort Cochin	10.0	76.2	3	9.8	0.79	1.82	2.02	2.24	2.06	2.20	1.87	2.00	2.09	2.06	1.78	1.62	1.58
33	271	Patna Airport	25.6	85.1	60	17.7	0.74	0.83	1.05	1.32	1.76	1.92	1.88	1.76	1.43	1.32	0.83	0.56	0.68
34	278	Port Blair	11.7	92.7	79	6.6	0.82	2.10	1.71	1.37	1.35	2.79	4.16	4.23	4.05	3.43	1.99	1.78	2.17
35	281	Pune Airport	18.6	73.9	593	3.0	0.93	1.74	2.03	2.57	3.11	4.65	5.12	4.82	4.57	3.53	2.05	1.81	1.55
36	314	Shillong	25.6	91.9	1600	11.6	0.78	0.50	0.65	1.08	1.57	1.62	1.19	0.73	0.60	0.54	0.63	0.43	0.35
37	320	Silchar - Khumbhigram	24.9	93.0	97	10.5	0.78	1.70	1.81	1.96	1.81	1.61	1.37	1.22	1.13	1.18	1.29	1.26	1.48
38	325	Srinagar Airport	34.0	74.8	1666	18.0	0.74	0.51	0.62	1.08	1.11	1.15	1.22	1.17	1.02	0.90	0.79	0.53	0.44
39	340	Trivandrum Airport	8.5	77.0	8	6.0	0.83	1.34	1.43	1.68	1.57	2.14	2.01	2.12	2.49	2.08	1.57	1.20	1.18
40	342	Tuticorin	8.8	78.2	4	5.6	0.84	4.66	4.77	3.96	3.07	3.14	3.96	4.28	4.21	3.77	2.79	3.65	4.56
41	352	Veraval	20.9	70.4	8	11.0	0.78	3.04	3.28	3.73	4.19	4.47	5.71	7.35	5.88	4.45	3.06	2.73	2.95
42	353	Vishakhapatnam	17.7	83.2	3	9.1	0.80	1.84	1.81	2.21	3.19	3.38	3.34	3.67	2.94	2.06	1.53	1.92	1.75

Mean Wind Speed for the Period 8:30-177:30 Corrected to 2 m Height, Uday (m/s)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Height (m)	CF	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	13.7	0.76	1.60	2.06	2.29	2.66	2.98	3.68	3.39	2.54	2.26	1.48	1.22	1.28
2	5	Ahmadabad Airport	23.1	72.6	55	6.2	0.83	2.37	2.14	2.14	2.00	2.39	2.51	2.14	1.66	1.59	1.47	1.86	2.16
3	9	Akola Airport	20.7	77.1	309	9.7	0.79	2.29	2.33	2.18	2.55	3.41	3.85	3.36	2.94	2.75	2.04	2.15	2.04
4	13	Allahabad Airport	25.5	81.7	98	5.9	0.83	1.32	1.64	2.01	2.20	2.33	2.52	2.26	1.92	1.80	1.29	0.95	1.04
5	19	Amini Divi	11.1	72.7	4	12.1	0.77	1.93	2.00	2.04	2.41	3.61	5.48	6.53	5.95	4.75	2.36	1.65	1.76
6	21	Amritsar Airport	31.6	74.9	234	7.0	0.82	1.64	2.16	2.70	2.75	3.02	2.98	2.98	2.36	2.02	1.84	1.45	1.52
7	37	Bangalore Airport	13.0	77.6	897	14.9	0.76	2.28	2.22	2.17	2.14	2.89	4.37	4.95	4.01	3.35	2.12	2.33	2.24
8	59	Bhopal Airport	23.3	77.4	523	11.6	0.78	2.20	2.46	2.87	3.24	4.27	4.88	4.70	4.31	3.32	2.33	1.92	1.42
9	64	Bikaner	28.0	73.3	224	5.5	0.84	1.14	1.47	1.94	2.01	2.61	3.41	2.96	2.57	2.22	1.68	1.21	1.17
10	69	Bombay-Colaba	18.9	72.8	11	15.8	0.75	2.03	2.19	2.65	2.78	2.61	2.63	3.16	2.84	2.26	1.90	1.69	1.76
11	70	Bombay-Santacruz	19.1	72.9	14	7.6	0.81	2.43	2.84	3.43	3.90	4.30	4.64	5.39	4.71	3.49	2.43	2.30	2.28
12	75	Calcutta-Alipore	22.5	88.3	6	17.0	0.75	1.31	1.76	2.32	2.57	3.03	2.47	2.28	2.03	1.80	1.47	1.31	1.29
13	76	Calcutta-Dum Dum	22.7	88.5	6	7.7	0.81	1.35	1.60	2.03	2.68	3.42	2.90	2.86	2.52	2.18	1.64	1.22	1.19
14	97	Cuttack	20.5	85.9	27	12.0	0.77	1.07	1.31	1.76	2.17	2.49	2.11	1.91	1.76	1.55	1.18	0.92	0.84
15	48	Belgaum Airport	15.9	74.6	747	8.4	0.80	2.34	2.48	2.50	2.41	3.28	4.82	4.82	4.33	3.26	2.14	2.48	2.30
16	112	Dibrugarh Airport	27.5	95.0	111	1.8	1.02	1.22	1.74	2.08	2.08	1.93	1.88	1.42	1.25	1.19	1.08	1.02	1.05
17	126	Gannavaram Airport	16.5	80.8	24	9.1	0.80	3.12	3.01	3.41	3.52	3.92	4.91	4.67	4.05	3.25	2.81	3.23	2.92
18	127	Gauhati Airport	26.1	91.6	54	6.6	0.82	1.14	1.44	1.97	1.83	1.97	1.76	1.65	1.65	1.51	1.39	1.17	1.07
19	131	Gao-Panjim	15.5	73.8	60	17.7	0.74	2.42	2.71	3.12	3.41	3.61	3.35	4.28	3.88	2.77	2.27	2.19	2.27
20	153	Hyderabad-Begumpet	17.5	78.5	545	7.4	0.81	2.55	2.71	2.73	2.73	3.55	5.45	6.19	5.27	3.91	2.62	2.44	2.42
21	156	Indore Airport	22.7	75.8	567	11.2	0.78	2.38	2.75	3.31	3.51	4.87	5.87	5.76	5.22	4.27	2.56	2.10	2.14
22	158	Jagdalpur	19.1	82.0	553	11.2	0.78	1.02	1.47	1.52	1.62	1.75	1.95	2.10	1.91	1.60	1.32	1.21	0.97
23	159	Jaipur Airport	26.8	75.8	390	9.8	0.79	1.45	1.53	1.83	2.09	2.69	3.17	2.65	2.10	2.03	1.42	1.21	1.13
24	172	Jodhpur	26.3	73.0	217	8.1	0.81	1.79	2.08	2.42	2.53	3.40	4.37	3.65	3.22	3.18	1.70	1.97	1.66
25	194	Kodaikanal	10.2	77.5	2343	13.1	0.77	2.56	2.81	2.85	3.00	2.54	2.71	3.43	2.73	2.39	2.26	2.64	2.85
26	200	Kota Airport	25.2	75.9	274	5.1	0.85	1.84	2.26	2.47	3.20	4.10	4.36	3.98	3.65	2.80	2.03	1.81	1.70
27	209	Madras- Minambakkam	13.0	80.2	16	14.6	0.76	3.10	2.82	3.08	3.39	3.27	3.83	3.54	3.14	2.82	2.49	3.05	2.93
28	231	Minicoy	8.3	73.0	2	14.6	0.76	1.71	1.81	1.98	2.02	3.14	3.52	3.64	3.41	3.05	2.23	1.73	1.54
29	239	Nagpur Airport	21.1	79.1	310	11.8	0.78	1.92	2.15	2.35	2.63	3.55	3.92	3.83	3.40	3.12	2.26	2.09	1.85
30	250	New Dehli - Safdarjung	28.6	77.2	216	16.1	0.75	2.61	3.30	3.32	3.48	3.78	4.28	2.67	2.38	2.65	2.02	2.00	2.46
31	256	Okha	22.5	69.1	7	7.1	0.82	3.79	3.93	4.31	5.38	5.88	5.97	6.35	6.15	4.61	3.29	3.22	3.38
32	122	Fort Cochin	10.0	76.2	3	9.8	0.79	2.59	2.92	3.23	2.90	2.85	2.35	2.59	2.83	2.72	2.33	2.20	2.20
33	271	Patna Airport	25.6	85.1	60	17.7	0.74	1.57	1.94	2.27	2.79	2.46	2.25	2.27	1.82	1.88	1.40	1.18	1.34
34	278	Port Blair	11.7	92.7	79	6.6	0.82	2.42	2.22	1.94	1.92	3.66	5.26	5.33	5.08	4.60	2.61	2.10	2.45
35	281	Pune Airport	18.6	73.9	593	3.0	0.93	2.33	2.63	3.33	3.81	5.43	6.36	5.98	5.86	4.67	2.83	2.51	2.09
36	314	Shillong	25.6	91.9	1600	11.6	0.78	0.63	0.73	1.19	1.73	1.81	1.17	0.97	0.82	0.69	0.60	0.54	0.47
37	320	Silchar - Khumbhigram	24.9	93.0	97	10.5	0.78	1.26	1.53	1.72	1.70	1.63	1.57	1.37	1.24	1.31	1.11	1.09	1.18
38	325	Srinagar Airport	34.0	74.8	1666	18.0	0.74	0.66	0.76	1.32	1.33	1.35	1.42	1.36	1.24	1.08	0.90	0.63	0.54
39	340	Trivandrum Airport	8.5	77.0	8	6.0	0.83	1.08	0.99	1.50	1.78	2.95	2.35	2.91	3.32	2.95	1.96	1.22	0.99
40	342	Tuticorin	8.8	78.2	4	5.6	0.84	4.96	5.05	4.40	4.10	4.28	4.87	5.00	5.00	4.80	3.72	4.26	5.00
41	352	Veraval	20.9	70.4	8	11.0	0.78	3.64	4.03	4.64	5.14	5.05	5.66	7.31	5.81	4.86	3.86	3.51	3.51
42	353	Vishakhapatnam	17.7	83.2	3	9.1	0.80	3.47	3.52	3.87	5.18	5.02	4.67	4.91	4.27	3.12	2.59	3.34	3.14

Mean Wind Speed for the Period 8:30-17:30 (kmph)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Height (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	13.7	7.6	9.7	10.8	12.5	14.1	17.3	16.0	12.0	10.6	7.0	5.7	6.0
2	5	Ahmadabad Airport	23.1	72.6	55	6.2	10.3	9.3	9.3	8.7	10.4	10.9	9.3	7.2	6.9	6.4	8.1	9.4
3	9	Akola Airport	20.7	77.1	309	9.7	10.4	10.6	9.9	11.6	15.5	17.5	15.3	13.4	12.5	9.3	9.8	9.3
4	13	Allahabad Airport	25.5	81.7	98	5.9	5.7	7.1	8.7	9.5	10.1	10.9	9.8	8.3	7.8	5.6	4.1	4.5
5	19	Amini Divi	11.1	72.7	4	12.1	9.0	9.3	9.5	11.2	16.8	25.5	30.4	27.7	22.1	11.0	7.7	8.2
6	21	Amritsar Airport	31.6	74.9	234	7.0	7.2	9.5	11.9	12.1	13.3	13.1	13.1	10.4	8.9	8.1	6.4	6.7
7	37	Bangalore Airport	13.0	77.6	897	14.9	10.8	10.6	10.3	10.2	13.7	20.8	23.6	19.1	15.9	10.1	11.1	10.6
8	59	Bhopal Airport	23.3	77.4	523	11.6	10.2	11.4	13.3	15.0	19.8	22.6	21.8	20.0	15.4	10.8	8.9	6.6
9	64	Bikaner	28.0	73.3	224	5.5	4.9	6.3	8.3	8.6	11.2	14.6	12.7	11.0	9.5	7.2	5.2	5.0
10	69	Bombay-Colaba	18.9	72.8	11	15.8	9.7	10.5	12.7	13.3	12.5	12.6	15.1	13.6	10.8	9.1	8.1	8.4
11	70	Bombay-Santacruz	19.1	72.9	14	7.6	10.8	12.6	15.2	17.3	19.1	20.6	23.9	20.9	15.5	10.8	10.2	10.1
12	75	Calcutta-Alipore	22.5	88.3	6	17.0	6.3	8.5	11.2	12.4	14.6	11.9	11.0	9.8	8.7	7.1	6.3	6.2
13	76	Calcutta-Dum Dum	22.7	88.5	6	7.7	6.0	7.1	9.0	11.9	15.2	12.9	12.7	11.2	9.7	7.3	5.4	5.3
14	97	Cuttack	20.5	85.9	27	12.0	5.0	6.1	8.2	10.1	11.6	9.8	8.9	8.2	7.2	5.5	4.3	3.9
15	48	Belgaum Airport	15.9	74.6	747	8.4	10.5	11.1	11.2	10.8	14.7	21.6	21.6	19.4	14.6	9.6	11.1	10.3
16	112	Dibrugarh Airport	27.5	95.0	111	1.8	4.3	6.1	7.3	7.3	6.8	6.6	5.0	4.4	4.2	3.8	3.6	3.7
17	126	Gannavaram Airport	16.5	80.8	24	9.1	14.1	13.6	15.4	15.9	17.7	22.2	21.1	18.3	14.7	12.7	14.6	13.2
18	127	Gauhati Airport	26.1	91.6	54	6.6	5.0	6.3	8.6	8.0	8.6	7.7	7.2	7.2	6.6	6.1	5.1	4.7
19	131	Gao-Panjim	15.5	73.8	60	17.7	11.7	13.1	15.1	16.5	17.5	16.2	20.7	18.8	13.4	11.0	10.6	11.0
20	153	Hyderabad-Begumpet	17.5	78.5	545	7.4	11.3	12.0	12.1	12.1	15.7	24.1	27.4	23.3	17.3	11.6	10.8	10.7
21	156	Indore Airport	22.7	75.8	567	11.2	11.0	12.7	15.3	16.2	22.5	27.1	26.6	24.1	19.7	11.8	9.7	9.9
22	158	Jagdalpur	19.1	82.0	553	11.2	4.7	6.8	7.0	7.5	8.1	9.0	9.7	8.8	7.4	6.1	5.6	4.5
23	159	Jaipur Airport	26.8	75.8	390	9.8	6.6	7.0	8.4	9.5	12.3	14.4	12.1	9.6	9.3	6.5	5.5	5.1
24	172	Jodhpur	26.3	73.0	217	8.1	8.0	9.3	10.8	11.3	15.2	19.5	16.3	14.4	14.2	7.6	8.8	7.4
25	194	Kodaikanal	10.2	77.5	2343	13.1	12.0	13.2	13.4	14.1	11.9	12.7	16.1	12.8	11.2	10.6	12.4	13.4
26	200	Kota Airport	25.2	75.9	274	5.1	7.8	9.6	10.5	13.6	17.4	18.5	16.9	15.5	11.9	8.6	7.7	7.2
27	209	Madras- Minambakkam	13.0	80.2	16	14.6	14.7	13.4	14.6	16.1	15.5	18.2	16.8	14.9	13.4	11.8	14.5	13.9
28	231	Minicoy	8.3	73.0	2	14.6	8.1	8.6	9.4	9.6	14.9	16.7	17.3	16.2	14.5	10.6	8.2	7.3
29	239	Nagpur Airport	21.1	79.1	310	11.8	8.9	10.0	10.9	12.2	16.5	18.2	17.8	15.8	14.5	10.5	9.7	8.6
30	250	New Dehli - Safdarjung	28.6	77.2	216	16.1	12.5	15.8	15.9	16.7	18.1	20.5	12.8	11.4	12.7	9.7	9.6	11.8
31	256	Okha	22.5	69.1	7	7.1	16.7	17.3	19.0	23.7	25.9	26.3	28.0	27.1	20.3	14.5	14.2	14.9
32	122	Fort Cochin	10.0	76.2	3	9.8	11.8	13.3	14.7	13.2	13.0	10.7	11.8	12.9	12.4	10.6	10.0	10.0
33	271	Patna Airport	25.6	85.1	60	17.7	7.6	9.4	11.0	13.5	11.9	10.9	11.0	8.8	9.1	6.8	5.7	6.5
34	278	Port Blair	11.7	92.7	79	6.6	10.6	9.7	8.5	8.4	16.0	23.0	23.3	22.2	20.1	11.4	9.2	10.7
35	281	Pune Airport	18.6	73.9	593	3.0	9.0	10.2	12.9	14.8	21.0	24.6	23.1	22.7	18.1	11.0	9.7	8.1
36	314	Shillong	25.6	91.9	1600	11.6	2.9	3.4	5.5	8.0	8.4	5.4	4.5	3.8	3.2	2.8	2.5	2.2
37	320	Silchar - Khumbhigram	24.9	93.0	97	10.5	5.8	7.0	7.9	7.8	7.5	7.2	6.3	5.7	6.0	5.1	5.0	5.4
38	325	Srinagar Airport	34.0	74.8	1666	18.0	3.2	3.7	6.4	6.4	6.6	6.9	6.6	6.0	5.2	4.4	3.1	2.6
39	340	Trivandrum Airport	8.5	77.0	8	6.0	4.7	4.3	6.5	7.7	12.8	10.2	12.6	14.4	12.8	8.5	5.3	4.3
40	342	Tuticorin	8.8	78.2	4	5.6	21.3	21.7	18.9	17.6	18.4	20.9	21.5	21.5	20.6	16.0	18.3	21.5
41	352	Veraval	20.9	70.4	8	11.0	16.8	18.6	21.4	23.7	23.3	26.1	33.7	26.8	22.4	17.8	16.2	16.2
42	353	Vishakhapatnam	17.7	83.2	3	9.1	15.7	15.9	17.5	23.4	22.7	21.1	22.2	19.3	14.1	11.7	15.1	14.2

St ETo	St Wind	Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra airport												
		5:30	3.3	4.7	5.1	5.9	7.9	11.4	10.1	7.9	6.9	3.5	2.2	2.7
		8:30	4.7	7.0	7.6	9.5	11.5	16.9	13.6	11.0	10.2	5.6	3.8	4.1
		11:30	10.3	12.0	12.5	13.6	14.3	18.0	14.8	12.7	11.9	9.1	8.5	8.7
		17:30	7.7	10.2	12.3	14.5	16.4	17.1	19.5	12.3	9.8	6.3	4.9	5.3
		23:30	2.8	4.4	5.1	5.9	8.1	11.5	9.6	7.0	6.0	3.5	2.1	2.9
		Mean	5.76	7.66	8.52	9.88	11.64	14.98	13.52	10.18	8.96	5.60	4.30	4.74
		Uday	7.57	9.73	10.80	12.53	14.07	17.33	15.97	12.00	10.63	7.00	5.73	6.03
		Unight	3.05	4.55	5.10	5.90	8.00	11.45	9.85	7.45	6.45	3.50	2.15	2.80
		Ud/Un	2.48	2.14	2.12	2.12	1.76	1.51	1.62	1.61	1.65	2.00	2.67	2.15
7	37	Bangalore airport												
		5:30	5.9	4.3	4.3	4.3	10.9	16.4	17.4	15.3	12.1	5.8	4.7	5.8
		8:30	8.4	7.2	7.6	8.6	13.6	19.2	21.8	18.8	15.8	9.2	9.9	8.3
		11:30	12.2	12.8	11.8	8.8	14.1	22.7	25.9	20.0	17.3	11.7	12.6	12.5
		17:30	11.9	11.7	11.6	13.1	13.5	20.5	23.0	18.4	14.7	9.3	10.8	11.1
		23:30	10.1	9.5	9.5	9.0	11.8	18.6	18.0	16.2	12.6	5.9	7.7	7.9
		Mean	9.70	9.10	8.96	8.76	12.78	19.48	21.22	17.74	14.50	8.38	9.14	9.12
		Uday	10.83	10.57	10.33	10.17	13.73	20.80	23.57	19.07	15.93	10.07	11.10	10.63
		Unight	8.00	6.90	6.90	6.65	11.35	17.50	17.70	15.75	12.35	5.85	6.20	6.85
		Ud/Un	1.35	1.53	1.50	1.53	1.21	1.19	1.33	1.21	1.29	1.72	1.79	1.55
23	159	Jaipur airport												
		2:30	5.5	4.7	5.7	5.4	5.5	6.4	5.2	4.0	3.4	3.0	4.6	4.2
		5:30	5.0	4.8	4.3	4.9	5.8	7.7	5.5	4.4	3.8	2.9	4.4	3.5
		8:30	4.0	3.9	4.6	5.9	9.7	15.8	11.1	9.5	6.7	3.7	4.8	3.6
		11:30	8.3	8.3	9.1	10.1	13.2	16.5	13.7	11.5	11.4	7.3	7.3	6.5
		14:30	8.6	9.4	11.2	10.6	13.5	13.0	12.0	9.3	11.2	9.7	6.5	6.3
		17:30	5.6	6.3	8.5	11.5	12.6	12.4	11.4	7.9	7.7	5.1	3.5	4.1
		20:30	5.4	5.0	4.3	4.0	5.8	5.9	5.9	4.2	3.0	3.1	4.5	4.7
		23:30	5.5	5.3	5.1	5.6	6.0	6.3	6.0	3.9	3.3	3.7	4.5	4.7
		Mean	5.99	5.96	6.60	7.25	9.01	10.50	8.85	6.84	6.31	4.81	5.01	4.70
		Uday	6.63	6.98	8.35	9.53	12.25	14.43	12.05	9.55	9.25	6.45	5.53	5.13
		Unight	5.35	4.95	4.85	4.98	5.78	6.58	5.65	4.13	3.38	3.18	4.50	4.28
		Ud/Un	1.24	1.41	1.72	1.91	2.12	2.19	2.13	2.32	2.74	2.03	1.23	1.20
35	281	Pune Airport												
		2:30	3.3	4.4	5.5	7.9	14.5	14.1	13.8	12.1	9.0	4.3	3.2	3.6
		5:30	3.3	3.8	4.9	7.0	12.8	12.3	13.1	11.1	7.5	3.6	3.9	3.1
		8:30	3.4	3.9	5.8	9.1	16.6	18.5	16.5	14.9	11.7	5.3	5.0	3.8
		11:30	11.1	11.3	12.2	11.6	18.6	25.2	25.1	25.1	17.8	13.4	14.6	10.9
		17:30	12.6	15.3	20.7	23.6	27.9	30.1	27.8	28.1	24.7	14.2	9.6	9.6
		23:30	6.8	8.5	10.6	13.0	17.6	18.8	15.6	14.8	11.4	6.9	5.7	5.0
		Mean	6.75	7.87	9.95	12.03	18.00	19.83	18.65	17.68	13.68	7.95	7.00	6.00
		Uday	9.03	10.17	12.90	14.77	21.03	24.60	23.13	22.70	18.07	10.97	9.73	8.10
		Unight	4.47	5.57	7.00	9.30	14.97	15.07	14.17	12.67	9.30	4.93	4.27	3.90
		Ud/Un	2.02	1.83	1.84	1.59	1.41	1.63	1.63	1.79	1.94	2.22	2.28	2.08
38	325	Srinagar												
		5:30	1.1	1.6	3.2	3.0	3.9	4.3	4.1	3.3	2.4	2.3	1.3	1.3
		8:30	3.1	2.8	5.0	4.1	4.1	4.2	4.7	4.3	3.1	2.7	2.0	2.3
		11:30	3.2	3.8	6.0	6.1	5.2	6.0	6.9	6.0	5.7	4.3	3.8	3.1
		17:30	3.3	4.5	8.2	9.1	10.4	10.5	8.2	7.7	6.9	6.1	3.4	2.4
		23:30	1.7	2.4	3.9	4.7	4.3	4.7	4.4	3.5	3.7	3.8	2.4	1.5
		Mean	2.48	3.02	5.26	5.40	5.58	5.94	5.66	4.96	4.36	3.84	2.58	2.12
		Uday	3.20	3.70	6.40	6.43	6.57	6.90	6.60	6.00	5.23	4.37	3.07	2.60
		Unight	1.40	2.00	3.55	3.85	4.10	4.50	4.25	3.40	3.05	3.05	1.85	1.40
		Ud/Un	2.29	1.85	1.80	1.67	1.60	1.53	1.55	1.76	1.72	1.43	1.66	1.86

APPENDIX N

EFFECTIVE PRECIPITATION

RAINFALL DATA
SUMMARY STATISTICS

Effective Rainfall, Pe (tenths of mm)
Summary Data

STAT 1	**422610 AGRA**											
N	124	123	125	123	122	124	125	125	125	126	124	123
Min	0	0	0	0	0	0	180	30	0	0	0	0
Max	720	960	980	710	1040	3560	4990	6180	6090	2690	760	630
20th %tile	0	0	0	0	10	146	1148	1124	296	0	0	0
Normal Dist: Mean	134.4	106.7	87.8	56.8	128.4	578.5	2195.9	2276.6	1251.9	202.9	35.4	68.4
St Dev	139.4	173.9	158.4	118.6	162.9	605.9	1165.8	1273.8	1065.9	416.3	105.8	123.1
20% Prob	17	0	0	0	0	69	1215	1204	355	0	0	0
Gamma Dist: Alpha	0.9	0.4	0.3	0.2	0.6	0.9	3.5	3.2	1.4	0.2	0.1	0.3
Beta	144.7	283.6	286.0	247.6	206.7	634.6	618.9	712.7	907.5	854.3	316.0	221.8
20% Prob	27	3	1	0	13	115	1206	1197	391	1	0	1
STAT 2	**426470 AHMADABAD**											
N	119	118	117	119	119	118	118	119	117	119	119	118
Min	0	0	0	0	0	0	36	10	0	0	0	0
Max	574	264	210	264	2310	10312	22225	15011	10236	2570	1000	310
20th %tile	0	0	0	0	0	268	1418	934	197	0	0	0
Normal Dist: Mean	17.5	15.8	10.3	12.8	108.2	1019.1	3256.0	2194.1	1369.5	140.3	62.9	13.6
St Dev	61.0	45.7	32.3	39.0	272.8	1191.1	2734.9	1829.1	1613.5	354.0	167.6	44.9
20% Prob	0	0	0	0	0	17	954	655	12	0	0	0
Gamma Dist: Alpha	0.1	0.1	0.1	0.1	0.2	0.7	1.4	1.4	0.7	0.2	0.1	0.1
Beta	212.7	132.7	101.0	118.8	687.7	1392.2	2297.2	1524.8	1900.9	893.6	446.6	148.4
20% Prob	0	0	0	0	0	145	1040	710	190	0	0	0
STAT 3	**429330 AKOLA**											
N	114	115	117	115	114	117	117	116	116	116	115	116
Min	0	0	0	0	0	70	400	100	50	0	0	0
Max	760	850	970	720	1040	3620	5470	5050	8100	2180	3420	1820
20th %tile	0	0	0	0	0	700	1420	930	610	0	0	0
Normal Dist: Mean	109.3	80.6	86.6	48.1	94.8	1395.6	2311.9	1670.3	1492.2	461.3	185.2	123.8
St Dev	180.3	148.7	158.9	98.5	178.4	740.7	1101.2	991.2	1106.1	585.6	418.6	308.7
20% Prob	0	0	0	0	0	772	1385	836	561	0	0	0
Gamma Dist: Alpha	0.4	0.3	0.3	0.2	0.3	3.5	4.4	2.8	1.8	0.6	0.2	0.2
Beta	297.5	274.5	291.7	201.9	335.7	393.2	524.5	588.2	819.9	743.3	946.2	770.0
20% Prob	3	1	1	0	1	766	1373	833	578	48	0	0
STAT 4	**424750 ALLAHABAD/BAMHRAULI**											
N	126	126	126	126	127	127	127	126	125	127	127	124
Min	0	0	0	0	0	0	262	152	0	0	0	0
Max	1260	1039	860	437	730	5265	7821	9150	7610	5712	920	729
20th %tile	0	5	0	0	0	206	1792	1880	788	0	0	0
Normal Dist: Mean	180.4	161.0	89.0	44.6	87.4	964.6	2999.9	2967.2	1758.1	466.1	76.5	60.0
St Dev	221.7	222.7	152.5	82.4	158.1	980.8	1406.2	1468.9	1190.3	784.4	193.9	125.9
20% Prob	0	0	0	0	0	139	1816	1731	756	0	0	0
Gamma Dist: Alpha	0.7	0.5	0.3	0.3	0.3	1.0	4.6	4.1	2.2	0.4	0.2	0.2
Beta	272.4	308.1	261.4	152.3	285.9	997.2	659.1	727.2	805.8	1320.2	491.5	264.1
20% Prob	22	12	2	0	1	207	1800	1716	764	10	0	0
STAT 5	**433110 AMINI**											
N	67	64	65	66	67	69	69	69	68	68	69	69
Min	0	0	0	0	3	1049	353	119	250	224	0	0
Max	1575	270	546	2466	6960	8357	7310	5588	5672	3962	3050	3927
20th %tile	0	0	0	0	280	2603	1724	816	578	758	169	4
Normal Dist: Mean	162.3	22.5	34.7	293.1	1302.9	3681.2	3034.1	1913.6	1464.6	1464.5	755.8	327.8
St Dev	305.9	56.6	93.1	460.3	1324.6	1290.0	1538.7	1212.0	1022.6	820.2	703.1	579.0
20% Prob	0	0	0	0	188	2595	1739	894	604	774	164	0
Gamma Dist: Alpha	0.3	0.2	0.1	0.4	1.0	8.1	3.9	2.5	2.1	3.2	1.2	0.3
Beta	576.5	142.9	249.9	722.8	1346.7	452.1	780.3	767.7	713.9	459.4	654.1	1022.5
20% Prob	1	0	0	10	279	2576	1724	895	613	770	199	5
STAT 6	**420710 AMRITSAR/RAJASANSI**											
N	39	39	39	39	39	39	39	37	39	40	40	39
Min	0	0	0	0	0	0	470	120	0	0	0	0
Max	1110	640	1720	1870	890	2370	5000	3920	3640	3630	580	970
20th %tile	30	62	92	26	30	78	1254	962	52	0	0	0
Normal Dist: Mean	291.0	261.8	352.3	198.5	169.5	489.5	2065.1	1744.6	903.3	246.5	64.3	154.9
St Dev	270.0	186.4	338.7	334.2	176.2	516.2	1051.3	1007.2	972.8	608.0	124.9	214.4
20% Prob	64	105	67	0	21	55	1180	897	85	0	0	0
Gamma Dist: Alpha	1.2	2.0	1.1	0.4	0.9	0.9	3.9	3.0	0.9	0.2	0.3	0.5
Beta	250.6	132.8	325.6	562.9	183.1	544.4	535.2	581.5	1047.7	1499.6	242.7	296.8
20% Prob	77	107	86	4	34	95	1170	893	166	0	0	11
STAT 7	**432950 BANGALORE**											
N	150	151	151	151	150	151	151	151	151	151	151	151
Min	0	0	0	0	13	46	0	206	84	30	0	0
Max	1019	899	1626	1656	3940	2189	3503	3607	5170	5220	8800	1473

20th %tile	0	0	0	81	612	432	488	610	945	710	110	0
Normal Dist: Mean	50.8	60.3	117.2	387.5	1138.7	787.0	1047.0	1376.1	1733.6	1577.3	630.6	166.9
St Dev	122.2	152.8	241.3	377.5	605.0	431.6	642.2	808.0	1014.7	981.4	904.3	256.7
20% Prob	0	0	0	70	629	424	506	696	880	751	0	0
Gamma Dist: Alpha	0.2	0.2	0.2	1.1	3.5	3.3	2.7	2.9	2.9	2.6	0.5	0.4
Beta	293.5	387.4	496.8	367.7	321.5	236.8	394.0	474.5	593.9	610.6	1296.7	394.9
20% Prob	0	0	0	92	625	421	506	693	876	751	38	7
STAT 8	**426710 SAGAR**											
N	112	114	112	114	110	115	115	115	115	116	115	113
Min	0	0	0	0	0	100	910	780	20	0	0	0
Max	1810	1050	990	560	840	6390	9150	10660	7470	2290	2110	2060
20th %tile	0	0	0	0	0	506	2500	2302	800	0	0	0
Normal Dist: Mean	215.4	124.7	90.4	44.3	103.3	1428.2	3993.0	3928.4	1928.6	340.4	169.4	117.1
St Dev	305.8	173.1	162.4	95.7	163.3	1099.5	1772.9	1987.5	1377.0	510.9	399.0	273.4
20% Prob	0	0	0	0	0	503	2501	2256	770	0	0	0
Gamma Dist: Alpha	0.5	0.5	0.3	0.2	0.4	1.7	5.1	3.9	2.0	0.4	0.2	0.2
Beta	434.0	240.2	291.7	206.8	258.3	846.5	787.2	1005.5	983.2	766.9	939.9	638.4
20% Prob	14	9	1	0	3	524	2478	2237	785	16	0	0
STAT 9	**421650 BIKANER**											
N	102	103	106	107	103	103	105	105	103	103	105	103
Min	0	0	0	0	0	0	0	0	0	0	0	0
Max	600	810	690	520	1200	1630	3720	3370	2230	1100	440	420
20th %tile	0	0	0	0	0	50	250	246	0	0	0	0
Normal Dist: Mean	68.6	74.3	63.8	51.9	173.5	313.0	857.2	872.2	382.8	56.1	21.7	39.5
St Dev	103.0	138.0	117.5	96.0	249.8	321.0	727.5	749.2	535.6	160.9	67.8	84.5
20% Prob	0	0	0	0	0	43	245	242	0	0	0	0
Gamma Dist: Alpha	0.4	0.3	0.3	0.3	0.5	1.0	1.4	1.4	0.5	0.1	0.1	0.2
Beta	154.6	256.6	216.5	177.6	359.6	329.3	617.3	643.5	749.3	461.5	211.7	180.5
20% Prob	3	1	1	0	10	66	269	268	26	0	0	0
STAT 10	**430570 BOMBAY/COLABA**											
N	141	141	140	140	141	171	171	171	171	171	141	141
Min	0	0	0	0	0	917	1080	833	323	0	0	0
Max	759	427	371	640	2794	12800	14999	12650	12449	5070	1641	510
20th %tile	0	0	0	0	0	3294	4090	1768	1194	3	0	0
Normal Dist: Mean	26.9	11.8	7.0	15.4	142.2	5188.3	6451.4	3840.6	2768.6	542.8	146.1	22.1
St Dev	96.0	44.8	35.7	69.4	387.0	2328.0	2759.3	2309.5	1960.5	750.6	306.3	73.2
20% Prob	0	0	0	0	0	3229	4129	1897	1119	0	0	0
Gamma Dist: Alpha	0.1	0.1	0.0	0.0	0.1	5.0	5.5	2.8	2.0	0.5	0.2	0.1
Beta	342.2	170.4	181.1	312.7	1053.3	1044.6	1180.2	1388.8	1388.3	1037.8	642.1	242.6
20% Prob	0	0	0	0	0	3199	4092	1892	1139	39	0	0
STAT 11	**430030 BOMBAY/SANTACRUZ**											
N	11	11	11	11	11	11	11	11	11	12	12	12
Min	0	0	0	0	0	1300	5890	1410	810	90	0	0
Max	10	90	10	10	960	9990	12670	12540	9200	3440	330	90
20th %tile	0	0	0	0	0	4070	8310	2770	1100	152	0	0
Normal Dist: Mean	1.8	8.2	0.9	3.6	182.7	6004.5	9350.0	6132.7	3441.8	1040.0	63.3	7.5
St Dev	4.0	27.1	3.0	5.0	306.4	2918.6	2170.0	3545.5	2742.9	1029.1	105.3	26.0
20% Prob	0	0	0	0	0	3548	7524	3149	1133	174	0	0
Gamma Dist: Alpha	0.2	0.1	0.1	0.5	0.4	4.2	18.6	3.0	1.6	1.0	0.4	0.1
Beta	9.0	90.0	10.0	7.0	513.7	1418.7	503.6	2049.8	2186.0	1018.2	174.9	90.0
20% Prob	0	0	0	0	4	3517	7492	3134	1199	238	1	0
STAT 12	**428070 CALCUTTA/ALIPORE**											
N	159	159	159	158	159	159	159	159	159	159	158	159
Min	0	0	0	0	20	406	1090	1224	561	0	0	0
Max	1210	2022	1593	2040	4346	9460	6444	6835	11570	4740	2385	1460
20th %tile	0	0	18	147	626	1644	2340	2474	1690	645	0	0
Normal Dist: Mean	123.3	245.7	326.3	530.4	1295.7	2893.9	3292.5	3383.6	2661.9	1306.4	205.8	65.9
St Dev	183.9	307.7	380.9	439.4	856.1	1521.9	1131.9	1181.0	1454.6	897.0	396.3	176.2
20% Prob	0	0	6	161	575	1613	2340	2390	1438	552	0	0
Gamma Dist: Alpha	0.4	0.6	0.7	1.5	2.3	3.6	8.5	8.2	3.3	2.1	0.3	0.1
Beta	274.2	385.3	444.7	364.1	565.6	800.4	389.1	412.2	794.8	615.8	762.8	471.0
20% Prob	6	27	47	173	579	1600	2322	2371	1428	558	1	0
STAT 13	**428090 CALCUTTA/DUM DUM**											
N	13	14	14	14	14	14	14	14	14	14	14	14
Min	0	0	0	20	70	780	1560	1690	1080	290	0	0
Max	380	800	800	1830	4030	5280	5290	4710	6150	3400	1810	290
20th %tile	0	6	34	182	712	1596	2012	2318	2012	638	0	0
Normal Dist: Mean	98.5	162.1	290.0	440.7	1174.3	2559.3	3160.0	2786.4	2865.0	1288.6	305.0	38.6
St Dev	131.5	207.6	272.6	463.3	934.2	1251.0	1192.6	772.1	1247.3	854.3	528.6	96.5
20% Prob	0	0	61	51	388	1506	2156	2137	1815	570	0	0
Gamma Dist: Alpha	0.6	0.6	1.1	0.9	1.6	4.2	7.0	13.0	5.3	2.3	0.3	0.2
Beta	175.5	265.8	256.2	487.1	743.2	611.5	450.1	214.0	543.0	566.3	916.1	241.3
20% Prob	8	16	75	87	410	1493	2138	2125	1799	574	5	0

STAT 14	**429700 CUTTACK**											
N	105	105	104	102	104	105	105	104	104	104	106	105
Min	0	0	0	0	20	260	990	1140	530	0	0	0
Max	810	1880	1540	1520	4830	5870	6910	9020	7860	4940	2930	960
20th %tile	0	0	0	10	360	1392	2446	2034	1736	500	0	0
Normal Dist: Mean	103.4	238.7	256.7	314.3	848.1	2470.3	3365.0	3328.8	2502.7	1504.1	384.9	52.1
St Dev	175.2	339.6	377.6	359.7	650.8	1401.4	1328.8	1469.4	1022.2	1102.0	632.1	145.5
20% Prob	0	0	0	12	300	1291	2247	2092	1642	577	0	0
Gamma Dist: Alpha	0.3	0.5	0.5	0.8	1.7	3.1	6.4	5.1	6.0	1.9	0.4	0.1
Beta	296.7	483.4	555.4	411.7	499.4	795.0	524.7	648.6	417.5	807.4	1038.0	406.3
20% Prob	2	15	13	48	313	1284	2227	2073	1628	592	10	0
STAT 15	**431970 BELGAUM**											
N	116	115	116	117	117	119	117	118	117	117	118	117
Min	0	0	0	0	0	99	792	523	23	46	0	0
Max	582	500	1128	1699	3970	6950	10721	6858	3162	5160	2710	1930
20th %tile	0	0	0	153	251	1129	2864	1380	569	633	13	0
Normal Dist: Mean	21.6	16.4	107.8	471.1	761.3	2158.8	4393.1	2524.5	1130.5	1272.5	355.5	86.9
St Dev	74.1	60.9	171.5	361.9	682.6	1145.1	1846.3	1415.6	701.7	847.9	444.6	229.3
20% Prob	0	0	0	166	187	1195	2839	1333	540	559	0	0
Gamma Dist: Alpha	0.1	0.1	0.4	1.7	1.2	3.6	5.7	3.2	2.6	2.3	0.6	0.1
Beta	254.7	226.2	273.0	278.1	612.0	607.4	775.9	793.8	435.5	565.0	556.1	604.5
20% Prob	0	0	3	173	216	1186	2814	1325	540	563	40	0
STAT 15	**431980 BELGAUM/SAMRA**											
N	11	12	12	12	12	12	12	12	12	12	12	12
Min	0	0	0	0	40	810	1090	710	490	40	0	0
Max	180	400	420	1110	1530	4940	3510	2900	2820	1830	1220	420
20th %tile	0	0	0	102	384	1066	1422	876	636	302	206	0
Normal Dist: Mean	20.0	35.8	104.2	412.5	762.5	1929.2	2189.2	1635.0	1153.3	760.0	509.2	52.5
St Dev	53.9	114.8	148.9	366.7	498.3	1127.1	875.7	718.7	692.0	531.8	400.7	122.6
20% Prob	0	0	0	104	343	981	1452	1030	571	312	172	0
Gamma Dist: Alpha	0.1	0.1	0.5	1.3	2.3	2.9	6.2	5.2	2.8	2.0	1.6	0.2
Beta	145.0	368.1	212.9	325.9	325.7	658.5	350.3	315.9	415.2	372.1	315.4	286.1
20% Prob	0	0	6	119	345	977	1440	1021	569	317	181	0
STAT 16	**423140 DIBRUGARH/MOHANBARI**											
N	81	79	81	81	82	84	85	85	82	84	83	82
Min	0	40	40	700	810	1860	2170	1410	970	60	0	0
Max	1230	1610	3580	5200	7070	8550	8860	7740	7480	4500	1370	1120
20th %tile	150	230	500	1470	1924	3452	4064	3136	2246	744	50	12
Normal Dist: Mean	336.7	557.5	1037.7	2245.2	3137.1	4626.5	5292.5	4445.8	3398.0	1527.9	295.9	182.8
St Dev	247.9	318.2	623.1	994.6	1357.8	1384.9	1463.9	1341.8	1386.4	987.6	315.5	210.8
20% Prob	128	290	513	1408	1994	3461	4060	3316	2231	697	30	5
Gamma Dist: Alpha	1.8	3.1	2.8	5.1	5.3	11.2	13.1	11.0	6.0	2.4	0.9	0.8
Beta	182.5	181.6	374.2	440.6	587.6	414.6	404.9	405.0	565.7	638.4	336.4	243.0
20% Prob	132	288	512	1395	1976	3439	4038	3296	2211	699	56	27
STAT 17	**431850 MASULIPATAM**											
N	122	122	125	123	124	125	124	125	125	122	125	125
Min	0	0	0	0	0	18	254	200	170	0	0	0
Max	803	1113	1580	1140	2416	2977	4760	5062	4432	6746	5390	2270
20th %tile	0	0	0	0	46	436	1006	795	838	845	66	0
Normal Dist: Mean	47.9	72.8	94.6	141.9	344.3	1037.3	1694.5	1595.3	1641.9	2206.7	1230.2	176.5
St Dev	127.1	175.6	267.5	271.2	458.8	630.6	872.4	864.4	827.0	1527.7	1333.8	388.2
20% Prob	0	0	0	0	0	507	960	868	946	921	108	0
Gamma Dist: Alpha	0.1	0.2	0.1	0.3	0.6	2.7	3.8	3.4	3.9	2.1	0.9	0.2
Beta	337.2	423.5	756.0	518.2	611.5	383.4	449.1	468.3	416.6	1057.7	1446.1	853.7
20% Prob	0	0	0	1	29	506	952	862	938	934	222	0
STAT 18	**424100 GAUHATI**											
N	84	82	85	81	83	85	84	84	84	84	85	85
Min	0	0	0	86	620	950	1328	710	250	0	0	0
Max	683	980	1885	4130	5652	5890	6470	5950	4478	2921	820	493
20th %tile	0	33	130	890	1698	2209	2182	1729	1058	291	0	0
Normal Dist: Mean	108.5	207.2	546.1	1484.4	2397.3	3140.9	3115.6	2622.2	1755.5	814.5	154.1	51.1
St Dev	146.6	213.9	451.4	767.6	932.1	1064.7	1086.9	994.1	849.8	631.6	174.4	99.0
20% Prob	0	27	166	838	1613	2245	2201	1786	1040	283	7	0
Gamma Dist: Alpha	0.5	0.9	1.5	3.7	6.6	8.7	8.2	7.0	4.3	1.7	0.8	0.3
Beta	198.1	220.8	373.1	396.9	362.4	360.9	379.2	376.8	411.4	489.7	197.2	192.0
20% Prob	9	43	179	832	1599	2228	2184	1771	1031	296	24	0
STAT 18	**424110 GAUHATI, INDIA**											
N	51	53	50	52	53	53	53	52	53	52	51	52
Min	0	0	0	582	0	1194	963	1092	30	0	0	0
Max	597	1580	2189	3406	6119	8687	7259	5019	4651	3368	1275	457
20th %tile	0	30	242	1018	1877	2130	1993	1681	1144	216	0	0
Normal Dist: Mean	153.5	224.0	620.6	1576.0	2496.2	3143.2	3157.0	2735.1	1946.3	763.0	148.2	62.1
St Dev	165.8	286.6	482.0	696.5	1079.1	1348.0	1416.5	1068.8	1029.1	728.4	271.1	103.4

20% Prob	14	0	215	990	1588	2009	1965	1836	1080	150	0	0
Gamma Dist: Alpha	0.9	0.6	1.7	5.1	5.4	5.4	5.0	6.5	3.6	1.1	0.3	0.4
Beta	179.1	366.7	374.4	307.8	466.5	578.1	635.6	417.6	544.1	695.4	495.7	172.1
20% Prob	28	23	225	981	1574	1990	1947	1820	1072	190	2	1
STAT 19	**431920 GOA/PANJIM**											
N	23	23	23	22	24	24	24	24	24	24	23	24
Min	0	0	0	0	0	1270	4290	1400	230	10	0	0
Max	10	30	130	650	3140	13330	13350	11930	6890	3730	1910	2160
20th %tile	0	0	0	0	36	7038	6772	3272	1262	264	52	0
Normal Dist: Mean	0.4	1.7	7.4	84.5	552.9	8363.3	8980.8	5596.3	2399.6	1187.5	389.6	113.8
St Dev	2.1	6.5	27.2	151.4	853.9	2411.7	2429.7	2632.5	1547.2	1140.0	513.9	440.3
20% Prob	0	0	0	0	0	6334	6936	3381	1097	228	0	0
Gamma Dist: Alpha	0.0	0.1	0.1	0.3	0.4	12.0	13.7	4.5	2.4	1.1	0.6	0.1
Beta	10.0	24.3	99.9	271.1	1318.8	695.5	657.4	1238.3	997.6	1094.4	677.9	1704.4
20% Prob	0	0	0	1	22	6296	6899	3350	1101	292	35	0
STAT 20	**431280 BEGAMPET**											
N	95	95	95	94	93	95	95	95	95	94	94	95
Min	0	0	0	0	0	70	310	210	140	0	0	0
Max	1330	990	2330	1610	1350	3150	3930	4000	4980	3670	2300	950
20th %tile	0	0	0	20	40	516	1088	842	824	238	30	0
Normal Dist: Mean	61.4	98.6	146.4	228.3	298.4	1033.3	1678.2	1491.3	1699.9	857.9	293.4	50.2
St Dev	180.8	171.4	330.2	281.2	308.3	566.5	754.8	773.3	1012.8	727.8	448.3	141.7
20% Prob	0	0	0	0	39	556	1043	840	847	245	0	0
Gamma Dist: Alpha	0.1	0.3	0.2	0.7	0.9	3.3	4.9	3.7	2.8	1.4	0.4	0.1
Beta	532.4	297.7	744.5	346.3	318.5	310.6	339.5	401.0	603.4	617.5	685.1	399.8
20% Prob	0	2	0	27	61	553	1033	834	845	269	12	0
STAT 21	**427540 INDORE**											
N	110	109	105	105	110	111	111	110	111	109	108	108
Min	0	0	0	0	0	0	560	160	80	0	0	0
Max	1050	400	350	570	1080	4300	7740	7070	7670	2300	2170	1090
20th %tile	0	0	0	0	0	630	1790	1398	580	6	0	0
Normal Dist: Mean	73.4	32.9	24.8	32.3	119.9	1366.7	2780.6	2490.8	1828.7	372.9	184.0	69.6
St Dev	149.9	63.9	55.0	72.9	199.0	913.4	1264.8	1312.1	1353.9	468.5	347.7	165.5
20% Prob	0	0	0	0	0	598	1716	1386	689	0	0	0
Gamma Dist: Alpha	0.2	0.3	0.2	0.2	0.4	2.2	4.8	3.6	1.8	0.6	0.3	0.2
Beta	306.3	124.2	122.2	164.6	330.4	610.5	575.4	691.2	1002.4	588.6	657.1	393.5
20% Prob	0	0	0	0	3	603	1700	1376	710	41	1	0
STAT 22	**430410 JAGDALPUR**											
N	77	78	77	77	77	78	78	78	78	79	79	78
Min	0	0	0	20	0	340	1400	1170	510	0	0	0
Max	880	2020	780	1420	2590	5290	6740	9050	5420	3740	1530	1430
20th %tile	0	0	0	232	252	1362	2584	2858	1720	398	0	0
Normal Dist: Mean	90.3	162.8	151.4	524.3	646.6	2411.8	3731.0	3833.5	2460.4	1031.5	236.3	81.0
St Dev	169.7	330.1	177.0	345.2	436.0	1124.1	1265.6	1425.1	1030.1	794.8	331.5	232.4
20% Prob	0	0	2	234	280	1466	2666	2634	1593	363	0	0
Gamma Dist: Alpha	0.3	0.2	0.7	2.3	2.2	4.6	8.7	7.2	5.7	1.7	0.5	0.1
Beta	319.2	669.3	206.9	227.3	294.0	523.9	429.3	529.8	431.3	612.4	465.0	666.3
20% Prob	1	1	22	235	282	1452	2646	2613	1579	378	16	0
STAT 23	**423480 JAIPUR / SANGANER**											
N	92	92	92	92	92	92	92	93	93	93	93	93
Min	0	0	0	0	0	0	102	0	0	0	0	0
Max	765	650	513	630	1000	3462	5451	5545	4201	2350	610	569
20th %tile	0	0	0	0	3	128	1157	545	183	0	0	0
Normal Dist: Mean	109.6	80.5	76.1	45.7	143.3	593.4	2014.6	2042.6	845.6	141.4	35.9	72.8
St Dev	151.4	128.2	124.7	87.5	174.2	655.3	1090.2	1463.4	846.1	329.3	85.8	128.5
20% Prob	0	0	0	0	0	42	1097	811	133	0	0	0
Gamma Dist: Alpha	0.5	0.4	0.4	0.3	0.7	0.8	3.4	1.9	1.0	0.2	0.2	0.3
Beta	209.3	204.1	204.2	167.6	211.7	723.6	590.0	1048.4	846.6	766.6	205.3	226.9
20% Prob	8	3	2	0	18	101	1089	828	188	0	0	1
STAT 24	**423390 JODHPUR**											
N	90	89	90	88	89	90	91	90	91	89	90	85
Min	0	0	0	0	0	0	0	0	0	0	0	0
Max	570	490	1000	1500	1170	1830	3910	5440	3690	1630	590	300
20th %tile	0	0	0	0	0	48	390	278	30	0	0	0
Normal Dist: Mean	39.8	47.2	48.1	47.6	124.4	327.4	1134.3	1270.7	584.2	81.8	30.7	19.6
St Dev	98.7	93.1	151.3	170.2	212.4	386.1	890.6	1112.6	755.9	225.1	94.7	52.6
20% Prob	0	0	0	0	0	3	385	334	0	0	0	0
Gamma Dist: Alpha	0.2	0.3	0.1	0.1	0.3	0.7	1.6	1.3	0.6	0.1	0.1	0.1
Beta	244.8	183.6	476.0	608.3	362.6	455.2	699.2	974.2	978.1	619.7	292.7	140.8
20% Prob	0	0	0	0	2	45	404	377	57	0	0	0
STAT 25	**433390 KODAIKANAL SO6 = 03Z**											
N	61	61	61	61	61	61	61	61	61	61	61	61
Min	0	0	0	117	305	142	250	528	70	754	23	0

Max	3546	1656	2967	4630	3528	2238	3193	4067	3770	6601	6228	3985
20th %tile	89	36	74	754	960	632	710	1010	960	1499	1173	305
Normal Dist: Mean	749.0	362.0	543.6	1420.5	1586.6	1055.6	1199.0	1664.9	1752.1	2579.1	2490.8	1289.9
St Dev	892.1	441.0	573.4	929.5	680.7	503.4	635.2	844.2	898.2	1106.0	1463.1	1014.4
20% Prob	0	0	61	638	1014	632	664	954	996	1648	1259	436
Gamma Dist: Alpha	0.7	0.7	0.9	2.3	5.4	4.4	3.6	3.9	3.8	5.4	2.9	1.6
Beta	1062.5	537.4	604.8	608.2	292.1	240.1	336.5	428.0	460.5	474.3	859.4	797.7
20% Prob	100	45	106	642	1005	626	659	946	988	1633	1255	459
STAT 26	**424510 KOTA**											
N	77	74	76	76	76	76	75	75	76	75	73	74
Min	0	0	0	0	0	0	300	10	30	0	0	0
Max	400	790	340	610	770	2250	7140	7040	4790	1560	760	520
20th %tile	0	0	0	0	0	190	1522	1376	350	0	0	0
Normal Dist: Mean	72.3	45.5	41.4	39.6	100.3	687.5	2777.6	2508.0	1242.0	154.8	51.1	48.8
St Dev	107.0	107.6	81.0	109.9	154.4	587.7	1482.6	1449.3	1073.0	322.8	136.2	108.3
20% Prob	0	0	0	0	0	193	1530	1288	339	0	0	0
Gamma Dist: Alpha	0.5	0.2	0.3	0.1	0.4	1.4	3.5	3.0	1.3	0.2	0.1	0.2
Beta	158.4	254.2	158.1	305.2	237.7	502.5	791.3	837.6	927.0	673.3	362.9	240.4
20% Prob	4	0	0	0	4	213	1518	1282	377	0	0	0
STAT 27	**432790 MADRAS / MINAMBAKKAM**											
N	175	175	175	175	175	175	175	175	175	175	175	175
Min	0	0	0	0	0	0	64	183	119	112	51	0
Max	2441	2840	2626	1910	5918	2192	2985	3950	3782	9583	10884	7200
20th %tile	0	0	0	0	0	198	480	629	591	1339	1345	178
Normal Dist: Mean	297.7	96.0	91.9	167.8	442.0	524.6	990.3	1232.2	1232.4	2857.1	3434.1	1379.4
St Dev	474.6	310.7	283.1	324.8	964.2	389.4	573.8	693.1	746.1	1806.7	2239.9	1414.2
20% Prob	0	0	0	0	0	197	507	649	604	1337	1549	189
Gamma Dist: Alpha	0.4	0.1	0.1	0.3	0.2	1.8	3.0	3.2	2.7	2.5	2.4	1.0
Beta	756.7	1005.8	872.7	628.4	2103.2	289.0	332.5	389.9	451.7	1142.5	1461.0	1449.9
20% Prob	9	0	0	1	1	203	505	645	603	1339	1557	289
STAT 28	**433690 MINICOY**											
N	93	90	92	91	94	92	93	92	92	94	91	88
Min	0	0	0	0	50	820	240	318	257	180	84	0
Max	2629	2280	1350	2639	6256	5438	5020	4572	4371	4520	3376	5390
20th %tile	35	4	0	165	959	2042	1350	994	617	845	620	224
Normal Dist: Mean	390.7	239.6	217.0	593.6	1867.7	2922.2	2299.8	2054.9	1669.3	1780.5	1416.5	890.0
St Dev	500.8	368.9	274.8	538.5	1169.1	1023.9	1078.9	1060.9	994.0	955.1	827.7	950.2
20% Prob	0	0	0	140	884	2060	1392	1162	833	977	720	90
Gamma Dist: Alpha	0.6	0.4	0.6	1.2	2.6	8.1	4.5	3.8	2.8	3.5	2.9	0.9
Beta	642.0	568.2	348.1	488.5	731.8	358.8	506.2	547.7	591.9	512.3	483.7	1014.5
20% Prob	39	9	23	164	884	2045	1379	1153	830	970	717	167
STAT 29	**428670 NAGPUR / SONEGAON**											
N	133	133	133	133	133	133	133	133	133	133	133	133
Min	0	0	0	0	0	3	399	452	230	0	0	0
Max	1229	1570	1040	1290	1646	5006	6096	5951	6271	3630	1623	1660
20th %tile	0	0	0	0	10	1107	2209	1771	917	10	0	0
Normal Dist: Mean	134.1	160.6	151.6	140.9	185.4	2020.1	3469.6	2737.0	1923.1	537.5	148.1	110.6
St Dev	253.2	248.1	212.1	218.0	265.2	1043.0	1278.9	1192.1	1114.2	660.9	284.5	275.0
20% Prob	0	0	0	0	0	1142	2393	1734	985	0	0	0
Gamma Dist: Alpha	0.3	0.4	0.5	0.4	0.5	3.8	7.4	5.3	3.0	0.7	0.3	0.2
Beta	478.3	383.3	296.6	337.3	379.3	538.5	471.4	519.3	645.5	812.5	546.5	683.4
20% Prob	1	6	10	5	11	1133	2374	1718	981	64	1	0
STAT 30	**421820 NEW DELHI / SAFDARJUNG**											
N	113	113	113	113	113	113	113	112	113	113	113	112
Min	0	0	0	0	0	0	41	0	0	0	0	0
Max	1732	1534	782	1830	750	4148	5380	5830	4923	2380	1000	1341
20th %tile	10	0	0	0	11	183	1105	817	196	0	0	0
Normal Dist: Mean	226.0	193.5	140.7	102.8	149.1	681.9	2023.2	1980.0	1209.9	190.1	30.5	101.8
St Dev	256.4	259.5	173.3	220.5	174.7	703.3	1139.7	1347.0	1075.4	413.3	107.1	197.4
20% Prob	10	0	0	0	2	90	1064	846	305	0	0	0
Gamma Dist: Alpha	0.8	0.6	0.7	0.2	0.7	0.9	3.2	2.2	1.3	0.2	0.1	0.3
Beta	290.9	348.1	213.5	473.4	204.7	725.4	642.0	916.3	955.8	898.4	375.5	382.6
20% Prob	36	16	17	0	21	141	1058	856	349	0	0	1
STAT 31	**427310 DWARKA**											
N	79	80	78	80	80	77	81	81	76	81	81	80
Min	0	0	0	0	0	0	0	0	0	0	0	0
Max	250	730	590	240	140	3070	9630	3570	3900	1580	3790	420
20th %tile	0	0	0	0	0	10	490	130	10	0	0	0
Normal Dist: Mean	23.2	34.0	17.4	3.8	5.8	511.7	1867.2	794.0	420.9	70.2	85.4	19.1
St Dev	50.8	101.0	74.7	26.9	23.4	723.7	1813.0	858.1	667.1	233.5	437.2	68.1
20% Prob	0	0	0	0	0	0	341	72	0	0	0	0
Gamma Dist: Alpha	0.2	0.1	0.1	0.0	0.1	0.5	1.1	0.9	0.4	0.1	0.0	0.1
Beta	111.4	300.0	320.2	192.7	95.4	1023.5	1760.4	927.3	1057.4	775.9	2236.9	242.8

20% Prob	0	0	0	0	0	33	447	144	14	0	0	0
STAT 32	**433510 FORT COCHIN**											
N	109	110	110	109	110	109	109	109	109	108	109	109
Min	0	0	0	15	157	2440	1240	772	210	785	5	0
Max	2113	1692	2450	3726	10775	12581	14530	11722	5880	9060	4760	2800
20th %tile	0	0	81	603	1524	5611	4258	2202	1266	1823	783	50
Normal Dist: Mean	212.5	260.2	486.0	1306.3	3193.3	7396.2	6183.1	3494.6	2548.3	3202.9	1645.2	469.5
St Dev	367.1	360.4	468.0	782.8	2004.1	2244.9	2499.2	1729.6	1414.6	1525.3	998.9	574.8
20% Prob	0	0	92	648	1507	5507	4080	2039	1358	1919	805	0
Gamma Dist: Alpha	0.3	0.5	1.1	2.8	2.5	10.9	6.1	4.1	3.2	4.4	2.7	0.7
Beta	634.3	499.0	450.7	469.1	1257.8	681.3	1010.2	856.0	785.2	726.4	606.5	703.8
20% Prob	4	19	118	646	1508	5472	4044	2021	1349	1902	803	57
STAT 33	**424910 PATNA**											
N	93	93	93	93	93	93	93	93	93	93	93	93
Min	0	0	0	0	0	130	950	1052	239	0	0	0
Max	1050	914	721	500	2441	7333	5941	7694	6502	3713	706	1506
20th %tile	0	8	0	0	34	699	1961	1881	1077	27	0	0
Normal Dist: Mean	173.9	175.5	91.8	81.3	351.6	1720.1	2857.4	3108.8	2181.2	625.9	69.0	42.4
St Dev	221.2	210.3	147.5	121.7	413.5	1250.6	1130.6	1457.3	1219.4	707.1	162.5	167.1
20% Prob	0	0	0	0	4	668	1906	1882	1155	31	0	0
Gamma Dist: Alpha	0.6	0.7	0.4	0.4	0.7	1.9	6.4	4.6	3.2	0.8	0.2	0.1
Beta	281.3	252.0	237.1	182.2	486.3	909.2	447.3	683.1	681.7	798.9	382.8	657.9
20% Prob	18	23	3	4	49	684	1889	1865	1148	100	0	0
STAT 34	**433330 PORT BLAIR**											
N	115	114	114	112	115	116	115	116	112	114	113	111
Min	0	0	0	0	198	1250	270	729	1262	823	241	0
Max	5837	2350	2062	3391	10610	10541	9300	9248	11230	5804	6487	6175
20th %tile	13	0	0	93	2368	3541	2563	2900	3352	1872	1173	390
Normal Dist: Mean	407.0	279.0	178.2	662.9	3830.2	4940.9	4031.3	4090.0	4730.1	2919.7	2239.7	1571.8
St Dev	692.7	482.1	337.0	669.3	1774.7	1594.9	1599.1	1608.2	1659.1	1055.7	1290.8	1428.0
20% Prob	0	0	0	100	2337	3599	2686	2737	3334	2031	1153	370
Gamma Dist: Alpha	0.3	0.3	0.3	1.0	4.7	9.6	6.4	6.5	8.1	7.6	3.0	1.2
Beta	1179.1	833.1	637.2	675.7	822.3	514.9	634.3	632.3	581.9	381.7	743.9	1297.4
20% Prob	8	5	1	144	2315	3574	2662	2713	3308	2015	1148	434
STAT 35	**430630 POONA**											
N	130	131	127	130	132	132	132	132	132	132	132	132
Min	0	0	0	0	0	0	0	50	30	0	0	0
Max	1290	310	380	700	1820	4370	5480	3170	3640	4590	2090	720
20th %tile	0	0	0	0	0	490	882	532	470	220	0	0
Normal Dist: Mean	27.1	13.7	32.8	145.7	346.4	1195.2	1738.9	1069.8	1257.8	906.2	263.7	50.4
St Dev	124.4	46.9	79.1	177.4	387.5	870.0	1002.5	667.2	801.3	831.4	387.5	127.2
20% Prob	0	0	0	0	20	463	895	508	583	206	0	0
Gamma Dist: Alpha	0.0	0.1	0.2	0.7	0.8	1.9	3.0	2.6	2.5	1.2	0.5	0.2
Beta	571.8	161.1	190.4	215.9	433.5	633.2	578.0	416.1	510.5	762.8	569.3	321.1
20% Prob	0	0	0	18	57	474	891	509	585	245	14	0
STAT 36	**425160 SHILLONG SO6=03Z**											
N	94	94	94	94	94	94	94	94	94	93	94	94
Min	0	0	0	0	1247	1361	899	1067	1350	64	0	0
Max	910	930	2238	4460	9606	12664	9560	7775	10140	5154	1923	572
20th %tile	7	41	137	578	1835	3210	2175	2069	2093	819	38	0
Normal Dist: Mean	139.4	235.2	532.8	1257.3	2768.1	4641.4	3583.9	3316.7	3320.2	1750.3	330.6	61.6
St Dev	184.0	213.0	453.5	798.1	1207.0	2016.5	1707.6	1318.6	1514.2	1079.2	421.1	100.6
20% Prob	0	56	151	586	1752	2944	2147	2207	2046	842	0	0
Gamma Dist: Alpha	0.6	1.2	1.4	2.5	5.3	5.3	4.4	6.3	4.8	2.6	0.6	0.4
Beta	242.9	193.0	386.1	506.6	526.3	876.1	813.6	524.2	690.6	665.4	536.4	164.3
20% Prob	12	65	166	587	1736	2918	2127	2188	2027	842	34	2
STAT 37	**426190 SILCHAR**											
N	105	104	105	105	105	105	104	106	106	105	104	105
Min	0	0	20	450	1390	2110	2360	860	610	150	0	0
Max	1730	1760	5620	10110	13140	10680	11190	10410	8180	5540	3750	1860
20th %tile	0	100	480	1960	2718	4314	3990	3740	2600	996	10	0
Normal Dist: Mean	188.5	483.6	1681.1	3470.8	4317.7	5850.5	5236.5	4988.2	3738.0	1911.0	418.2	94.4
St Dev	278.4	434.9	1276.8	1802.9	2078.8	1790.8	1691.8	1489.2	1340.1	1156.5	592.3	237.7
20% Prob	0	118	607	1953	2568	4343	3813	3735	2610	938	0	0
Gamma Dist: Alpha	0.5	1.2	1.7	3.7	4.3	10.7	9.6	11.2	7.8	2.7	0.5	0.2
Beta	411.1	391.2	969.7	936.6	1000.8	548.2	546.6	444.6	480.4	699.9	838.9	598.7
20% Prob	10	136	629	1938	2545	4315	3786	3712	2590	936	27	0
STAT 38	**420270 SRINAGAR**											
N	92	91	92	92	93	88	93	92	90	87	88	92
Min	0	50	40	90	10	10	100	30	0	0	0	0
Max	2690	2120	3650	2690	1910	1120	2930	2590	1810	1710	1020	2100
20th %tile	314	350	580	476	350	134	224	270	90	42	0	60
Normal Dist: Mean	686.1	713.8	1003.9	917.5	660.0	355.3	587.2	643.5	364.8	329.0	174.1	399.9

St Dev	467.5	417.7	545.6	504.2	394.0	257.7	475.8	443.5	347.0	360.8	238.3	403.5
20% Prob	293	362	545	493	328	138	187	270	73	25	0	60
Gamma Dist: Alpha	2.2	2.9	3.4	3.3	2.8	1.9	1.5	2.1	1.1	0.8	0.5	1.0
Beta	318.6	244.4	296.5	277.0	235.2	186.9	385.5	305.7	330.1	395.7	326.2	407.2
20% Prob	296	361	541	490	328	142	199	274	91	57	13	87
STAT 39	**433710 TRIANDRUM**											
N	110	111	118	121	121	120	121	121	122	122	121	118
Min	0	0	0	20	70	580	220	160	70	450	70	0
Max	2240	1500	1840	4160	10550	9600	5570	4510	4990	6560	7220	3440
20th %tile	18	0	80	660	790	1944	1260	620	460	1544	910	150
Normal Dist: Mean	239.1	232.5	401.3	1158.4	2077.9	3287.8	2042.6	1338.9	1320.3	2666.8	1799.8	663.4
St Dev	332.9	303.9	395.8	683.2	1695.1	1657.3	1037.2	876.1	1066.2	1277.1	1215.3	669.2
20% Prob	0	0	68	583	651	1893	1170	602	423	1592	777	100
Gamma Dist: Alpha	0.5	0.6	1.0	2.9	1.5	3.9	3.9	2.3	1.5	4.4	2.2	1.0
Beta	463.6	397.1	390.5	402.9	1382.8	835.4	526.7	573.3	860.9	611.6	820.6	675.1
20% Prob	17	22	93	581	697	1877	1160	605	450	1578	784	145
STAT 40	**433630 PAMBAN**											
N	94	93	95	95	94	94	95	94	95	93	95	94
Min	0	0	0	0	0	0	0	0	0	30	330	60
Max	3690	3080	1480	2670	2170	700	1740	1040	1330	6270	6920	8400
20th %tile	90	0	0	110	16	0	0	0	0	924	1486	846
Normal Dist: Mean	582.9	232.8	202.1	535.3	321.3	35.5	121.6	121.5	245.8	2005.6	2930.2	1964.5
St Dev	702.8	422.2	306.7	573.0	417.8	84.6	268.5	216.1	315.3	1235.8	1463.7	1576.2
20% Prob	0	0	0	53	0	0	0	0	0	966	1698	638
Gamma Dist: Alpha	0.7	0.3	0.4	0.9	0.6	0.2	0.2	0.3	0.6	2.6	4.0	1.6
Beta	847.5	765.7	465.3	613.5	543.4	201.6	593.1	384.4	404.4	761.4	731.1	1264.7
20% Prob	75	3	9	100	31	0	0	2	25	965	1684	677
STAT 41	**429090 VERAVAL**											
N	90	91	93	95	94	93	95	95	91	93	91	95
Min	0	0	0	0	0	10	100	50	0	0	0	0
Max	140	200	220	1380	1810	9290	7190	6960	4580	2930	4430	280
20th %tile	0	0	0	0	0	114	856	288	90	0	0	0
Normal Dist: Mean	8.7	16.5	8.0	16.0	48.4	1447.2	2349.4	1317.8	731.6	193.1	126.3	14.0
St Dev	26.5	41.1	32.7	141.9	221.3	1600.9	1712.2	1405.4	951.0	483.1	527.9	43.6
20% Prob	0	0	0	0	0	100	908	135	0	0	0	0
Gamma Dist: Alpha	0.1	0.2	0.1	0.0	0.0	0.8	1.9	0.9	0.6	0.2	0.1	0.1
Beta	81.0	102.2	134.3	1258.3	1011.9	1770.9	1247.8	1498.7	1236.1	1208.6	2207.2	135.6
20% Prob	0	0	0	0	0	246	931	249	70	0	0	0
STAT 42	**431490 VISHAKHAPATNAM**											
N	122	122	122	122	122	122	122	122	121	118	121	122
Min	0	0	0	0	0	109	74	173	305	0	0	0
Max	1656	1219	1252	2250	3683	3607	3010	4300	5596	7671	5311	6553
20th %tile	0	0	0	0	82	483	715	717	970	881	51	0
Normal Dist: Mean	97.8	128.7	93.9	208.5	545.3	1048.2	1204.6	1338.3	1765.6	2338.6	1012.2	197.6
St Dev	230.0	238.8	202.1	356.9	659.7	721.3	605.4	782.3	985.7	1577.5	1135.6	687.8
20% Prob	0	0	0	0	0	441	695	680	936	1011	56	0
Gamma Dist: Alpha	0.2	0.3	0.2	0.3	0.7	2.1	4.0	2.9	3.2	2.2	0.8	0.1
Beta	540.6	443.1	434.7	610.6	798.2	496.3	304.2	457.3	550.3	1064.1	1274.0	2394.2
20% Prob	0	1	0	4	69	447	689	677	930	1021	165	0

APPENDIX P

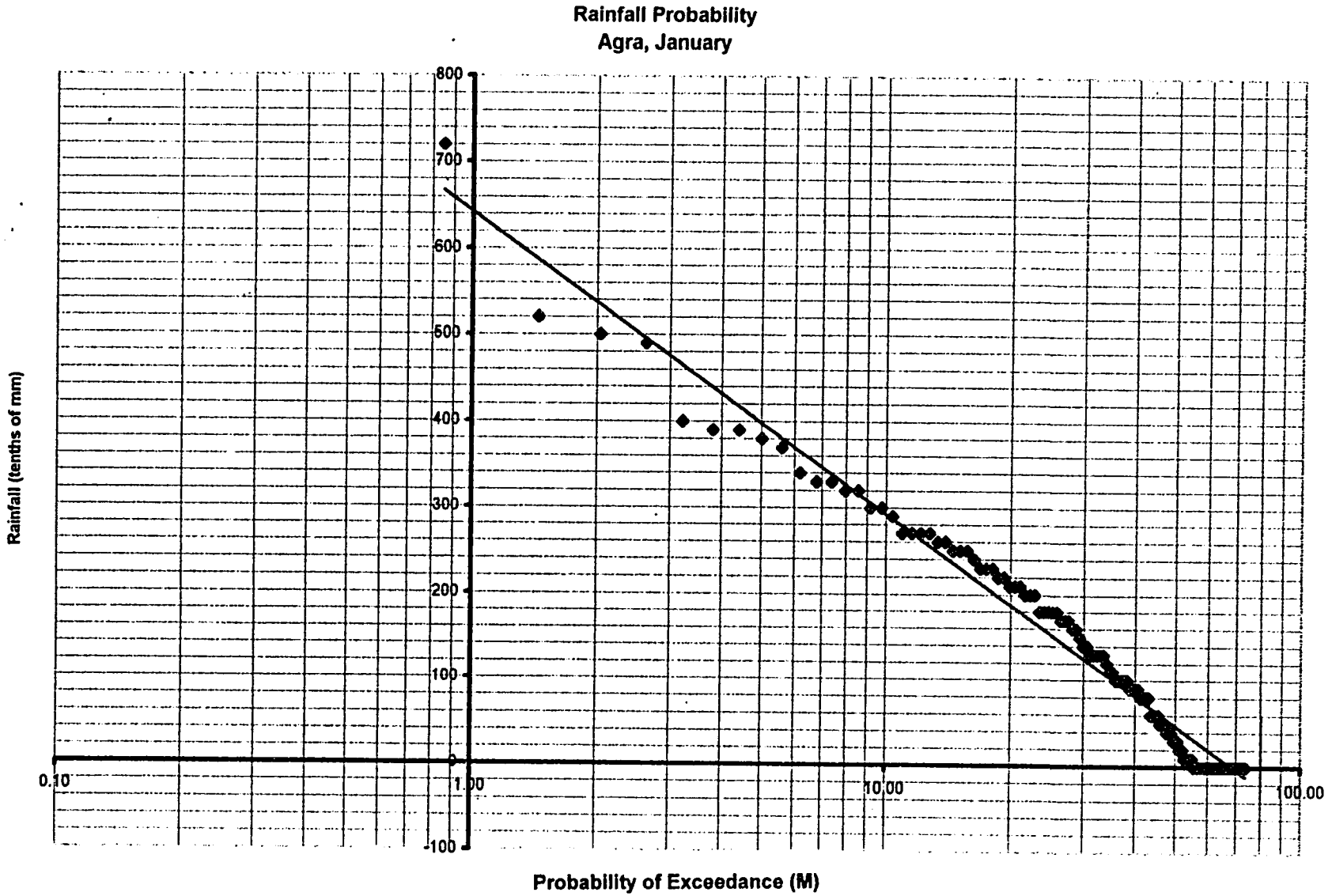
EFFECTIVE PRECIPITATION

METHOD 2
DOORENBOS AND PRUITT (1977)

Data and Log-Normal Plots

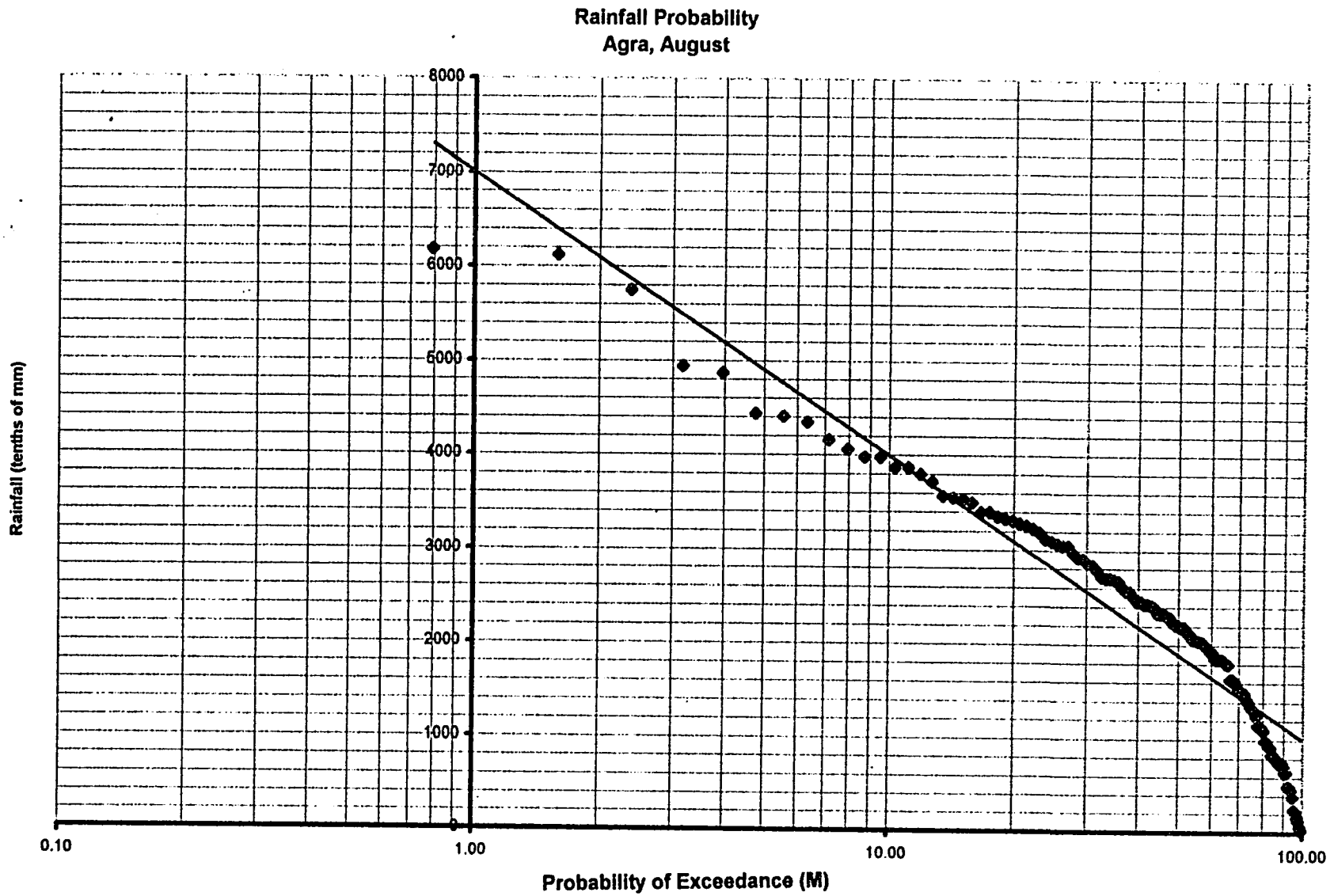
STAT 1 AGRA (JANUARY) **p = 0.285**

m	Data	M	Mp	m	Data	M	Mp	m	Data	M	Mp
1	720	0.80	0.85	42	180	33.60	25.19	83	30	66.40	49.52
2	520	1.60	1.45	43	180	34.40	25.78	84	30	67.20	50.12
3	500	2.40	2.04	44	170	35.20	26.37	85	30	68.00	50.71
4	490	3.20	2.63	45	170	36.00	26.97	86	20	68.80	51.30
5	400	4.00	3.23	46	170	36.80	27.56	87	20	69.60	51.90
6	390	4.80	3.82	47	160	37.60	28.15	88	10	70.40	52.49
7	390	5.60	4.41	48	160	38.40	28.75	89	10	71.20	53.08
8	380	6.40	5.01	49	150	39.20	29.34	90	10	72.00	53.68
9	370	7.20	5.60	50	140	40.00	29.94	91	10	72.80	54.27
10	340	8.00	6.19	51	140	40.80	30.53	92	10	73.60	54.86
11	330	8.80	6.79	52	130	41.60	31.12	93	0	74.40	55.46
12	330	9.60	7.38	53	130	42.40	31.72	94	0	75.20	56.05
13	320	10.40	7.97	54	130	43.20	32.31	95	0	76.00	56.65
14	320	11.20	8.57	55	130	44.00	32.90	96	0	76.80	57.24
15	300	12.00	9.16	56	130	44.80	33.50	97	0	77.60	57.83
16	300	12.80	9.75	57	120	45.60	34.09	98	0	78.40	58.43
17	290	13.60	10.35	58	110	46.40	34.68	99	0	79.20	59.02
18	270	14.40	10.94	59	110	47.20	35.28	100	0	80.00	59.61
19	270	15.20	11.54	60	100	48.00	35.87	101	0	80.80	60.21
20	270	16.00	12.13	61	100	48.80	36.46	102	0	81.60	60.80
21	270	16.80	12.72	62	100	49.60	37.06	103	0	82.40	61.39
22	260	17.60	13.32	63	100	50.40	37.65	104	0	83.20	61.99
23	260	18.40	13.91	64	100	51.20	38.25	105	0	84.00	62.58
24	250	19.20	14.50	65	90	52.00	38.84	106	0	84.80	63.17
25	250	20.00	15.10	66	90	52.80	39.43	107	0	85.60	63.77
26	250	20.80	15.69	67	90	53.60	40.03	108	0	86.40	64.36
27	240	21.60	16.28	68	90	54.40	40.62	109	0	87.20	64.95
28	230	22.40	16.88	69	80	55.20	41.21	110	0	88.00	65.55
29	230	23.20	17.47	70	80	56.00	41.81	111	0	88.80	66.14
30	230	24.00	18.06	71	80	56.80	42.40	112	0	89.60	66.74
31	220	24.80	18.66	72	80	57.60	42.99	113	0	90.40	67.33
32	220	25.60	19.25	73	60	58.40	43.59	114	0	91.20	67.92
33	210	26.40	19.85	74	60	59.20	44.18	115	0	92.00	68.52
34	210	27.20	20.44	75	60	60.00	44.77	116	0	92.80	69.11
35	210	28.00	21.03	76	60	60.80	45.37	117	0	93.60	69.70
36	200	28.80	21.63	77	50	61.60	45.96	118	0	94.40	70.30
37	200	29.60	22.22	78	50	62.40	46.55	119	0	95.20	70.89
38	200	30.40	22.81	79	50	63.20	47.15	120	0	96.00	71.48
39	180	31.20	23.41	80	40	64.00	47.74	121	0	96.80	72.08
40	180	32.00	24.00	81	40	64.80	48.34	122	0	97.60	72.67
41	180	32.80	24.59	82	40	65.60	48.93	123	0	98.40	73.26
								124	0	99.20	73.86


Rainfall Probability
Agra, January
Rainfall (tenths of mm)
800
700
600
500
400
300
200
100
0
-100
0.10
1.00
10.00
100.00
Probability of Exceedance (M)

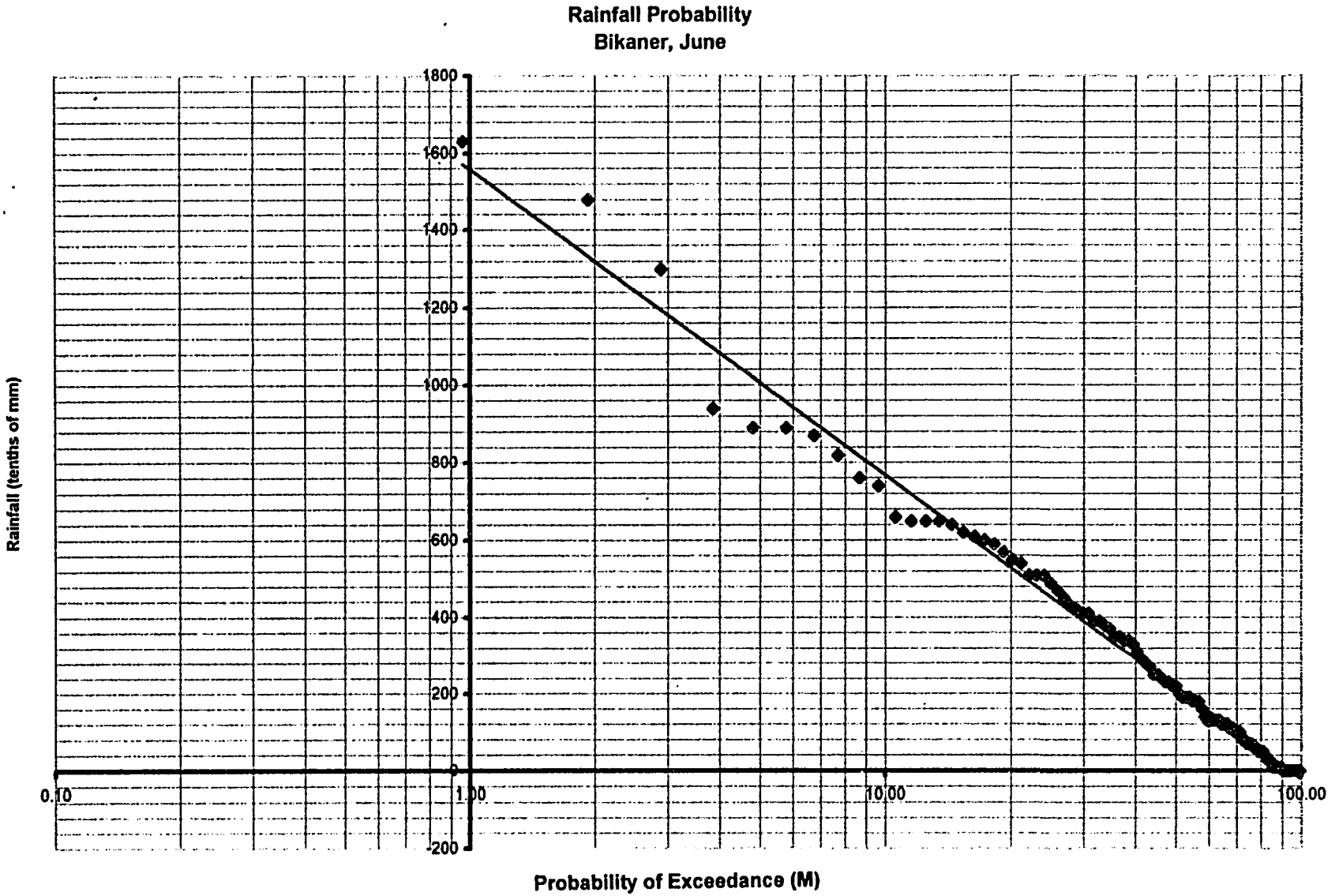
STAT 1 AGRA (AUGUST) **p = 0.000**

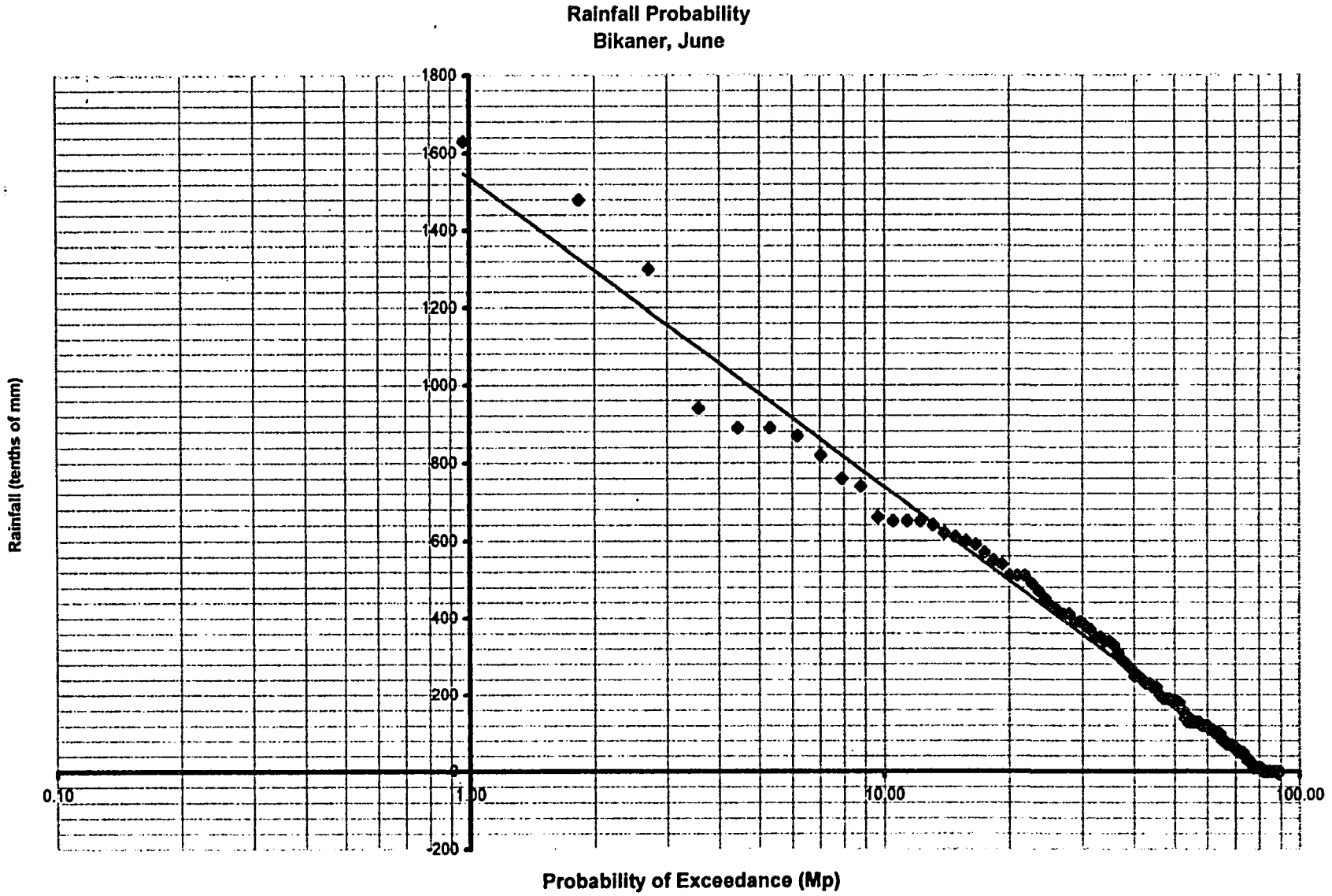
m	Data	M	Mp	m	Data	M	Mp	m	Data	M	Mp
1	6180	0.79	0.79	43	2700	34.13	34.13	85	1640	67.46	67.46
2	6120	1.59	1.59	44	2690	34.92	34.92	86	1620	68.25	68.25
3	5750	2.38	2.38	45	2670	35.71	35.71	87	1580	69.05	69.05
4	4940	3.17	3.17	46	2610	36.51	36.51	88	1540	69.84	69.84
5	4870	3.97	3.97	47	2570	37.30	37.30	89	1510	70.63	70.63
6	4440	4.76	4.76	48	2560	38.10	38.10	90	1500	71.43	71.43
7	4410	5.56	5.56	49	2510	38.89	38.89	91	1490	72.22	72.22
8	4350	6.35	6.35	50	2460	39.68	39.68	92	1430	73.02	73.02
9	4160	7.14	7.14	51	2460	40.48	40.48	93	1400	73.81	73.81
10	4060	7.94	7.94	52	2430	41.27	41.27	94	1350	74.60	74.60
11	3980	8.73	8.73	53	2430	42.06	42.06	95	1330	75.40	75.40
12	3980	9.52	9.52	54	2420	42.86	42.86	96	1300	76.19	76.19
13	3870	10.32	10.32	55	2400	43.65	43.65	97	1250	76.98	76.98
14	3870	11.11	11.11	56	2340	44.44	44.44	98	1150	77.78	77.78
15	3800	11.90	11.90	57	2330	45.24	45.24	99	1140	78.57	78.57
16	3720	12.70	12.70	58	2330	46.03	46.03	100	1130	79.37	79.37
17	3570	13.49	13.49	59	2310	46.83	46.83	101	1100	80.16	80.16
18	3550	14.29	14.29	60	2290	47.62	47.62	102	990	80.95	80.95
19	3540	15.08	15.08	61	2240	48.41	48.41	103	980	81.75	81.75
20	3500	15.87	15.87	62	2220	49.21	49.21	104	940	82.54	82.54
21	3400	16.67	16.67	63	2210	50.00	50.00	105	920	83.33	83.33
22	3400	17.46	17.46	64	2190	50.79	50.79	106	840	84.13	84.13
23	3350	18.25	18.25	65	2190	51.59	51.59	107	840	84.92	84.92
24	3330	19.05	19.05	66	2140	52.38	52.38	108	820	85.71	85.71
25	3310	19.84	19.84	67	2120	53.17	53.17	109	790	86.51	86.51
26	3280	20.63	20.63	68	2070	53.97	53.97	110	760	87.30	87.30
27	3260	21.43	21.43	69	2060	54.76	54.76	111	760	88.10	88.10
28	3230	22.22	22.22	70	2050	55.56	55.56	112	760	88.89	88.89
29	3190	23.02	23.02	71	2040	56.35	56.35	113	720	89.68	89.68
30	3120	23.81	23.81	72	2030	57.14	57.14	114	660	90.48	90.48
31	3100	24.60	24.60	73	2000	57.94	57.94	115	660	91.27	91.27
32	3070	25.40	25.40	74	1970	58.73	58.73	116	510	92.06	92.06
33	3050	26.19	26.19	75	1940	59.52	59.52	117	500	92.86	92.86
34	3050	26.98	26.98	76	1930	60.32	60.32	118	470	93.65	93.65
35	2970	27.78	27.78	77	1860	61.11	61.11	119	390	94.44	94.44
36	2920	28.57	28.57	78	1850	61.90	61.90	120	250	95.24	95.24
37	2910	29.37	29.37	79	1850	62.70	62.70	121	230	96.03	96.03
38	2860	30.16	30.16	80	1850	63.49	63.49	122	170	96.83	96.83
39	2840	30.95	30.95	81	1840	64.29	64.29	123	130	97.62	97.62
40	2790	31.75	31.75	82	1810	65.08	65.08	124	70	98.41	98.41
41	2720	32.54	32.54	83	1800	65.87	65.87	125	30	99.21	99.21
42	2700	33.33	33.33	84	1640	66.67	66.67				


Rainfall Probability
Agra, August
Rainfall (tenths of mm)
8000
7000
6000
5000
4000
3000
2000
1000
0
0.10
1.00
10.00
100.00
Probability of Exceedance (M)

STAT 9 BIKANER (JUNE) p = 0.019

m	Data	M	Mp	m	Data	M	Mp
1	1630	0.96	0.97	53	200	50.96	46.11
2	1480	1.92	1.83	54	190	51.92	46.98
3	1300	2.88	2.70	55	190	52.88	47.85
4	940	3.85	3.57	56	190	53.85	48.72
5	890	4.81	4.44	57	180	54.81	49.58
6	890	5.77	5.31	58	180	55.77	50.45
7	870	6.73	6.17	59	180	56.73	51.32
8	820	7.69	7.04	60	160	57.69	52.19
9	760	8.65	7.91	61	140	58.65	53.06
10	740	9.62	8.78	62	130	59.62	53.92
11	660	10.58	9.65	63	130	60.58	54.79
12	650	11.54	10.52	64	130	61.54	55.66
13	650	12.50	11.38	65	130	62.50	56.53
14	650	13.46	12.25	66	130	63.46	57.40
15	640	14.42	13.12	67	120	64.42	58.27
16	620	15.38	13.99	68	120	65.38	59.13
17	610	16.35	14.86	69	120	66.35	60.00
18	600	17.31	15.72	70	110	67.31	60.87
19	590	18.27	16.59	71	110	68.27	61.74
20	570	19.23	17.46	72	100	69.23	62.61
21	550	20.19	18.33	73	100	70.19	63.47
22	540	21.15	19.20	74	100	71.15	64.34
23	510	22.12	20.07	75	80	72.12	65.21
24	510	23.08	20.93	76	80	73.08	66.08
25	510	24.04	21.80	77	70	74.04	66.95
26	490	25.00	22.67	78	70	75.00	67.82
27	470	25.96	23.54	79	70	75.96	68.68
28	450	26.92	24.41	80	60	76.92	69.55
29	430	27.88	25.27	81	60	77.88	70.42
30	420	28.85	26.14	82	50	78.85	71.29
31	410	29.81	27.01	83	50	79.81	72.16
32	410	30.77	27.88	84	50	80.77	73.02
33	390	31.73	28.75	85	40	81.73	73.89
34	390	32.69	29.62	86	30	82.69	74.76
35	380	33.65	30.48	87	30	83.65	75.63
36	370	34.62	31.35	88	20	84.62	76.50
37	350	35.58	32.22	89	10	85.58	77.37
38	350	36.54	33.09	90	10	86.54	78.23
39	340	37.50	33.96	91	10	87.50	79.10
40	340	38.46	34.82	92	10	88.46	79.97
41	330	39.42	35.69	93	10	89.42	80.84
42	310	40.38	36.56	94	0	90.38	81.71
43	290	41.35	37.43	95	0	91.35	82.57
44	280	42.31	38.30	96	0	92.31	83.44
45	270	43.27	39.17	97	0	93.27	84.31
46	250	44.23	40.03	98	0	94.23	85.18
47	250	45.19	40.90	99	0	95.19	86.05
48	240	46.15	41.77	100	0	96.15	86.92
49	230	47.12	42.64	101	0	97.12	87.78
50	230	48.08	43.51	102	0	98.08	88.65
51	220	49.04	44.37	103	0	99.04	89.52
52	220	50.00	45.24				

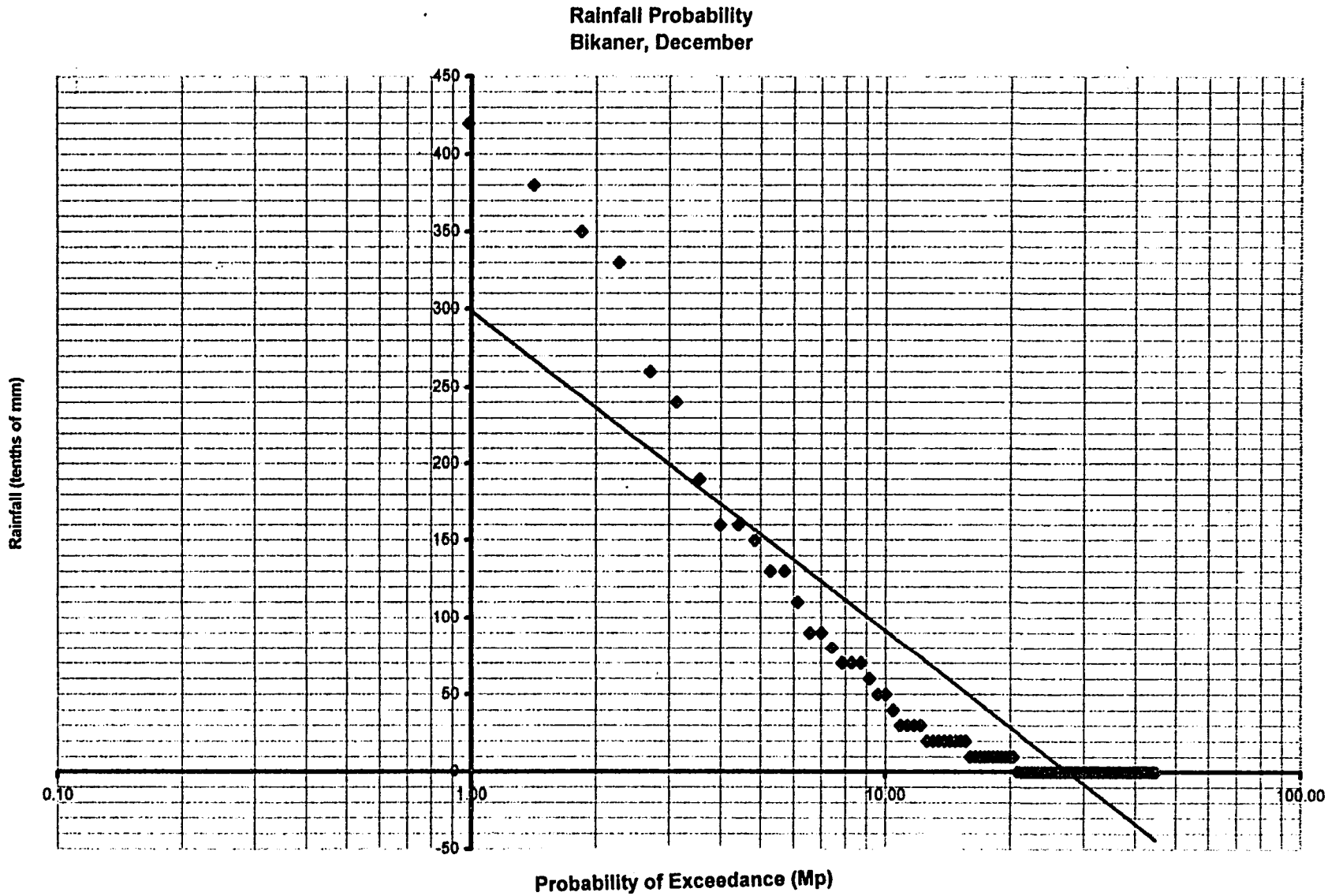

Rainfall Probability
Bikaner, June
Rainfall (tenths of mm)
1800
1600
1400
1200
1000
800
600
400
200
0
-200
0.10
1.00
10.00
100.00
Probability of Exceedance (M)

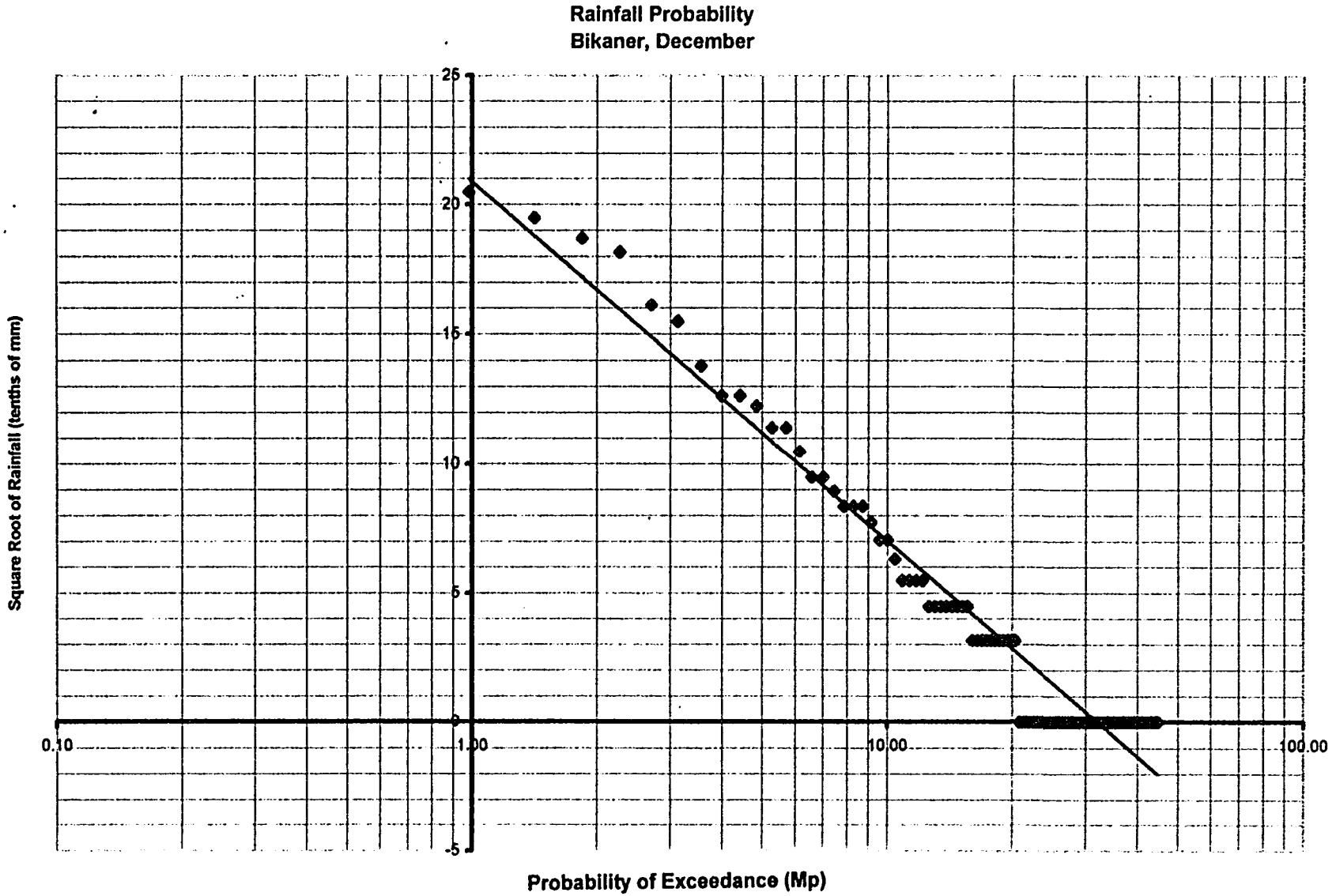

Rainfall Probability
Bikaner, June
Rainfall (tenths of mm)
1800
1600
1400
1200
1000
800
600
400
200
0
-200
0.10
1.00
10.00
100.00
Probability of Exceedance (Mp)

STAT 9 BIKANER (DECEMBER)

p = 0.553

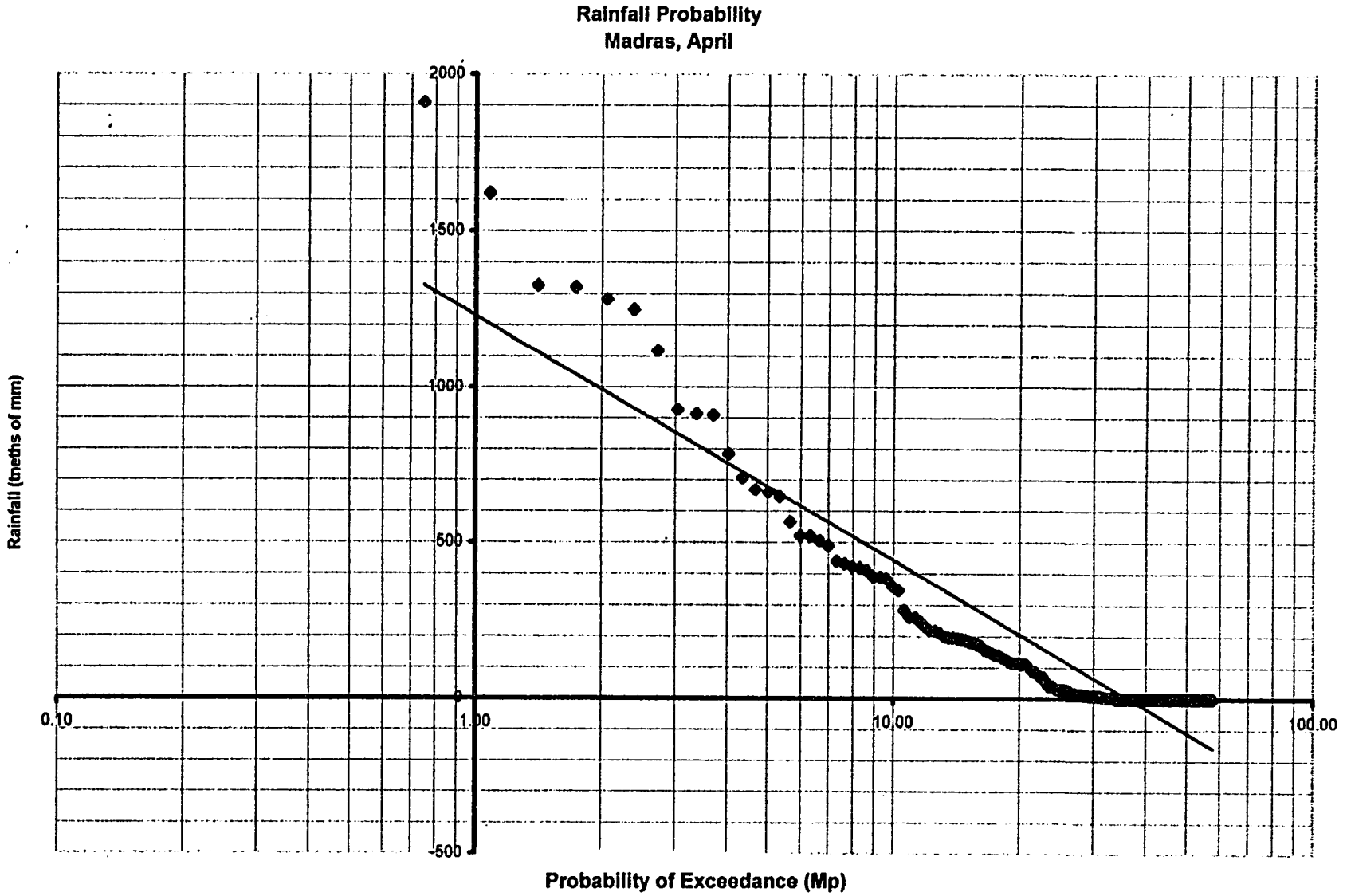
m	Data	Sqrt(Data)	M	Mp	m	Data	Sqrt(Data)	M	Mp
1	420	4.53	0.96	0.98	53	0	0.00	50.96	23.31
2	380	4.42	1.92	1.41	54	0	0.00	51.92	23.74
3	350	4.33	2.88	1.84	55	0	0.00	52.88	24.17
4	330	4.26	3.85	2.27	56	0	0.00	53.85	24.60
5	260	4.02	4.81	2.70	57	0	0.00	54.81	25.03
6	240	3.94	5.77	3.13	58	0	0.00	55.77	25.46
7	190	3.71	6.73	3.56	59	0	0.00	56.73	25.89
8	160	3.56	7.69	3.99	60	0	0.00	57.69	26.32
9	160	3.56	8.65	4.42	61	0	0.00	58.65	26.75
10	150	3.50	9.62	4.85	62	0	0.00	59.62	27.18
11	130	3.38	10.58	5.28	63	0	0.00	60.58	27.61
12	130	3.38	11.54	5.71	64	0	0.00	61.54	28.04
13	110	3.24	12.50	6.14	65	0	0.00	62.50	28.47
14	90	3.08	13.46	6.57	66	0	0.00	63.46	28.90
15	90	3.08	14.42	6.99	67	0	0.00	64.42	29.32
16	80	2.99	15.38	7.42	68	0	0.00	65.38	29.75
17	70	2.89	16.35	7.85	69	0	0.00	66.35	30.18
18	70	2.89	17.31	8.28	70	0	0.00	67.31	30.61
19	70	2.89	18.27	8.71	71	0	0.00	68.27	31.04
20	60	2.78	19.23	9.14	72	0	0.00	69.23	31.47
21	50	2.66	20.19	9.57	73	0	0.00	70.19	31.90
22	50	2.66	21.15	10.00	74	0	0.00	71.15	32.33
23	40	2.51	22.12	10.43	75	0	0.00	72.12	32.76
24	30	2.34	23.08	10.86	76	0	0.00	73.08	33.19
25	30	2.34	24.04	11.29	77	0	0.00	74.04	33.62
26	30	2.34	25.00	11.72	78	0	0.00	75.00	34.05
27	30	2.34	25.96	12.15	79	0	0.00	75.96	34.48
28	20	2.11	26.92	12.58	80	0	0.00	76.92	34.91
29	20	2.11	27.88	13.01	81	0	0.00	77.88	35.34
30	20	2.11	28.85	13.44	82	0	0.00	78.85	35.77
31	20	2.11	29.81	13.87	83	0	0.00	79.81	36.20
32	20	2.11	30.77	14.29	84	0	0.00	80.77	36.63
33	20	2.11	31.73	14.72	85	0	0.00	81.73	37.05
34	20	2.11	32.69	15.15	86	0	0.00	82.69	37.48
35	20	2.11	33.65	15.58	87	0	0.00	83.65	37.91
36	10	1.78	34.62	16.01	88	0	0.00	84.62	38.34
37	10	1.78	35.58	16.44	89	0	0.00	85.58	38.77
38	10	1.78	36.54	16.87	90	0	0.00	86.54	39.20
39	10	1.78	37.50	17.30	91	0	0.00	87.50	39.63
40	10	1.78	38.46	17.73	92	0	0.00	88.46	40.06
41	10	1.78	39.42	18.16	93	0	0.00	89.42	40.49
42	10	1.78	40.38	18.59	94	0	0.00	90.38	40.92
43	10	1.78	41.35	19.02	95	0	0.00	91.35	41.35
44	10	1.78	42.31	19.45	96	0	0.00	92.31	41.78
45	10	1.78	43.27	19.88	97	0	0.00	93.27	42.21
46	10	1.78	44.23	20.31	98	0	0.00	94.23	42.64
47	0	0.00	45.19	20.74	99	0	0.00	95.19	43.07
48	0	0.00	46.15	21.17	100	0	0.00	96.15	43.50
49	0	0.00	47.12	21.60	101	0	0.00	97.12	43.93
50	0	0.00	48.08	22.02	102	0	0.00	98.08	44.35
51	0	0.00	49.04	22.45	103	0	0.00	99.04	44.78
52	0	0.00	50.00	22.88					

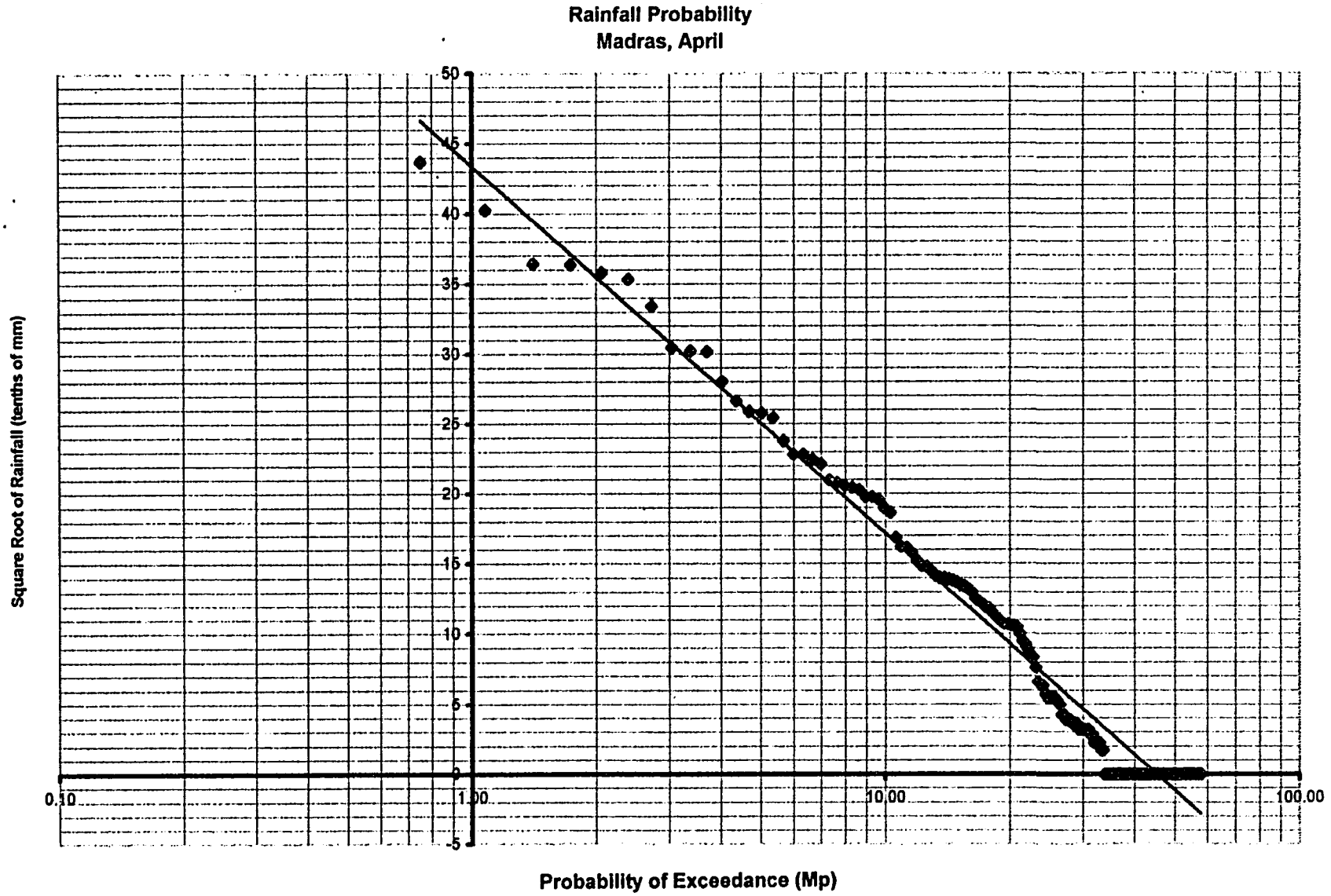

Rainfall Probability
Bikaner, December
Rainfall (tenths of mm)
450
400
350
300
250
200
150
100
50
0
-50
0.10
1.00
10.00
100.00
Probability of Exceedance (Mp)


Rainfall Probability
Bikaner, December
Square Root of Rainfall (tenths of mm)
25
20
15
10
5
0
-5
0.10
1.00
10.00
100.00
Probability of Exceedance (Mp)

STAT 27 **MADRAS (APRIL)** **p =** **0.423**

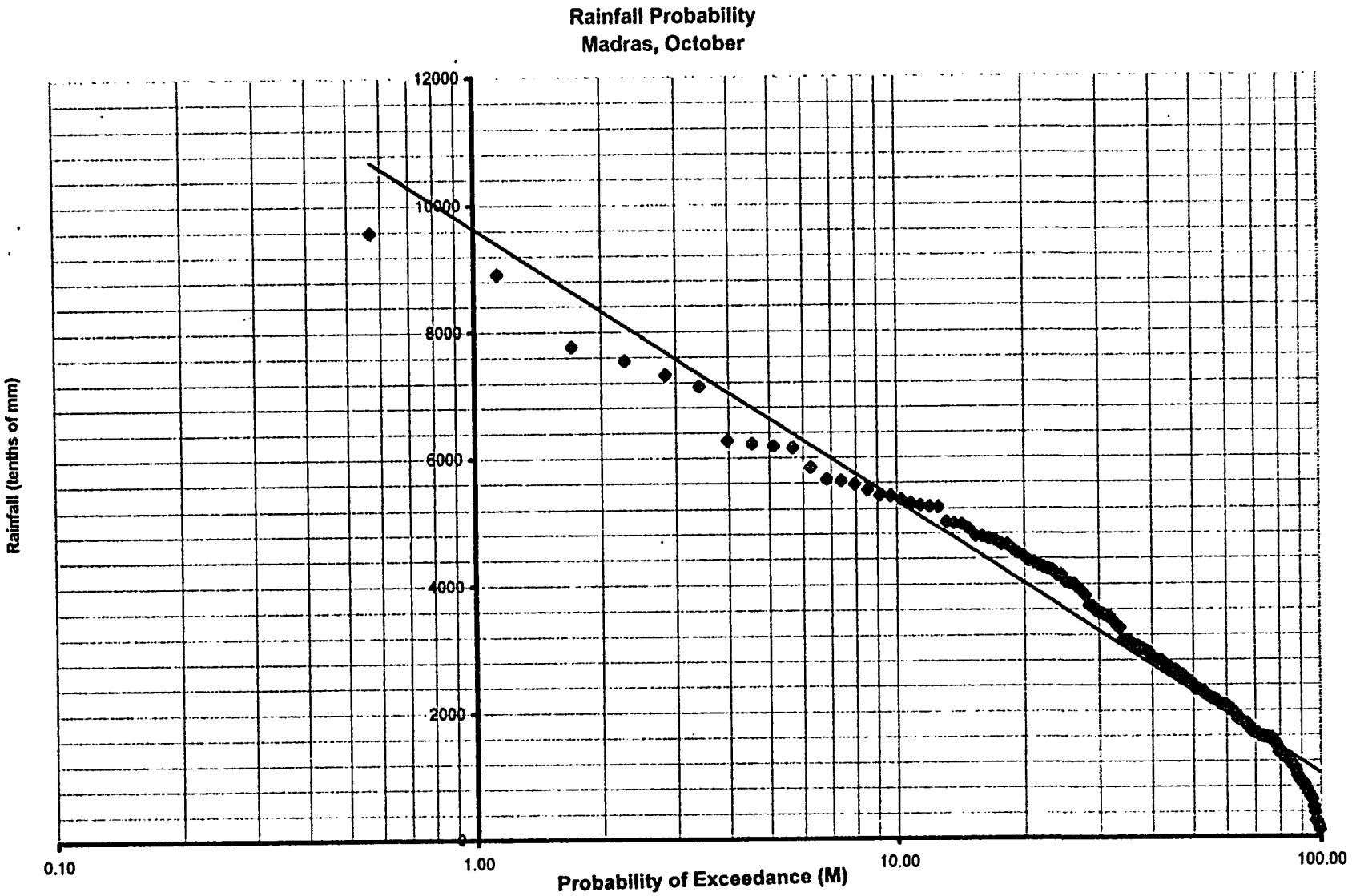
m	Data	Sqrt(Data)	M	Mp	m	Data	Sqrt(Data)	M	Mp	m	Data	Sqrt(Data)	M	Mp
1	1910	43.70	0.57	0.75	59	114	10.68	33.52	19.77	117	0	0.00	66.48	38.79
2	1621	40.26	1.14	1.08	60	112	10.58	34.09	20.10	118	0	0.00	67.05	39.12
3	1328	36.44	1.70	1.41	61	112	10.58	34.66	20.43	119	0	0.00	67.61	39.45
4	1323	36.37	2.27	1.73	62	110	10.49	35.23	20.75	120	0	0.00	68.18	39.77
5	1283	35.82	2.84	2.06	63	100	10.00	35.80	21.08	121	0	0.00	68.75	40.10
6	1250	35.36	3.41	2.39	64	90	9.49	36.36	21.41	122	0	0.00	69.32	40.43
7	1118	33.44	3.98	2.72	65	86	9.27	36.93	21.74	123	0	0.00	69.89	40.76
8	927	30.45	4.55	3.05	66	79	8.89	37.50	22.07	124	0	0.00	70.45	41.09
9	914	30.23	5.11	3.37	67	70	8.37	38.07	22.39	125	0	0.00	71.02	41.41
10	910	30.17	5.68	3.70	68	70	8.37	38.64	22.72	126	0	0.00	71.59	41.74
11	785	28.02	6.25	4.03	69	58	7.62	39.20	23.05	127	0	0.00	72.16	42.07
12	709	26.63	6.82	4.36	70	43	6.56	39.77	23.38	128	0	0.00	72.73	42.40
13	670	25.88	7.39	4.69	71	41	6.40	40.34	23.71	129	0	0.00	73.30	42.72
14	663	25.75	7.95	5.01	72	40	6.32	40.91	24.03	130	0	0.00	73.86	43.05
15	648	25.46	8.52	5.34	73	33	5.74	41.48	24.36	131	0	0.00	74.43	43.38
16	566	23.79	9.09	5.67	74	30	5.48	42.05	24.69	132	0	0.00	75.00	43.71
17	521	22.83	9.66	6.00	75	30	5.48	42.61	25.02	133	0	0.00	75.57	44.04
18	521	22.83	10.23	6.33	76	30	5.48	43.18	25.34	134	0	0.00	76.14	44.36
19	505	22.47	10.80	6.65	77	30	5.48	43.75	25.67	135	0	0.00	76.70	44.69
20	490	22.14	11.36	6.98	78	28	5.29	44.32	26.00	136	0	0.00	77.27	45.02
21	440	20.98	11.93	7.31	79	25	5.00	44.89	26.33	137	0	0.00	77.84	45.35
22	432	20.78	12.50	7.64	80	18	4.24	45.45	26.66	138	0	0.00	78.41	45.68
23	422	20.54	13.07	7.97	81	18	4.24	46.02	26.98	139	0	0.00	78.98	46.00
24	419	20.47	13.64	8.29	82	15	3.87	46.59	27.31	140	0	0.00	79.55	46.33
25	411	20.27	14.20	8.62	83	15	3.87	47.16	27.64	141	0	0.00	80.11	46.66
26	390	19.75	14.77	8.95	84	15	3.87	47.73	27.97	142	0	0.00	80.68	46.99
27	390	19.75	15.34	9.28	85	13	3.61	48.30	28.30	143	0	0.00	81.25	47.32
28	384	19.60	15.91	9.60	86	13	3.61	48.86	28.62	144	0	0.00	81.82	47.64
29	360	18.97	16.48	9.93	87	13	3.61	49.43	28.95	145	0	0.00	82.39	47.97
30	348	18.65	17.05	10.26	88	10	3.16	50.00	29.28	146	0	0.00	82.95	48.30
31	284	16.85	17.61	10.59	89	10	3.16	50.57	29.61	147	0	0.00	83.52	48.63
32	262	16.19	18.18	10.92	90	10	3.16	51.14	29.94	148	0	0.00	84.09	48.96
33	260	16.12	18.75	11.24	91	10	3.16	51.70	30.26	149	0	0.00	84.66	49.28
34	249	15.78	19.32	11.57	92	10	3.16	52.27	30.59	150	0	0.00	85.23	49.61
35	231	15.20	19.89	11.90	93	10	3.16	52.84	30.92	151	0	0.00	85.80	49.94
36	220	14.83	20.45	12.23	94	8	2.83	53.41	31.25	152	0	0.00	86.36	50.27
37	218	14.76	21.02	12.56	95	8	2.83	53.98	31.58	153	0	0.00	86.93	50.59
38	211	14.53	21.59	12.88	96	5	2.24	54.55	31.90	154	0	0.00	87.50	50.92
39	200	14.14	22.16	13.21	97	5	2.24	55.11	32.23	155	0	0.00	88.07	51.25
40	196	14.00	22.73	13.54	98	5	2.24	55.68	32.56	156	0	0.00	88.64	51.58
41	196	14.00	23.30	13.87	99	5	2.24	56.25	32.89	157	0	0.00	89.20	51.91
42	193	13.89	23.86	14.20	100	3	1.73	56.82	33.22	158	0	0.00	89.77	52.23
43	191	13.82	24.43	14.52	101	3	1.73	57.39	33.54	159	0	0.00	90.34	52.56
44	188	13.71	25.00	14.85	102	0	0.00	57.95	33.87	160	0	0.00	90.91	52.89
45	183	13.53	25.57	15.18	103	0	0.00	58.52	34.20	161	0	0.00	91.48	53.22
46	180	13.42	26.14	15.51	104	0	0.00	59.09	34.53	162	0	0.00	92.05	53.55
47	175	13.23	26.70	15.84	105	0	0.00	59.66	34.85	163	0	0.00	92.61	53.87
48	170	13.04	27.27	16.16	106	0	0.00	60.23	35.18	164	0	0.00	93.18	54.20
49	157	12.53	27.84	16.49	107	0	0.00	60.80	35.51	165	0	0.00	93.75	54.53
50	152	12.33	28.41	16.82	108	0	0.00	61.36	35.84	166	0	0.00	94.32	54.86
51	147	12.12	28.98	17.15	109	0	0.00	61.93	36.17	167	0	0.00	94.89	55.19
52	142	11.92	29.55	17.47	110	0	0.00	62.50	36.49	168	0	0.00	95.45	55.51
53	140	11.83	30.11	17.80	111	0	0.00	63.07	36.82	169	0	0.00	96.02	55.84
54	132	11.49	30.68	18.13	112	0	0.00	63.64	37.15	170	0	0.00	96.59	56.17
55	127	11.27	31.25	18.46	113	0	0.00	64.20	37.48	171	0	0.00	97.16	56.50
56	122	11.05	31.82	18.79	114	0	0.00	64.77	37.81	172	0	0.00	97.73	56.83
57	117	10.82	32.39	19.11	115	0	0.00	65.34	38.13	173	0	0.00	98.30	57.15
58	114	10.68	32.95	19.44	116	0	0.00	65.91	38.46	174	0	0.00	98.86	57.48
										175	0	0.00	99.43	57.81


Rainfall Probability
Madras, April
Rainfall (tneths of mm)
2000
1500
1000
500
0
-500
0.10
1.00
10.00
100.00
Probability of Exceedance (Mp)


Rainfall Probability
Madras, April
Square Root of Rainfall (tenths of mm)
50
45
40
35
30
25
20
15
10
5
0
0.10
1.00
10.00
100.00
Probability of Exceedance (Mp)

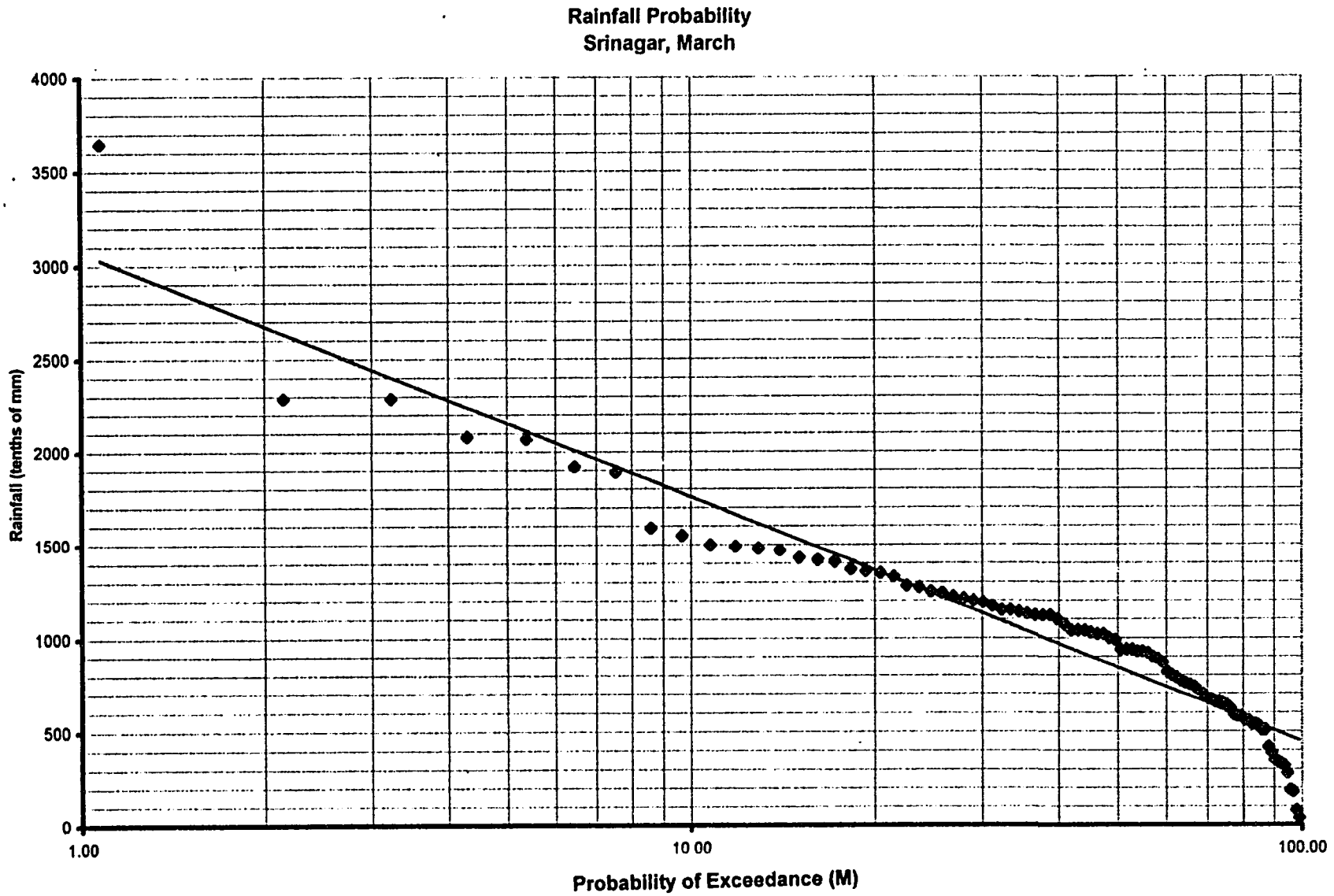
STAT 27 MADRAS (OCTOBER) p = 0.000

m	Data	M	Mp	m	Data	M	Mp	m	Data	M	Mp
1	9583	0.57	0.57	59	3310	33.52	33.52	117	1790	66.48	66.48
2	8918	1.14	1.14	60	3130	34.09	34.09	118	1788	67.05	67.05
3	7770	1.70	1.70	61	3119	34.66	34.66	119	1720	67.61	67.61
4	7550	2.27	2.27	62	3110	35.23	35.23	120	1699	68.18	68.18
5	7325	2.84	2.84	63	3066	35.80	35.80	121	1671	68.75	68.75
6	7145	3.41	3.41	64	3030	36.36	36.36	122	1670	69.32	69.32
7	6281	3.98	3.98	65	3030	36.93	36.93	123	1643	69.89	69.89
8	6231	4.55	4.55	66	2982	37.50	37.50	124	1640	70.45	70.45
9	6187	5.11	5.11	67	2977	38.07	38.07	125	1636	71.02	71.02
10	6165	5.68	5.68	68	2949	38.64	38.64	126	1603	71.59	71.59
11	5852	6.25	6.25	69	2934	39.20	39.20	127	1593	72.16	72.16
12	5662	6.82	6.82	70	2840	39.77	39.77	128	1590	72.73	72.73
13	5634	7.39	7.39	71	2817	40.34	40.34	129	1588	73.30	73.30
14	5583	7.95	7.95	72	2807	40.91	40.91	130	1580	73.86	73.86
15	5494	8.52	8.52	73	2799	41.48	41.48	131	1577	74.43	74.43
16	5410	9.09	9.09	74	2794	42.05	42.05	132	1570	75.00	75.00
17	5400	9.66	9.66	75	2750	42.61	42.61	133	1570	75.57	75.57
18	5347	10.23	10.23	76	2695	43.18	43.18	134	1562	76.14	76.14
19	5286	10.80	10.80	77	2695	43.75	43.75	135	1560	76.70	76.70
20	5250	11.36	11.36	78	2680	44.32	44.32	136	1501	77.27	77.27
21	5232	11.93	11.93	79	2642	44.89	44.89	137	1488	77.84	77.84
22	5225	12.50	12.50	80	2642	45.45	45.45	138	1478	78.41	78.41
23	4991	13.07	13.07	81	2596	46.02	46.02	139	1430	78.98	78.98
24	4970	13.64	13.64	82	2581	46.59	46.59	140	1341	79.55	79.55
25	4958	14.20	14.20	83	2563	47.16	47.16	141	1330	80.11	80.11
26	4882	14.77	14.77	84	2507	47.73	47.73	142	1303	80.68	80.68
27	4760	15.34	15.34	85	2489	48.30	48.30	143	1295	81.25	81.25
28	4750	15.91	15.91	86	2461	48.86	48.86	144	1283	81.82	81.82
29	4712	16.48	16.48	87	2449	49.43	49.43	145	1250	82.39	82.39
30	4694	17.05	17.05	88	2375	50.00	50.00	146	1230	82.95	82.95
31	4630	17.61	17.61	89	2339	50.57	50.57	147	1222	83.52	83.52
32	4620	18.18	18.18	90	2337	51.14	51.14	148	1219	84.09	84.09
33	4547	18.75	18.75	91	2334	51.70	51.70	149	1190	84.66	84.66
34	4488	19.32	19.32	92	2306	52.27	52.27	150	1170	85.23	85.23
35	4437	19.89	19.89	93	2304	52.84	52.84	151	1125	85.80	85.80
36	4370	20.45	20.45	94	2253	53.41	53.41	152	1107	86.36	86.36
37	4341	21.02	21.02	95	2245	53.98	53.98	153	1097	86.93	86.93
38	4300	21.59	21.59	96	2210	54.55	54.55	154	1054	87.50	87.50
39	4272	22.16	22.16	97	2187	55.11	55.11	155	986	88.07	88.07
40	4247	22.73	22.73	98	2182	55.68	55.68	156	942	88.64	88.64
41	4220	23.30	23.30	99	2174	56.25	56.25	157	904	89.20	89.20
42	4145	23.86	23.86	100	2162	56.82	56.82	158	876	89.77	89.77
43	4143	24.43	24.43	101	2120	57.39	57.39	159	876	90.34	90.34
44	4036	25.00	25.00	102	2103	57.95	57.95	160	861	90.91	90.91
45	4020	25.57	25.57	103	2090	58.52	58.52	161	838	91.48	91.48
46	4011	26.14	26.14	104	2083	59.09	59.09	162	762	92.05	92.05
47	3945	26.70	26.70	105	2073	59.66	59.66	163	754	92.61	92.61
48	3886	27.27	27.27	106	2060	60.23	60.23	164	700	93.18	93.18
49	3818	27.84	27.84	107	2009	60.80	60.80	165	690	93.75	93.75
50	3660	28.41	28.41	108	2007	61.36	61.36	166	640	94.32	94.32
51	3645	28.98	28.98	109	2007	61.93	61.93	167	625	94.89	94.89
52	3574	29.55	29.55	110	1961	62.50	62.50	168	592	95.45	95.45
53	3538	30.11	30.11	111	1948	63.07	63.07	169	485	96.02	96.02
54	3528	30.68	30.68	112	1870	63.64	63.64	170	391	96.59	96.59
55	3495	31.25	31.25	113	1869	64.20	64.20	171	264	97.16	97.16
56	3482	31.82	31.82	114	1842	64.77	64.77	172	251	97.73	97.73
57	3409	32.39	32.39	115	1830	65.34	65.34	173	211	98.30	98.30
58	3340	32.95	32.95	116	1803	65.91	65.91	174	155	98.86	98.86
								175	112	99.43	99.43


Rainfall Probability
Madras, October
Rainfall (tenths of mm)
12000
10000
8000
6000
4000
2000
0
0.10
1.00
10.00
100.00
Probability of Exceedance (M)

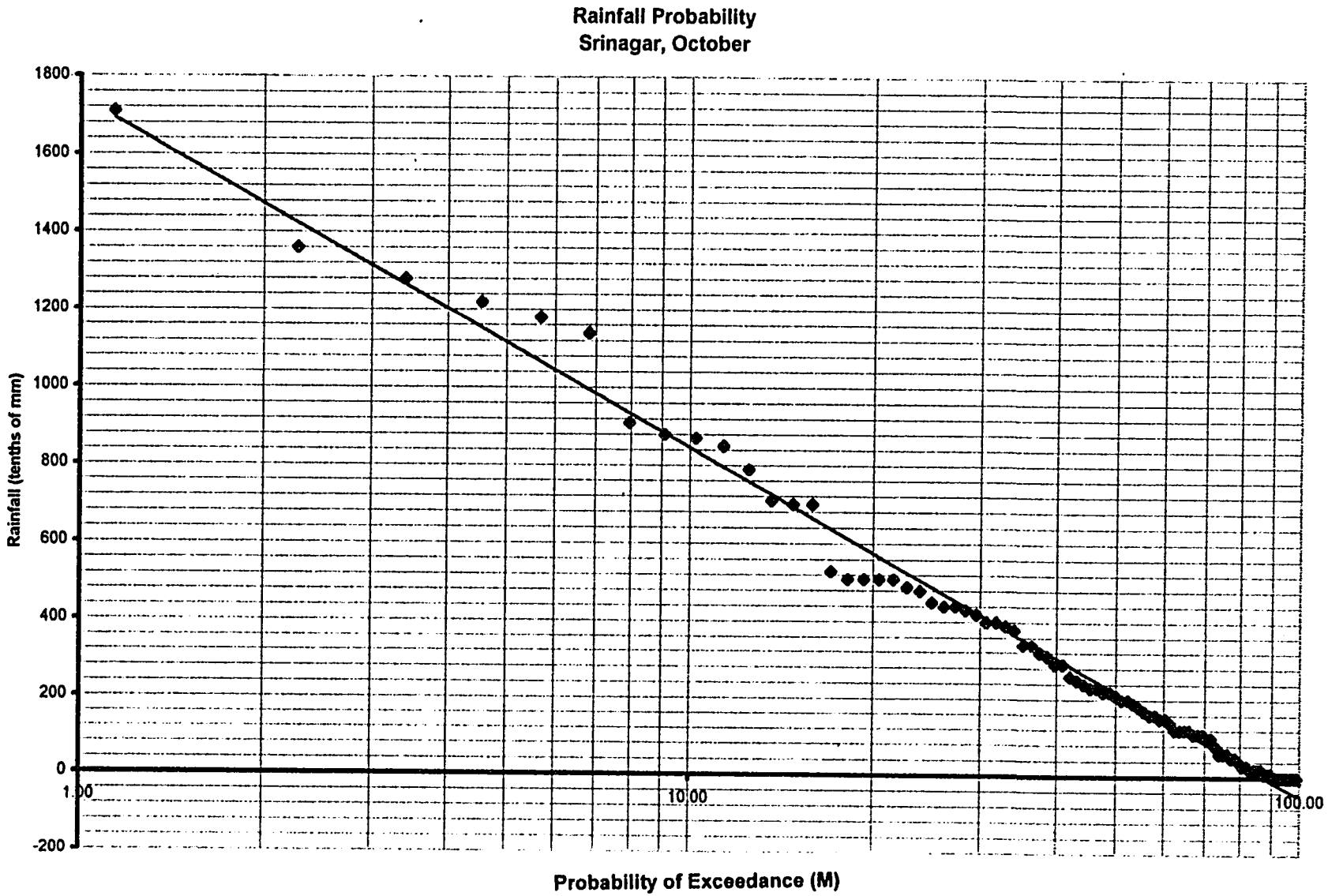
STAT 38 **SRINAGAR (MARCH)** **p =** **0.000**

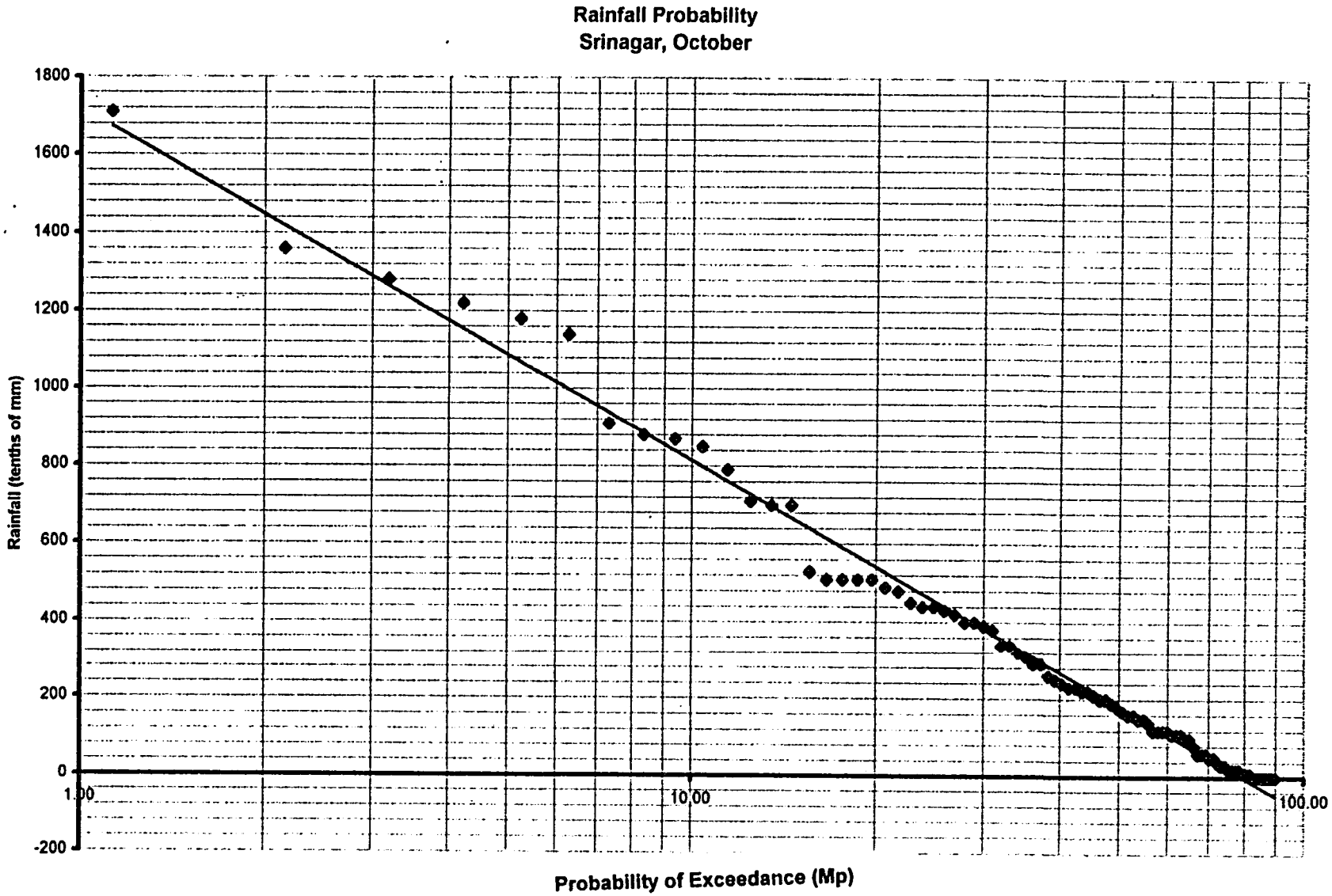
m	Data	M	Mp	m	Data	M	Mp
1	3650	1.08	1.08	47	940	50.54	50.54
2	2290	2.15	2.15	48	940	51.61	51.61
3	2290	3.23	3.23	49	940	52.69	52.69
4	2080	4.30	4.30	50	930	53.76	53.76
5	2070	5.38	5.38	51	930	54.84	54.84
6	1920	6.45	6.45	52	920	55.91	55.91
7	1890	7.53	7.53	53	900	56.99	56.99
8	1590	8.60	8.60	54	890	58.06	58.06
9	1550	9.68	9.68	55	870	59.14	59.14
10	1500	10.75	10.75	56	820	60.22	60.22
11	1490	11.83	11.83	57	800	61.29	61.29
12	1480	12.90	12.90	58	790	62.37	62.37
13	1470	13.98	13.98	59	770	63.44	63.44
14	1430	15.05	15.05	60	760	64.52	64.52
15	1420	16.13	16.13	61	750	65.59	65.59
16	1410	17.20	17.20	62	740	66.67	66.67
17	1370	18.28	18.28	63	720	67.74	67.74
18	1360	19.35	19.35	64	700	68.82	68.82
19	1350	20.43	20.43	65	680	69.89	69.89
20	1330	21.51	21.51	66	670	70.97	70.97
21	1280	22.58	22.58	67	660	72.04	72.04
22	1270	23.66	23.66	68	660	73.12	73.12
23	1250	24.73	24.73	69	650	74.19	74.19
24	1240	25.81	25.81	70	640	75.27	75.27
25	1220	26.88	26.88	71	620	76.34	76.34
26	1210	27.96	27.96	72	590	77.42	77.42
27	1200	29.03	29.03	73	580	78.49	78.49
28	1190	30.11	30.11	74	580	79.57	79.57
29	1170	31.18	31.18	75	560	80.65	80.65
30	1150	32.26	32.26	76	560	81.72	81.72
31	1150	33.33	33.33	77	540	82.80	82.80
32	1140	34.41	34.41	78	540	83.87	83.87
33	1130	35.48	35.48	79	530	84.95	84.95
34	1120	36.56	36.56	80	510	86.02	86.02
35	1120	37.63	37.63	81	510	87.10	87.10
36	1120	38.71	38.71	82	420	88.17	88.17
37	1100	39.78	39.78	83	390	89.25	89.25
38	1070	40.86	40.86	84	350	90.32	90.32
39	1040	41.94	41.94	85	340	91.40	91.40
40	1040	43.01	43.01	86	330	92.47	92.47
41	1040	44.09	44.09	87	320	93.55	93.55
42	1030	45.16	45.16	88	280	94.62	94.62
43	1020	46.24	46.24	89	190	95.70	95.70
44	1020	47.31	47.31	90	180	96.77	96.77
45	1000	48.39	48.39	91	80	97.85	97.85
46	990	49.46	49.46	92	40	98.92	98.92


Rainfall Probability
Srinagar, March
Rainfall (tenths of mm)
4000
3500
3000
2500
2000
1500
1000
500
0
1.00
10 00
100.00
Probability of Exceedance (M)

STAT 38 **SRINAGAR (OCTOBER)** **p =** **0.092**

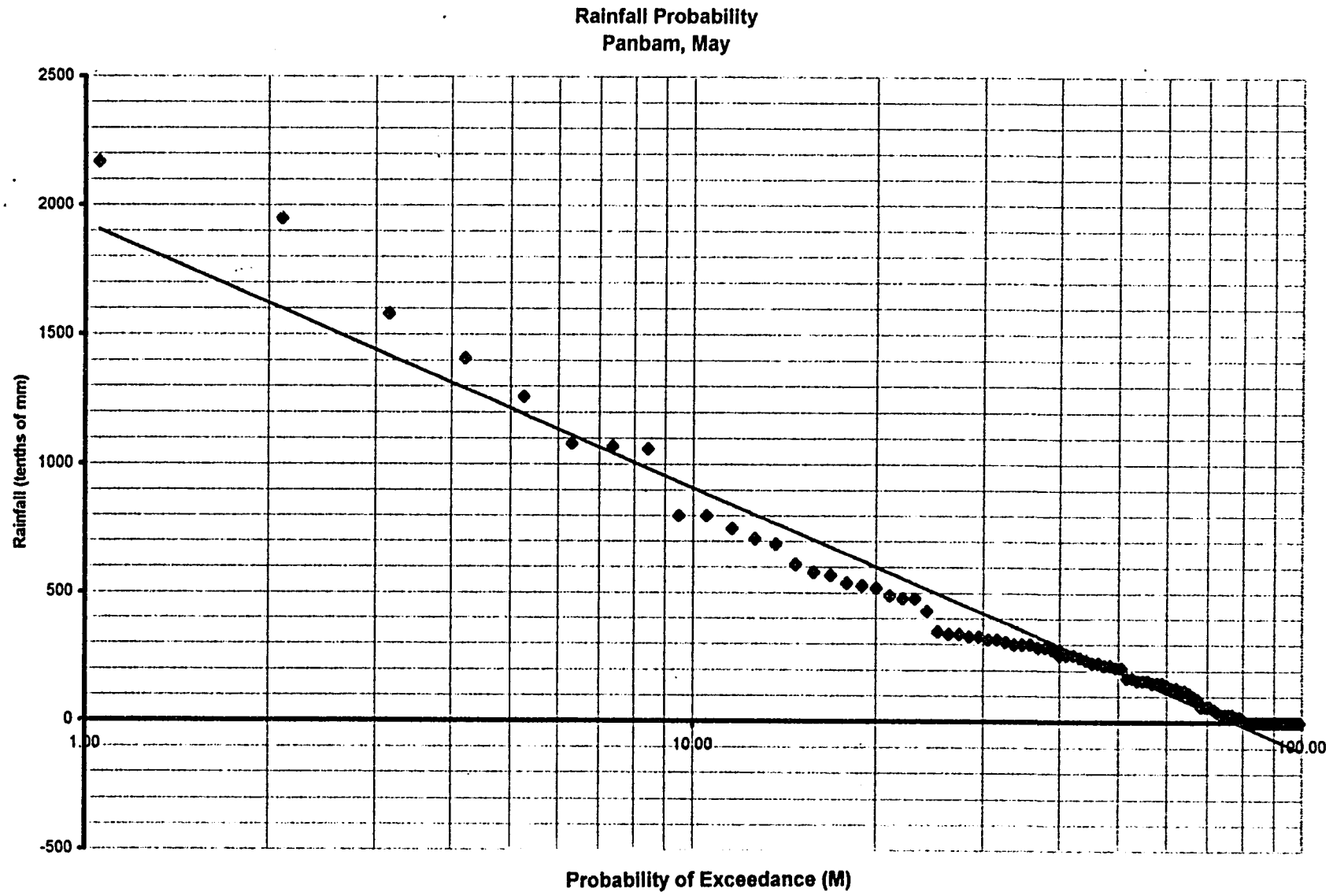
m	Data	M	Mp	m	Data	M	Mp
1	1710	1.14	1.12	44	210	50.00	45.49
2	1360	2.27	2.16	45	200	51.14	46.53
3	1280	3.41	3.19	46	200	52.27	47.56
4	1220	4.55	4.22	47	190	53.41	48.59
5	1180	5.68	5.25	48	180	54.55	49.62
6	1140	6.82	6.28	49	170	55.68	50.65
7	910	7.95	7.32	50	160	56.82	51.69
8	880	9.09	8.35	51	160	57.95	52.72
9	870	10.23	9.38	52	150	59.09	53.75
10	850	11.36	10.41	53	150	60.23	54.78
11	790	12.50	11.44	54	140	61.36	55.81
12	710	13.64	12.47	55	120	62.50	56.84
13	700	14.77	13.51	56	120	63.64	57.88
14	700	15.91	14.54	57	120	64.77	58.91
15	530	17.05	15.57	58	120	65.91	59.94
16	510	18.18	16.60	59	110	67.05	60.97
17	510	19.32	17.63	60	110	68.18	62.00
18	510	20.45	18.67	61	110	69.32	63.04
19	510	21.59	19.70	62	100	70.45	64.07
20	490	22.73	20.73	63	100	71.59	65.10
21	480	23.86	21.76	64	80	72.73	66.13
22	450	25.00	22.79	65	60	73.86	67.16
23	440	26.14	23.82	66	60	75.00	68.20
24	440	27.27	24.86	67	60	76.14	69.23
25	430	28.41	25.89	68	50	77.27	70.26
26	420	29.55	26.92	69	50	78.41	71.29
27	400	30.68	27.95	70	40	79.55	72.32
28	400	31.82	28.98	71	30	80.68	73.35
29	390	32.95	30.02	72	30	81.82	74.39
30	380	34.09	31.05	73	20	82.95	75.42
31	340	35.23	32.08	74	20	84.09	76.45
32	340	36.36	33.11	75	20	85.23	77.48
33	320	37.50	34.14	76	20	86.36	78.51
34	310	38.64	35.18	77	10	87.50	79.55
35	290	39.77	36.21	78	10	88.64	80.58
36	290	40.91	37.24	79	10	89.77	81.61
37	260	42.05	38.27	80	0	90.91	82.64
38	250	43.18	39.30	81	0	92.05	83.67
39	240	44.32	40.33	82	0	93.18	84.71
40	230	45.45	41.37	83	0	94.32	85.74
41	230	46.59	42.40	84	0	95.45	86.77
42	220	47.73	43.43	85	0	96.59	87.80
43	220	48.86	44.46	86	0	97.73	88.83
				87	0	98.86	89.86

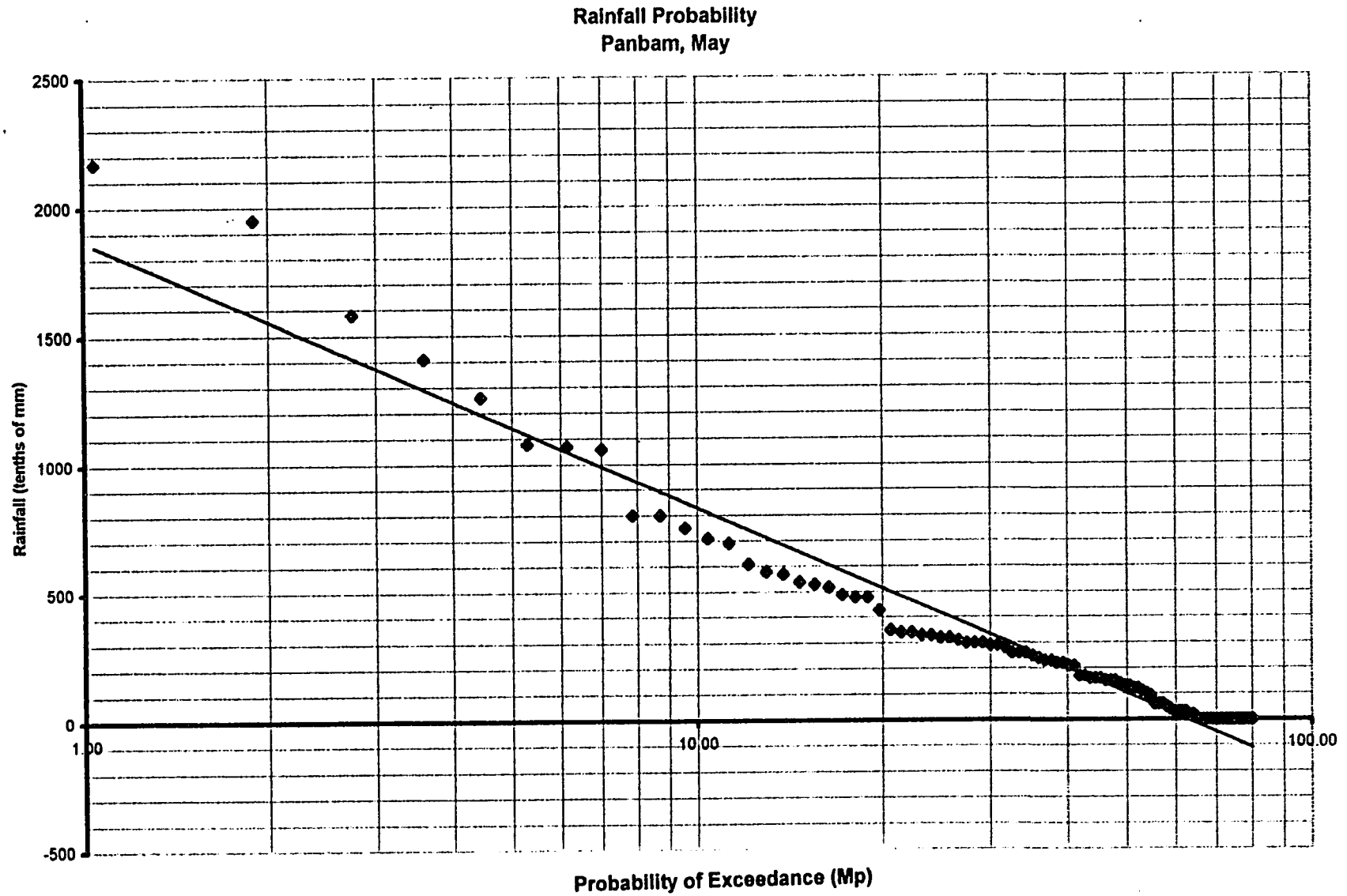

Rainfall Probability
Srinagar, October
Rainfall (tenths of mm)
1800
1600
1400
1200
1000
800
600
400
200
0
-200
1.00
10.00
100.00
Probability of Exceedance (M)


Rainfall Probability
Srinagar, October
1800
1600
1400
1200
1000
800
600
400
200
0
-200
Rainfall (tenths of mm)
1.00
10.00
100.00
Probability of Exceedance (Mp)

STAT 40 **PAMBAN (MAY)** **p =** **0.191**

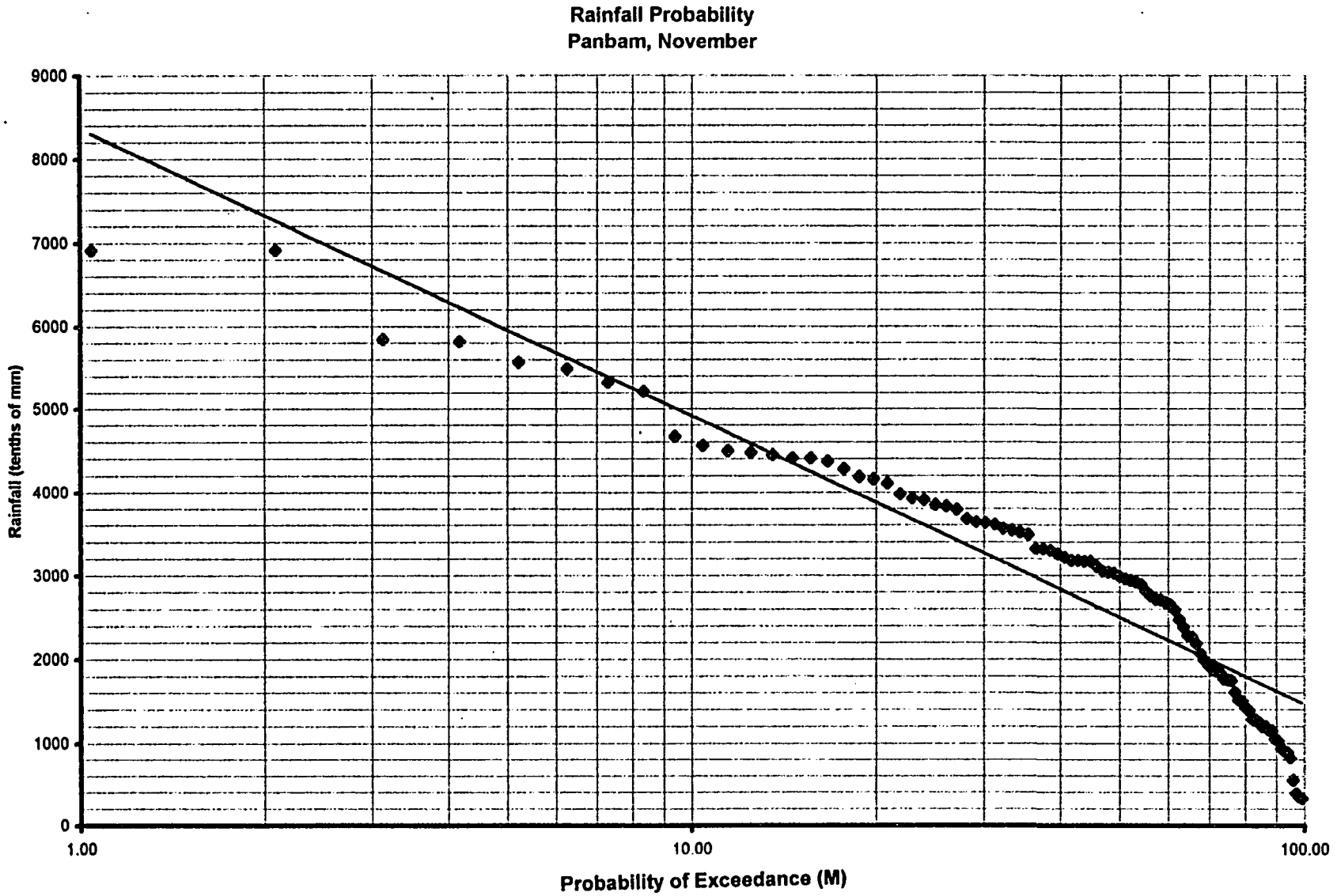
m	Data	M	Mp	m	Data	M	Mp
1	2170	1.05	1.04	48	210	50.53	41.04
2	1950	2.11	1.89	49	170	51.58	41.89
3	1580	3.16	2.74	50	170	52.63	42.74
4	1410	4.21	3.60	51	160	53.68	43.60
5	1260	5.26	4.45	52	160	54.74	44.45
6	1080	6.32	5.30	53	160	55.79	45.30
7	1070	7.37	6.15	54	150	56.84	46.15
8	1060	8.42	7.00	55	150	57.89	47.00
9	800	9.47	7.85	56	150	58.95	47.85
10	800	10.53	8.70	57	140	60.00	48.70
11	750	11.58	9.55	58	130	61.05	49.55
12	710	12.63	10.40	59	130	62.11	50.40
13	690	13.68	11.26	60	120	63.16	51.26
14	610	14.74	12.11	61	120	64.21	52.11
15	580	15.79	12.96	62	110	65.26	52.96
16	570	16.84	13.81	63	100	66.32	53.81
17	540	17.89	14.66	64	90	67.37	54.66
18	530	18.95	15.51	65	60	68.42	55.51
19	520	20.00	16.36	66	60	69.47	56.36
20	490	21.05	17.21	67	60	70.53	57.21
21	480	22.11	18.06	68	50	71.58	58.06
22	480	23.16	18.91	69	40	72.63	58.91
23	430	24.21	19.77	70	30	73.68	59.77
24	350	25.26	20.62	71	30	74.74	60.62
25	340	26.32	21.47	72	30	75.79	61.47
26	340	27.37	22.32	73	30	76.84	62.32
27	330	28.42	23.17	74	20	77.89	63.17
28	330	29.47	24.02	75	20	78.95	64.02
29	320	30.53	24.87	76	10	80.00	64.87
30	320	31.58	25.72	77	0	81.05	65.72
31	310	32.63	26.57	78	0	82.11	66.57
32	300	33.68	27.43	79	0	83.16	67.43
33	300	34.74	28.28	80	0	84.21	68.28
34	300	35.79	29.13	81	0	85.26	69.13
35	290	36.84	29.98	82	0	86.32	69.98
36	290	37.89	30.83	83	0	87.37	70.83
37	280	38.95	31.68	84	0	88.42	71.68
38	260	40.00	32.53	85	0	89.47	72.53
39	260	41.05	33.38	86	0	90.53	73.38
40	260	42.11	34.23	87	0	91.58	74.23
41	250	43.16	35.09	88	0	92.63	75.09
42	240	44.21	35.94	89	0	93.68	75.94
43	230	45.26	36.79	90	0	94.74	76.79
44	230	46.32	37.64	91	0	95.79	77.64
45	220	47.37	38.49	92	0	96.84	78.49
46	220	48.42	39.34	93	0	97.89	79.34
47	210	49.47	40.19	94	0	98.95	80.19


Rainfall Probability
Panbam, May
2500
2000
1500
1000
500
0
-500
Rainfall (tenths of mm)
1.00
10.00
100.00
Probability of Exceedance (M)


Rainfall Probability
Panbam, May
2500
2000
1500
1000
500
0
-500
Rainfall (tenths of mm)
1.00
10.00
100.00
Probability of Exceedance (Mp)

STAT 40 **PAMBAN (NOVEMBER)** **p =** **0.000**

m	Data	M	Mp	m	Data	M	Mp
1	6920	1.04	1.04	48	2990	50.00	50.00
2	6920	2.08	2.08	49	2960	51.04	51.04
3	5850	3.13	3.13	50	2940	52.08	52.08
4	5820	4.17	4.17	51	2920	53.13	53.13
5	5570	5.21	5.21	52	2890	54.17	54.17
6	5490	6.25	6.25	53	2810	55.21	55.21
7	5330	7.29	7.29	54	2760	56.25	56.25
8	5220	8.33	8.33	55	2720	57.29	57.29
9	4670	9.38	9.38	56	2710	58.33	58.33
10	4560	10.42	10.42	57	2680	59.38	59.38
11	4500	11.46	11.46	58	2660	60.42	60.42
12	4480	12.50	12.50	59	2590	61.46	61.46
13	4450	13.54	13.54	60	2480	62.50	62.50
14	4410	14.58	14.58	61	2390	63.54	63.54
15	4410	15.63	15.63	62	2290	64.58	64.58
16	4370	16.67	16.67	63	2270	65.63	65.63
17	4280	17.71	17.71	64	2190	66.67	66.67
18	4190	18.75	18.75	65	2070	67.71	67.71
19	4160	19.79	19.79	66	1990	68.75	68.75
20	4110	20.83	20.83	67	1930	69.79	69.79
21	3980	21.88	21.88	68	1880	70.83	70.83
22	3930	22.92	22.92	69	1860	71.88	71.88
23	3910	23.96	23.96	70	1840	72.92	72.92
24	3850	25.00	25.00	71	1770	73.96	73.96
25	3830	26.04	26.04	72	1760	75.00	75.00
26	3790	27.08	27.08	73	1750	76.04	76.04
27	3680	28.13	28.13	74	1610	77.08	77.08
28	3640	29.17	29.17	75	1520	78.13	78.13
29	3630	30.21	30.21	76	1500	79.17	79.17
30	3610	31.25	31.25	77	1430	80.21	80.21
31	3560	32.29	32.29	78	1390	81.25	81.25
32	3540	33.33	33.33	79	1290	82.29	82.29
33	3520	34.38	34.38	80	1280	83.33	83.33
34	3490	35.42	35.42	81	1250	84.38	84.38
35	3320	36.46	36.46	82	1200	85.42	85.42
36	3320	37.50	37.50	83	1200	86.46	86.46
37	3300	38.54	38.54	84	1160	87.50	87.50
38	3260	39.58	39.58	85	1150	88.54	88.54
39	3220	40.63	40.63	86	1060	89.58	89.58
40	3180	41.67	41.67	87	1030	90.63	90.63
41	3180	42.71	42.71	88	940	91.67	91.67
42	3170	43.75	43.75	89	910	92.71	92.71
43	3170	44.79	44.79	90	890	93.75	93.75
44	3110	45.83	45.83	91	820	94.79	94.79
45	3050	46.88	46.88	92	550	95.83	95.83
46	3040	47.92	47.92	93	390	96.88	96.88
47	3030	48.96	48.96	94	350	97.92	97.92
				95	330	98.96	98.96


Rainfall Probability
Panbam, November
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Rainfall (tenths of mm)
1.00
10.00
100.00
Probability of Exceedance (M)

APPENDIX Q

EFFECTIVE PRECIPITATION

METHOD 3
NORMAL DISTRIBUTION

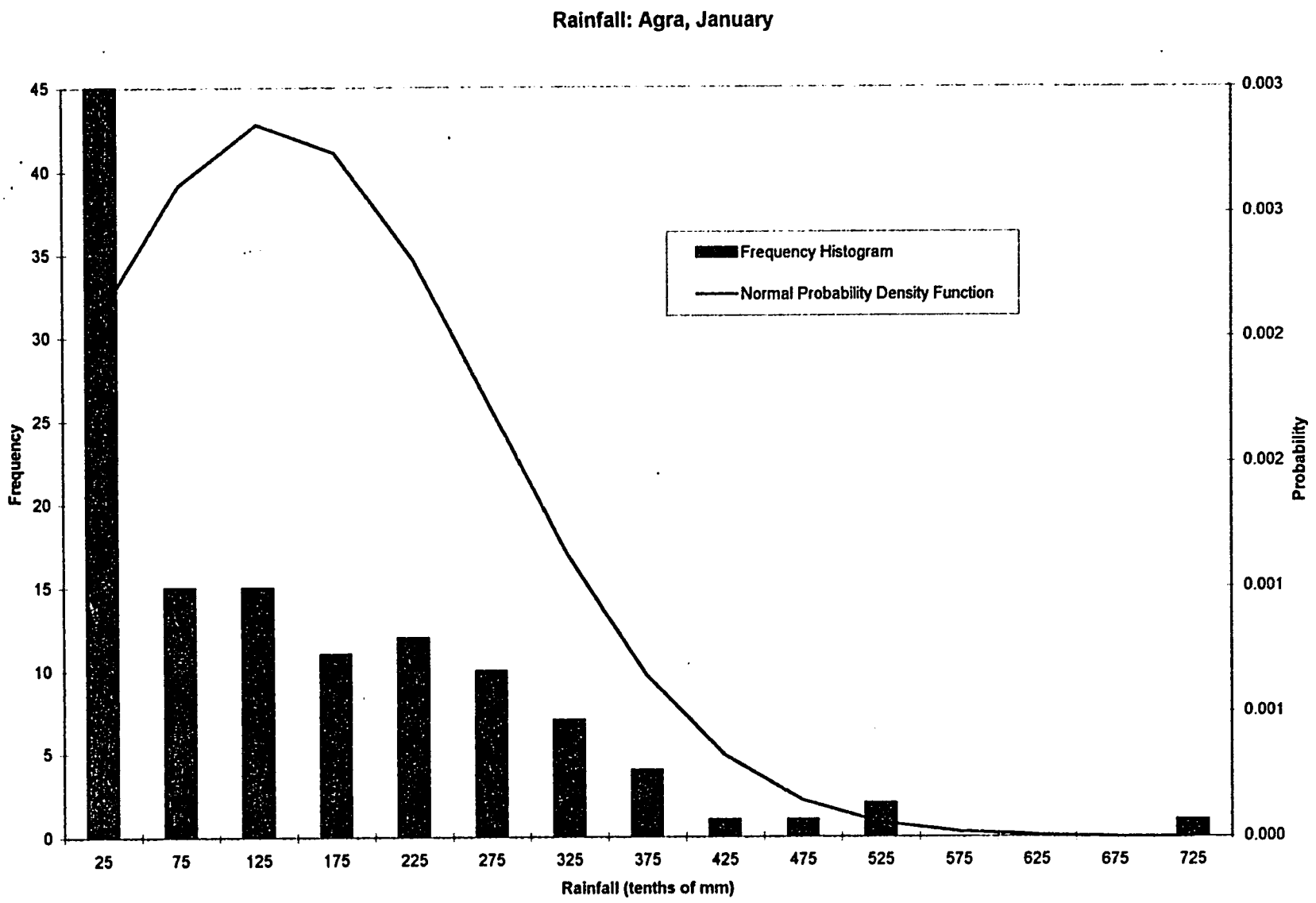
Rainfall Frequency Histograms
Normal Probability Density Function
Cumulative Normal Distribution Function

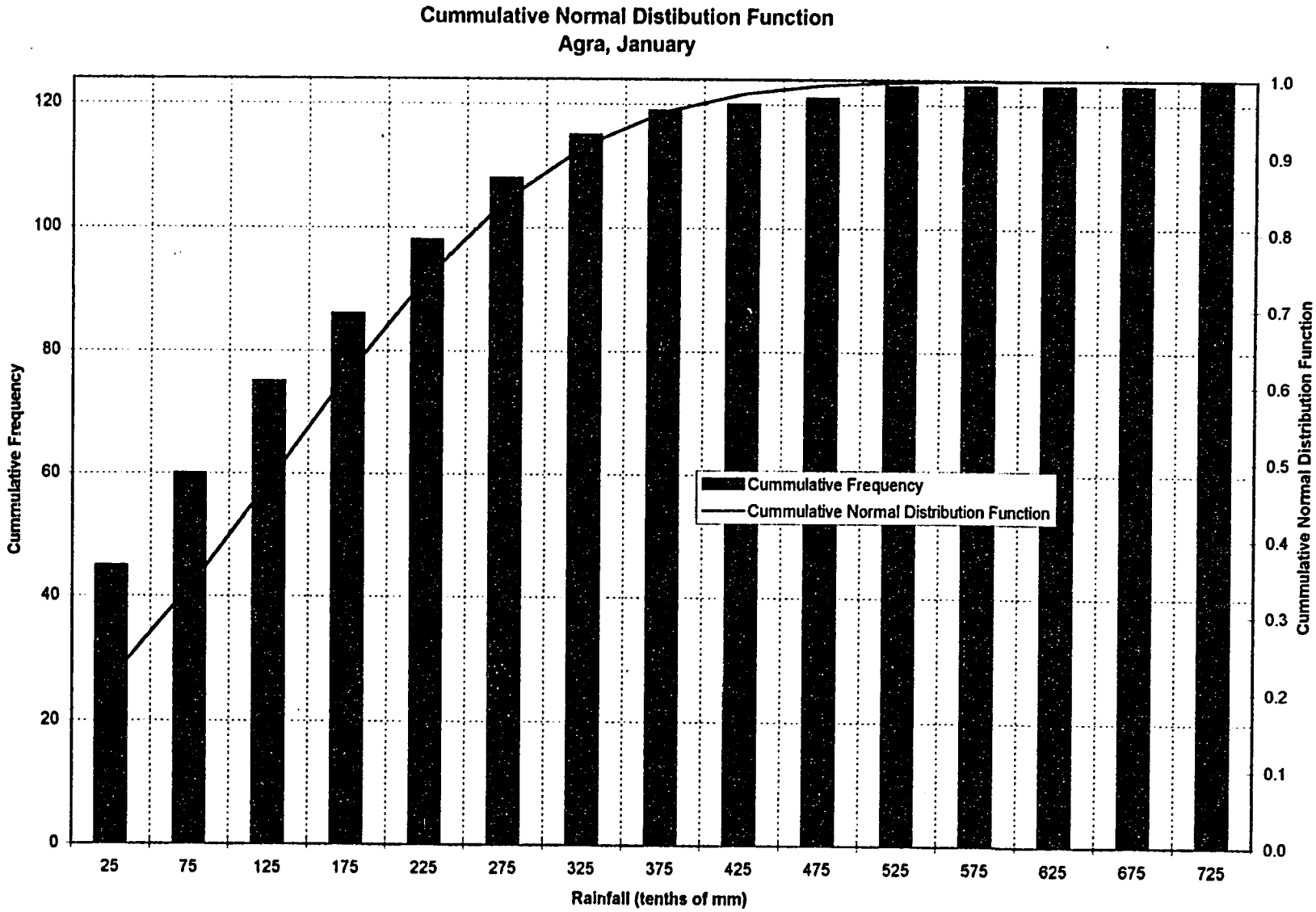
Frequency Histogram

min	0
max	720
Mean	134.354839
St Dev	139.436974

Station 1 Agra, January

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 49	25	45	45	0.00210	0.21644
50 - 99	75	15	60	0.00261	0.33517
100 - 149	125	15	75	0.00285	0.47325
150 - 199	175	11	86	0.00274	0.61466
200 - 249	225	12	98	0.00232	0.74218
250 - 299	275	10	108	0.00172	0.84343
300 - 349	325	7	115	0.00112	0.91423
350 - 399	375	4	119	0.00065	0.95781
400 - 449	425	1	120	0.00033	0.98144
450 - 499	475	1	121	0.00014	0.99272
500 - 549	525	2	123	0.00006	0.99746
550 - 599	575	0	123	0.00002	0.99921
600 - 649	625	0	123	0.00001	0.99978
650 - 699	675	0	123	0.00000	0.99995
700 - 749	725	1	124	0.00000	0.99999
		124			


Rainfall: Agra, January
Frequency
Probability
Frequency Histogram
Normal Probability Density Function
Rainfall (tenths of mm)
0
5
10
15
20
25
30
35
40
45
0.000
0.001
0.001
0.002
0.002
0.003
0.003
25
75
125
175
225
275
325
375
425
475
525
575
625
675
725

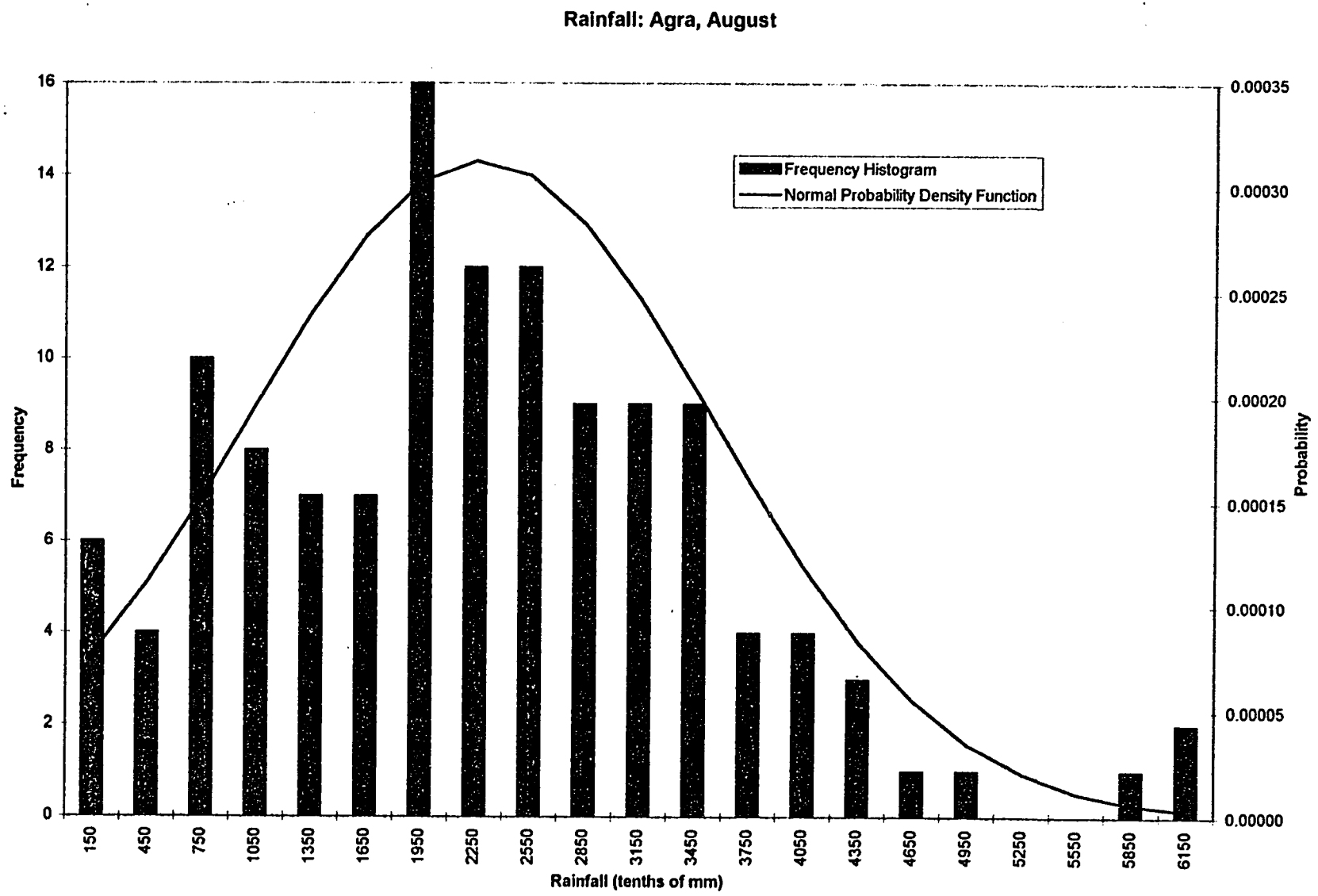

Cummulative Normal Distibution Function
Agra, January
Cummulative Frequency
Cummulative Normal Distribution Function
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
0
20
40
60
80
100
120
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
25
75
125
175
225
275
325
375
425
475
525
575
625
675
725

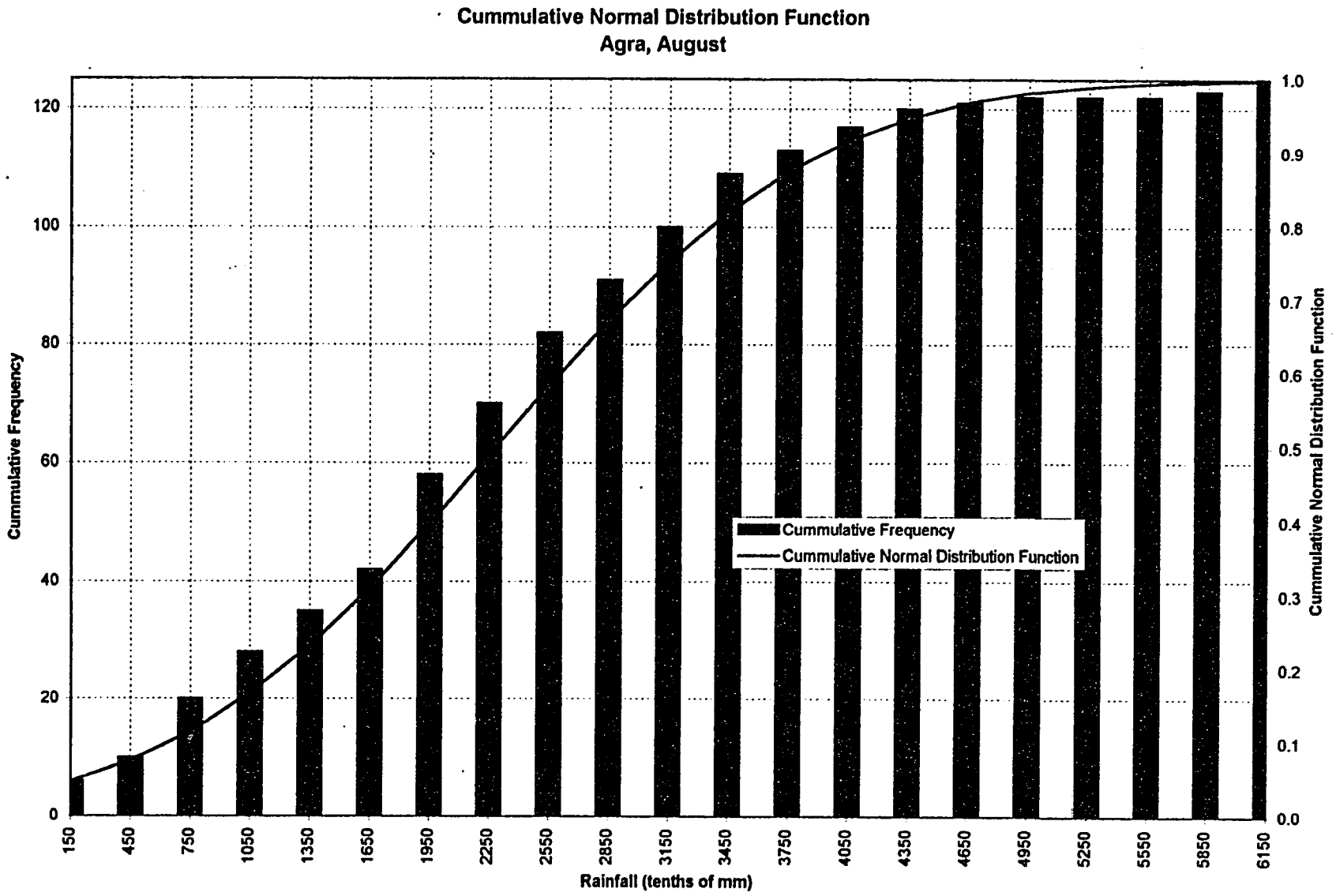
Frequency Histogram	
min	0
max	6180
Mean	2276.56
St Dev	1273.81007

Station 1 Agra, August

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 299	150	6	6	0.00008	0.04751
300 - 599	450	4	10	0.00011	0.07580
600 - 899	750	10	20	0.00015	0.11538
900 - 1199	1050	8	28	0.00020	0.16780
1200 - 1499	1350	7	35	0.00024	0.23349
1500 - 1799	1650	7	42	0.00028	0.31140
1800 - 2099	1950	16	58	0.00030	0.39883
2100 - 2399	2250	12	70	0.00031	0.49168
2400 - 2699	2550	12	82	0.00031	0.58498
2700 - 2999	2850	9	91	0.00028	0.67371
3000 - 3299	3150	9	100	0.00025	0.75355
3300 - 3599	3450	9	109	0.00020	0.82153
3600 - 3899	3750	4	113	0.00016	0.87631
3900 - 4199	4050	4	117	0.00012	0.91807
4200 - 4499	4350	3	120	0.00008	0.94821
4500 - 4799	4650	1	121	0.00006	0.96879
4800 - 5099	4950	1	122	0.00003	0.98208
5100 - 5399	5250	0	122	0.00002	0.99021
5400 - 5699	5550	0	122	0.00001	0.99491
5700 - 5999	5850	1	123	0.00001	0.99749
6000 - 6299	6150	2	125	0.00000	0.99882
		125			

Sheet2 Chart 16



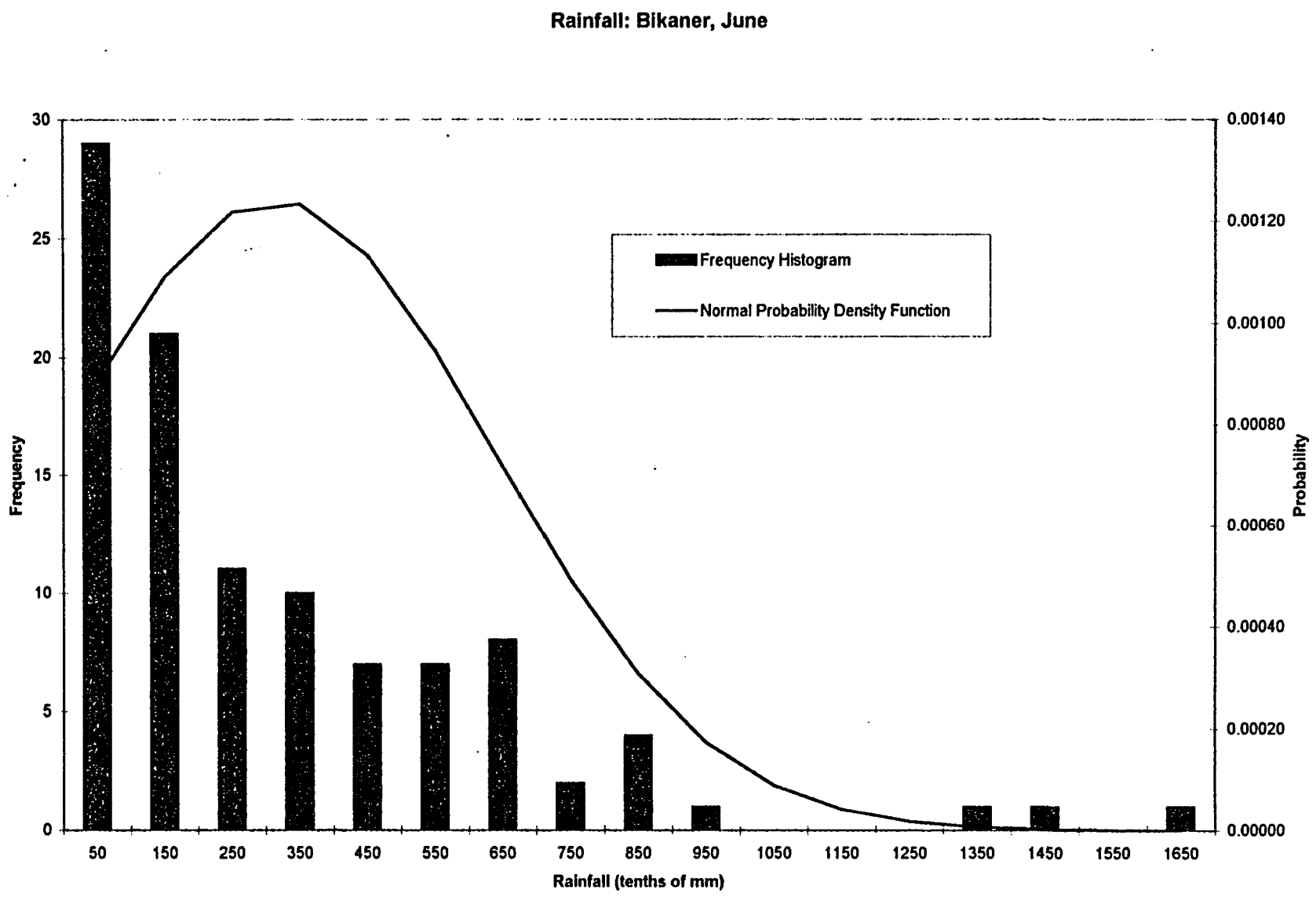

Cummulative Normal Distribution Function
Agra, August
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
Cummulative Frequency
Cummulative Normal Distribution Function
0
20
40
60
80
100
120
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
150
450
750
1050
1350
1650
1950
2250
2550
2850
3150
3450
3750
4050
4350
4650
4950
5250
5550
5850
6150

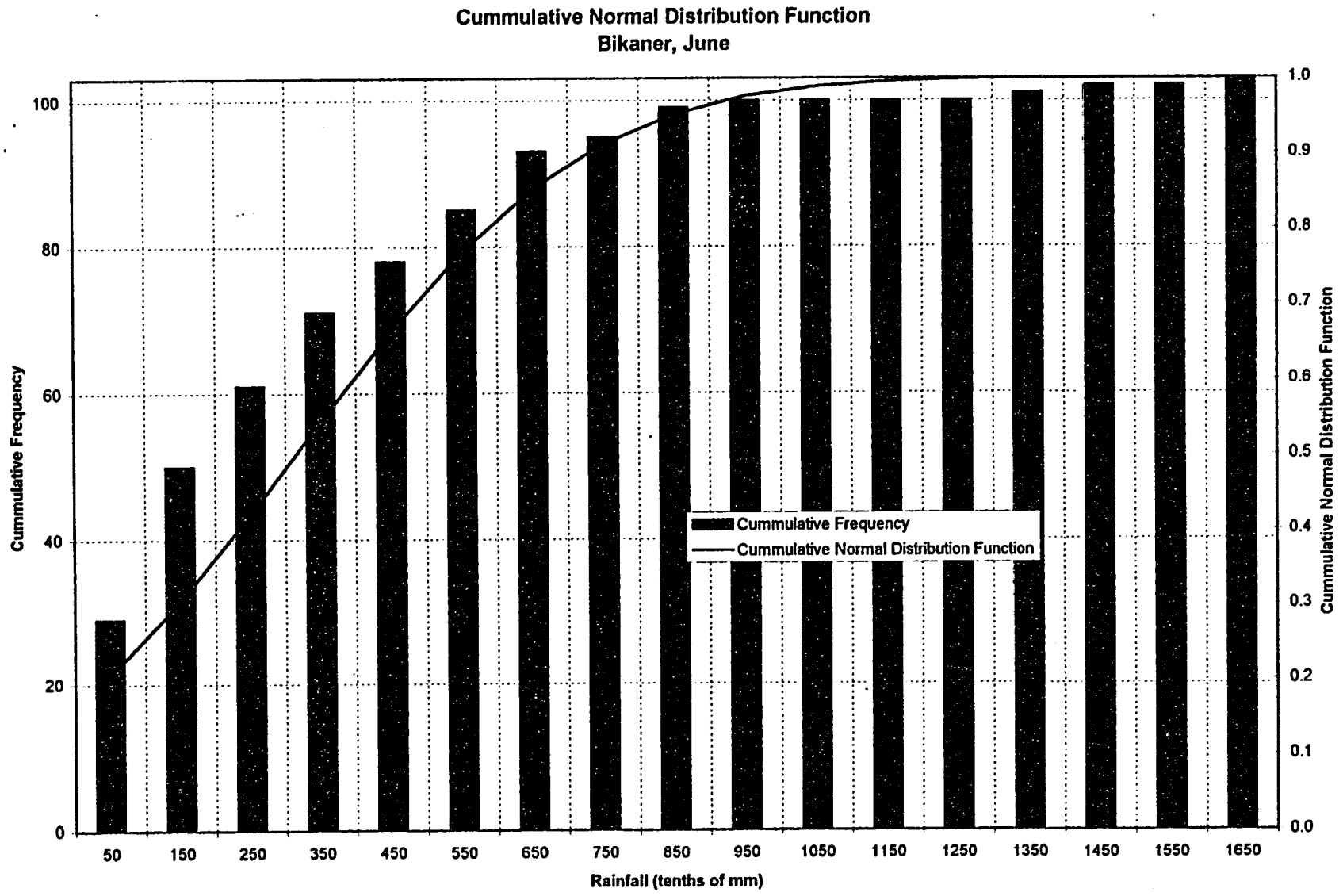
Frequency Histogram

min	0
max	1630
Mean	313.0097087
St Dev	321.0303112

Station 9 Bikaner, June

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 99	50	29	29	0.00089	0.20632
100 - 199	150	21	50	0.00109	0.30581
200 - 299	250	11	61	0.00122	0.42220
300 - 399	350	10	71	0.00123	0.54587
400 - 499	450	7	78	0.00113	0.66521
500 - 599	550	7	85	0.00095	0.76981
600 - 699	650	8	93	0.00072	0.85308
700 - 799	750	2	95	0.00049	0.91328
800 - 899	850	4	99	0.00031	0.95281
900 - 999	950	1	100	0.00017	0.97638
1000 - 1099	1050	0	100	0.00009	0.98915
1100 - 1199	1150	0	100	0.00004	0.99544
1200 - 1299	1250	0	100	0.00002	0.99824
1300 - 1399	1350	1	101	0.00001	0.99938
1400 - 1499	1450	1	102	0.00000	0.99980
1500 - 1599	1550	0	102	0.00000	0.99994
1600 - 1699	1650	1	103	0.00000	0.99998
		103			

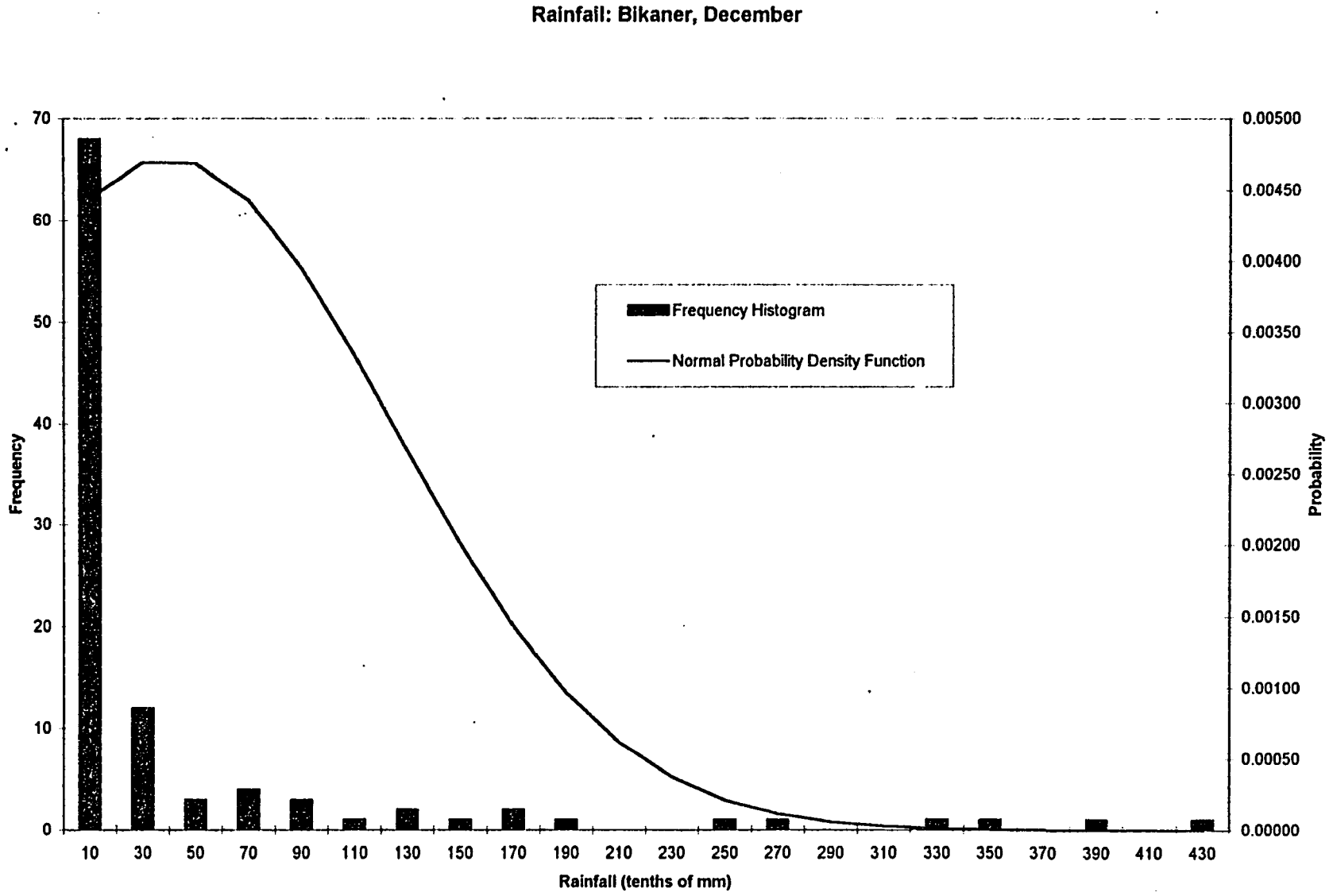

Rainfall: Bikaner, June
Frequency Histogram
Normal Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
5
10
15
20
25
30
0.00000
0.00020
0.00040
0.00060
0.00080
0.00100
0.00120
0.00140
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650

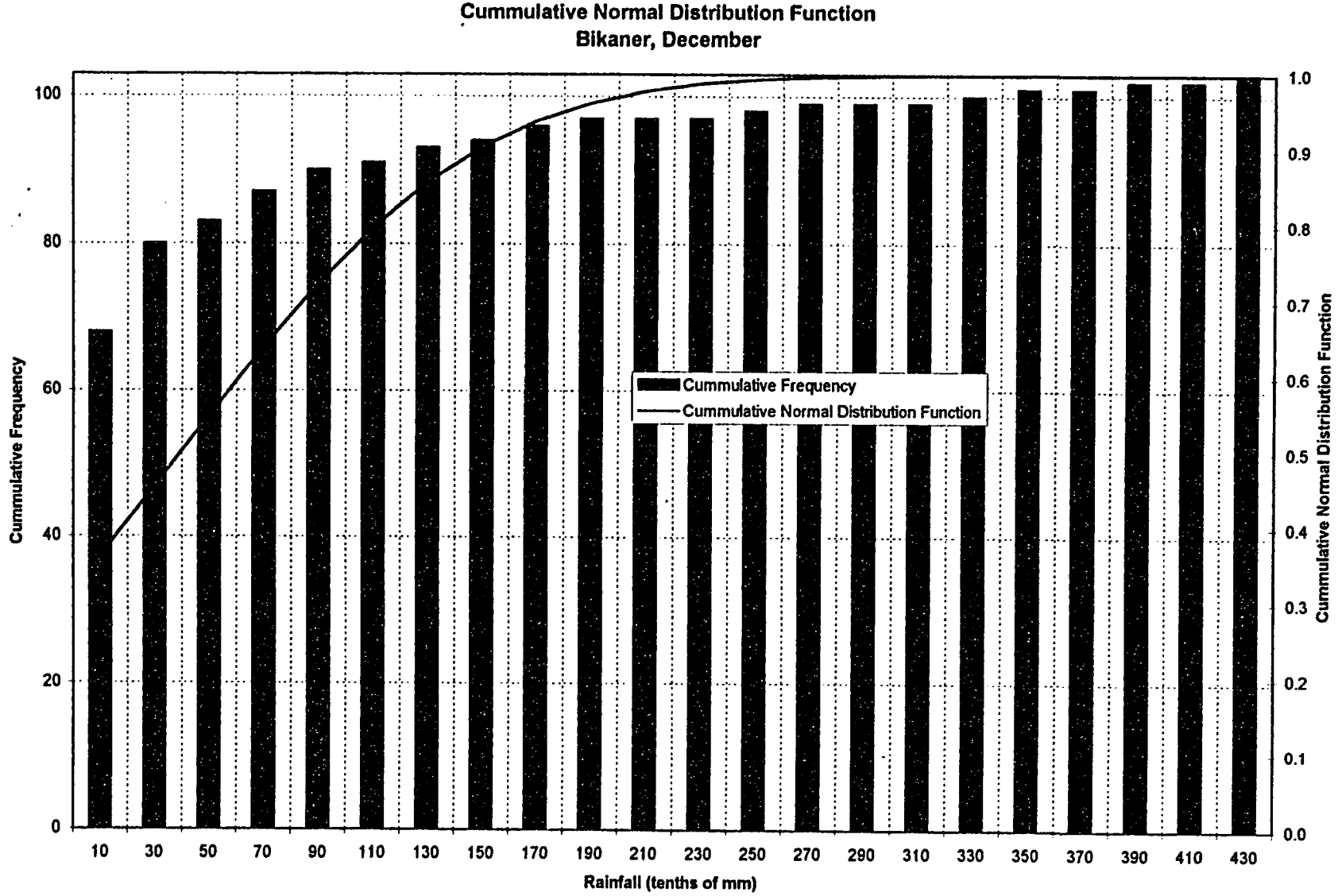

Cummulative Normal Distribution Function
Bikaner, June
Cummulative Frequency
Cummulative Normal Distribution Function
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650

Frequency Histogram	
min	0
max	1630
Mean	39.51456311
St Dev	84.46345817

Station 9 Bikaner, December

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 19	10	68	68	0.00444	0.36338
20 - 39	30	12	80	0.00469	0.45516
40 - 59	50	3	83	0.00469	0.54940
60 - 79	70	4	87	0.00443	0.64092
80 - 99	90	3	90	0.00395	0.72499
100 - 119	110	1	91	0.00333	0.79800
120 - 139	130	2	93	0.00266	0.85798
140 - 159	150	1	94	0.00201	0.90458
160 - 179	170	2	96	0.00143	0.93881
180 - 199	190	1	97	0.00097	0.96260
200 - 219	210	0	97	0.00062	0.97823
220 - 239	230	0	97	0.00037	0.98794
240 - 259	250	1	98	0.00021	0.99365
260 - 279	270	1	99	0.00011	0.99682
280 - 299	290	0	99	0.00006	0.99849
300 - 319	310	0	99	0.00003	0.99932
320 - 339	330	1	100	0.00001	0.99971
340 359	350	1	101	0.00001	0.99988
360 379	370	0	101	0.00000	0.99995
380 399	390	1	102	0.00000	0.99998
400 419	410	0	102	0.00000	0.99999
420 439	430	1	103	0.00000	1.00000
		103			


Rainfall: Bikaner, December
Frequency
Probability
Frequency Histogram
Normal Probability Density Function
Rainfall (tenths of mm)
0
10
20
30
40
50
60
70
0.00000
0.00050
0.00100
0.00150
0.00200
0.00250
0.00300
0.00350
0.00400
0.00450
0.00500
10 30 50 70 90 110 130 150 170 190 210 230 250 270 290 310 330 350 370 390 410 430

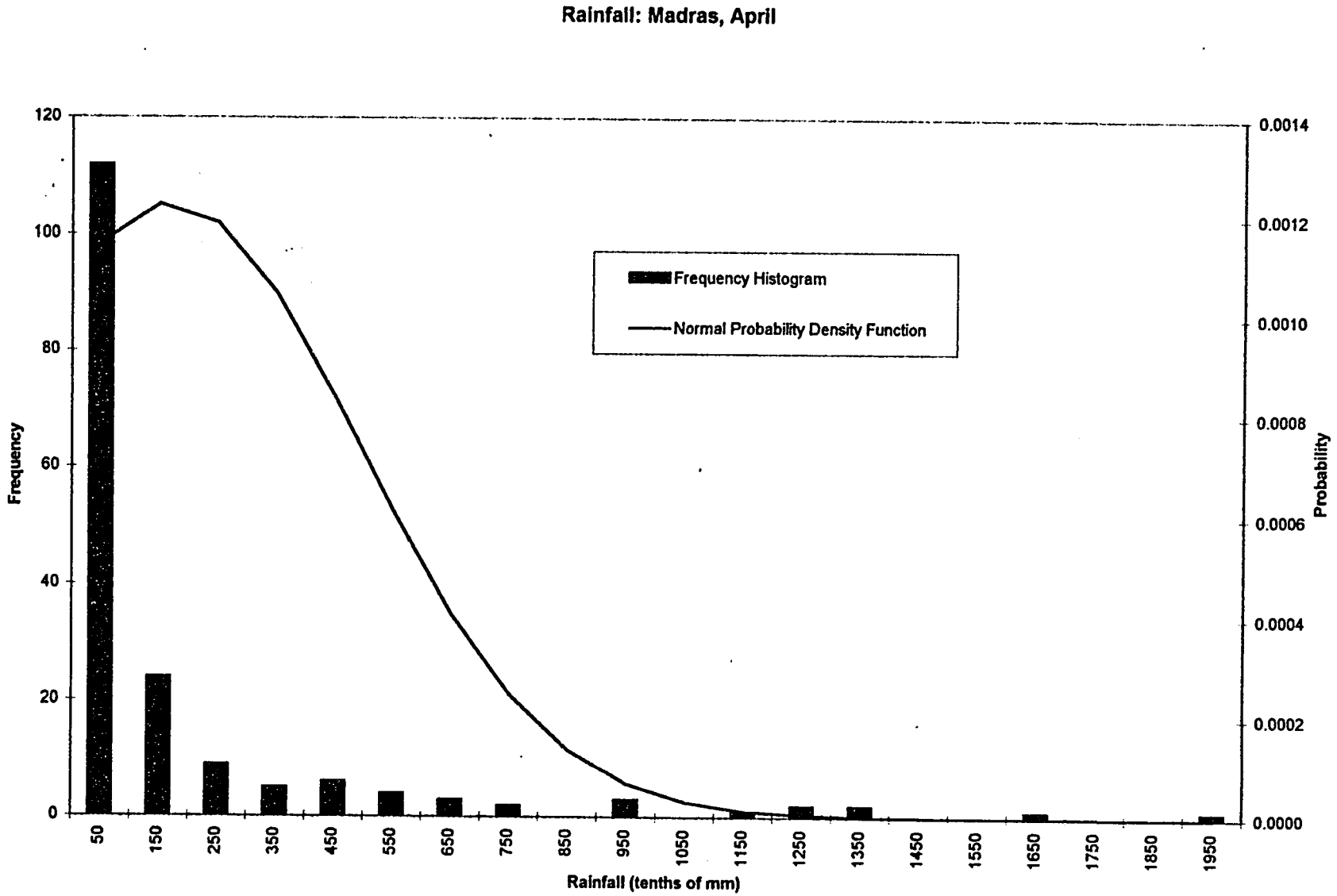

Cummulative Normal Distribution Function
Bikaner, December
Cummulative Frequency
Cummulative Normal Distribution Function
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
410
430

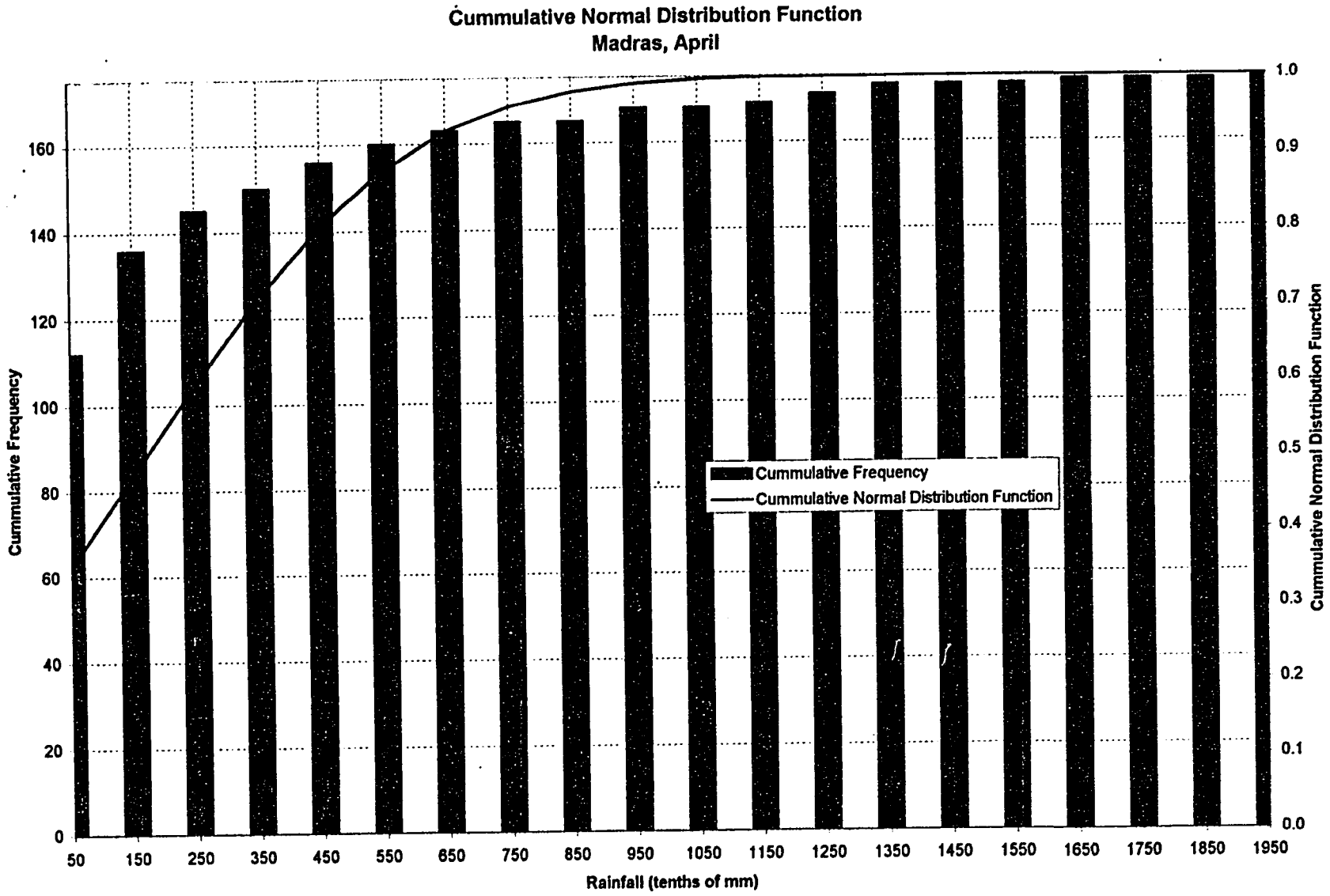
Frequency Histogram

min	0
max	1910
Mean	167.8171429
St Dev	324.7509581

Station 27 Madras, April

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 99	50	112	112	0.00115	0.35838
100 - 199	150	24	136	0.00123	0.47812
200 - 299	250	9	145	0.00119	0.59989
300 - 399	350	5	150	0.00105	0.71260
400 - 499	450	6	156	0.00084	0.80755
500 - 599	550	4	160	0.00061	0.88037
600 - 699	650	3	163	0.00041	0.93120
700 - 799	750	2	165	0.00025	0.96349
800 - 899	850	0	165	0.00014	0.98216
900 - 999	950	3	168	0.00007	0.99199
1000 - 1099	1050	0	168	0.00003	0.99670
1100 - 1199	1150	1	169	0.00001	0.99875
1200 - 1299	1250	2	171	0.00000	0.99957
1300 - 1399	1350	2	173	0.00000	0.99986
1400 - 1499	1450	0	173	0.00000	0.99996
1500 - 1599	1550	0	173	0.00000	0.99999
1600 - 1699	1650	1	174	0.00000	1.00000
1700 1799	1750	0	174	0.00000	1.00000
1800 1899	1850	0	174	0.00000	1.00000
1900 1999	1950	1	175	0.00000	1.00000
		175			


Rainfall: Madras, April
Frequency Histogram
Normal Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
120
100
80
60
40
20
0
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1850
1950

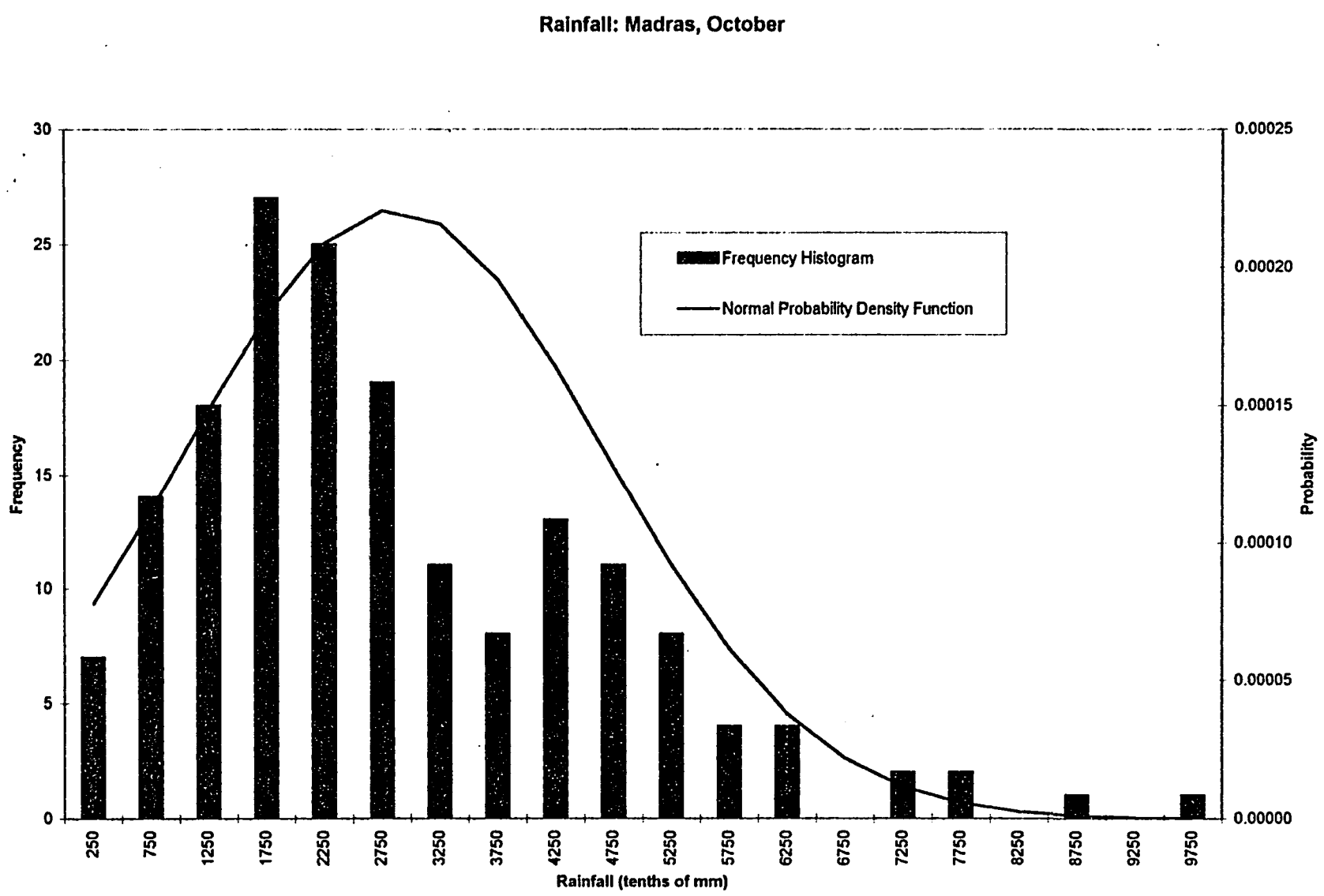

Cummulative Normal Distribution Function
Madras, April
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
0
20
40
60
80
100
120
140
160
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1850
1950

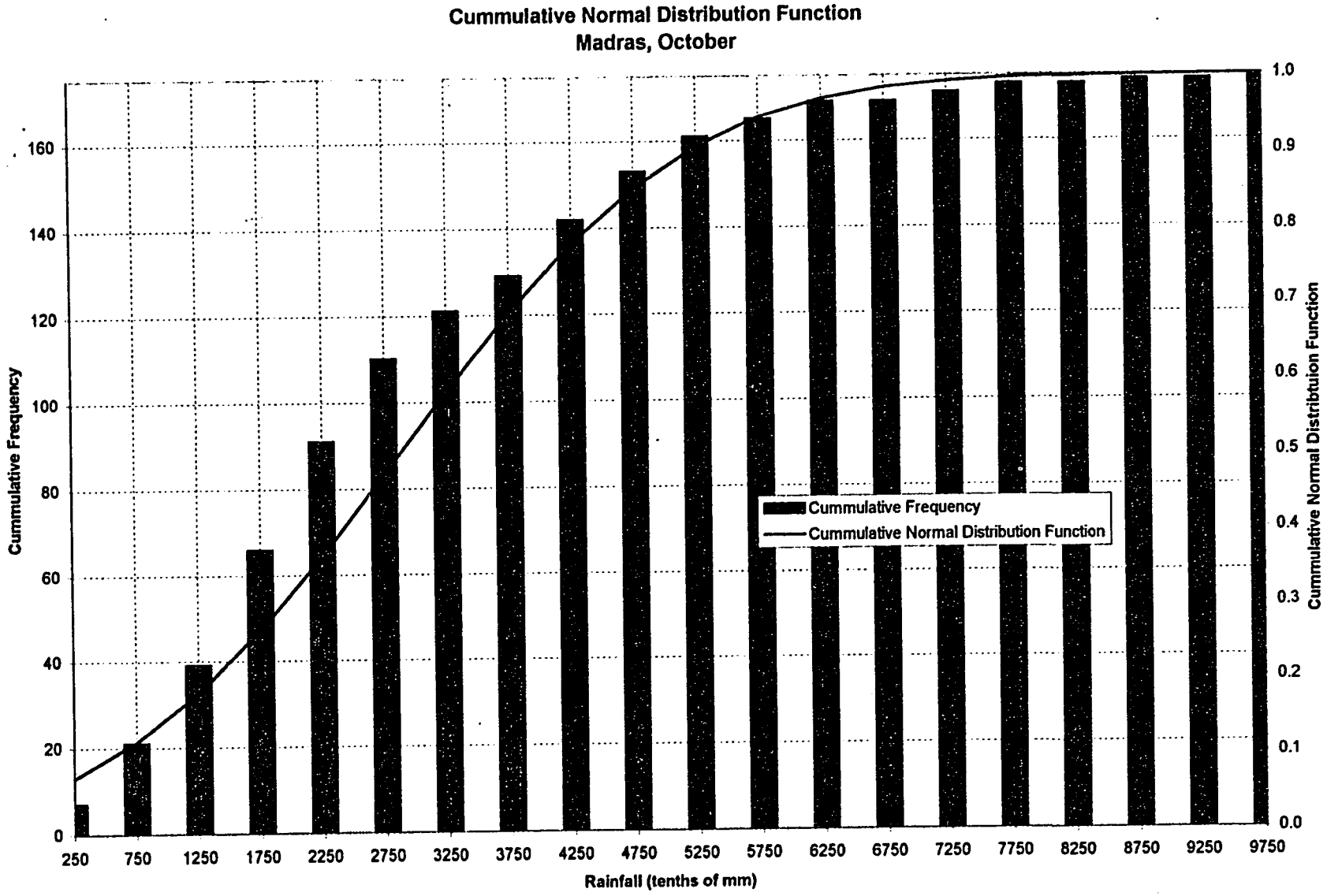
Frequency Histogram

min	0
max	9583
Mean	2857.137143
St Dev	1806.737962

Station 27 Madras, October

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 499	250	7	7	0.00008	0.07451
500 - 999	750	14	21	0.00011	0.12175
1000 - 1499	1250	18	39	0.00015	0.18686
1500 - 1999	1750	27	66	0.00018	0.27001
2000 - 2499	2250	25	91	0.00021	0.36842
2500 - 2999	2750	19	110	0.00022	0.47636
3000 - 3499	3250	11	121	0.00022	0.58607
3500 - 3999	3750	8	129	0.00020	0.68941
4000 - 4499	4250	13	142	0.00016	0.77962
4500 - 4999	4750	11	153	0.00013	0.85260
5000 - 5499	5250	8	161	0.00009	0.90732
5500 - 5999	5750	4	165	0.00006	0.94533
6000 - 6499	6250	4	169	0.00004	0.96980
6500 - 6999	6750	0	169	0.00002	0.98440
7000 - 7499	7250	2	171	0.00001	0.99248
7500 - 7999	7750	2	173	0.00001	0.99662
8000 - 8499	8250	0	173	0.00000	0.99858
8500 8999	8750	1	174	0.00000	0.99945
9000 9499	9250	0	174	0.00000	0.99980
9500 9999	9750	1	175	0.00000	0.99993
		175			


Rainfall: Madras, October
Frequency Histogram
Normal Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
5
10
15
20
25
30
0.00000
0.00005
0.00010
0.00015
0.00020
0.00025
250
750
1250
1750
2250
2750
3250
3750
4250
4750
5250
5750
6250
6750
7250
7750
8250
8750
9250
9750

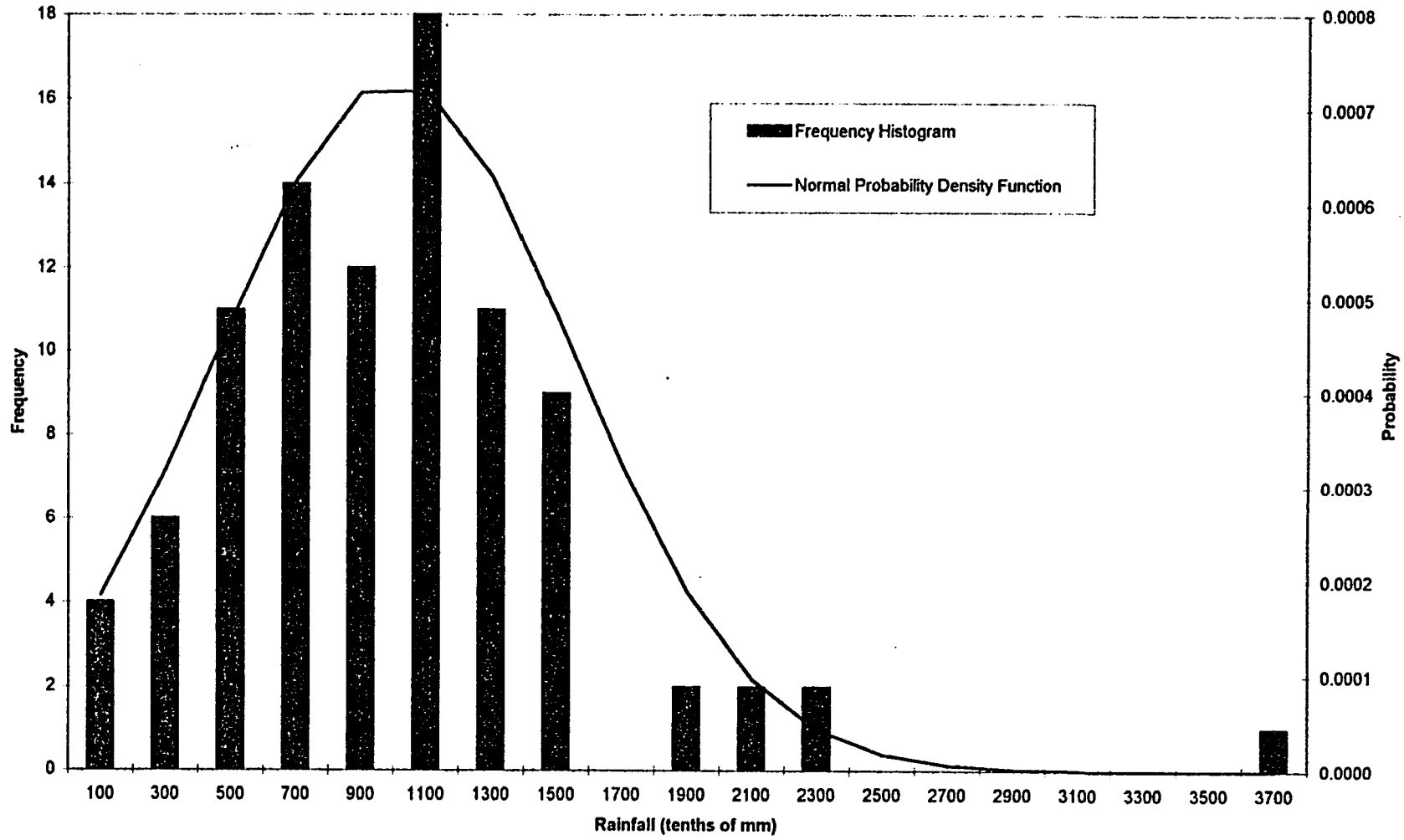

Cummulative Normal Distribution Function
Madras, October
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
Cummulative Normal Distribtuion Function
0
20
40
60
80
100
120
140
160
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
250
750
1250
1750
2250
2750
3250
3750
4250
4750
5250
5750
6250
6750
7250
7750
8250
8750
9250
9750

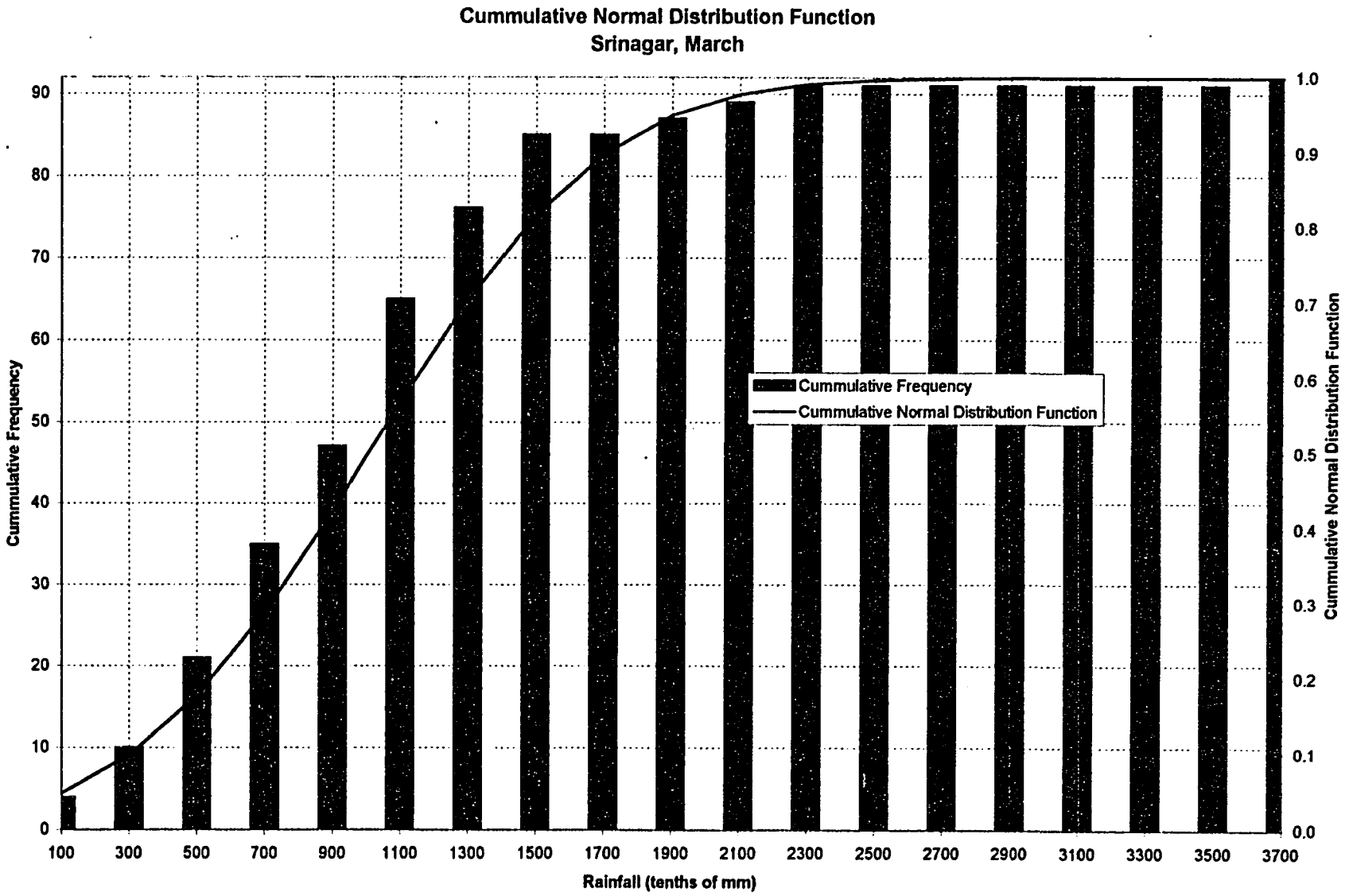
Frequency Histogram

min	0
max	3650
Mean	1003.91304
St Dev	545.603722

Station 38 Srinagar, March

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 199	100	4	4	0.00019	0.04879
200 - 399	300	6	10	0.00032	0.09850
400 - 599	500	11	21	0.00048	0.17785
600 - 799	700	14	35	0.00063	0.28876
800 - 999	900	12	47	0.00072	0.42448
1000 - 1199	1100	18	65	0.00072	0.56990
1200 - 1399	1300	11	76	0.00063	0.70632
1400 - 1599	1500	9	85	0.00048	0.81839
1600 - 1799	1700	0	85	0.00032	0.89899
1800 - 1999	1900	2	87	0.00019	0.94974
2000 - 2199	2100	2	89	0.00010	0.97773
2200 - 2399	2300	2	91	0.00004	0.99124
2400 - 2599	2500	0	91	0.00002	0.99695
2600 - 2799	2700	0	91	0.00001	0.99906
2800 - 2999	2900	0	91	0.00000	0.99974
3000 - 3199	3100	0	91	0.00000	0.99994
3200 - 3399	3300	0	91	0.00000	0.99999
3400 3599	3500	0	91	0.00000	1.00000
3600 3799	3700	1	92	0.00000	1.00000
		92			


Rainfall: Srinagar, March
Frequency Histogram
Normal Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
2
4
6
8
10
12
14
16
18
0.0000
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
0.0007
0.0008
100
300
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700

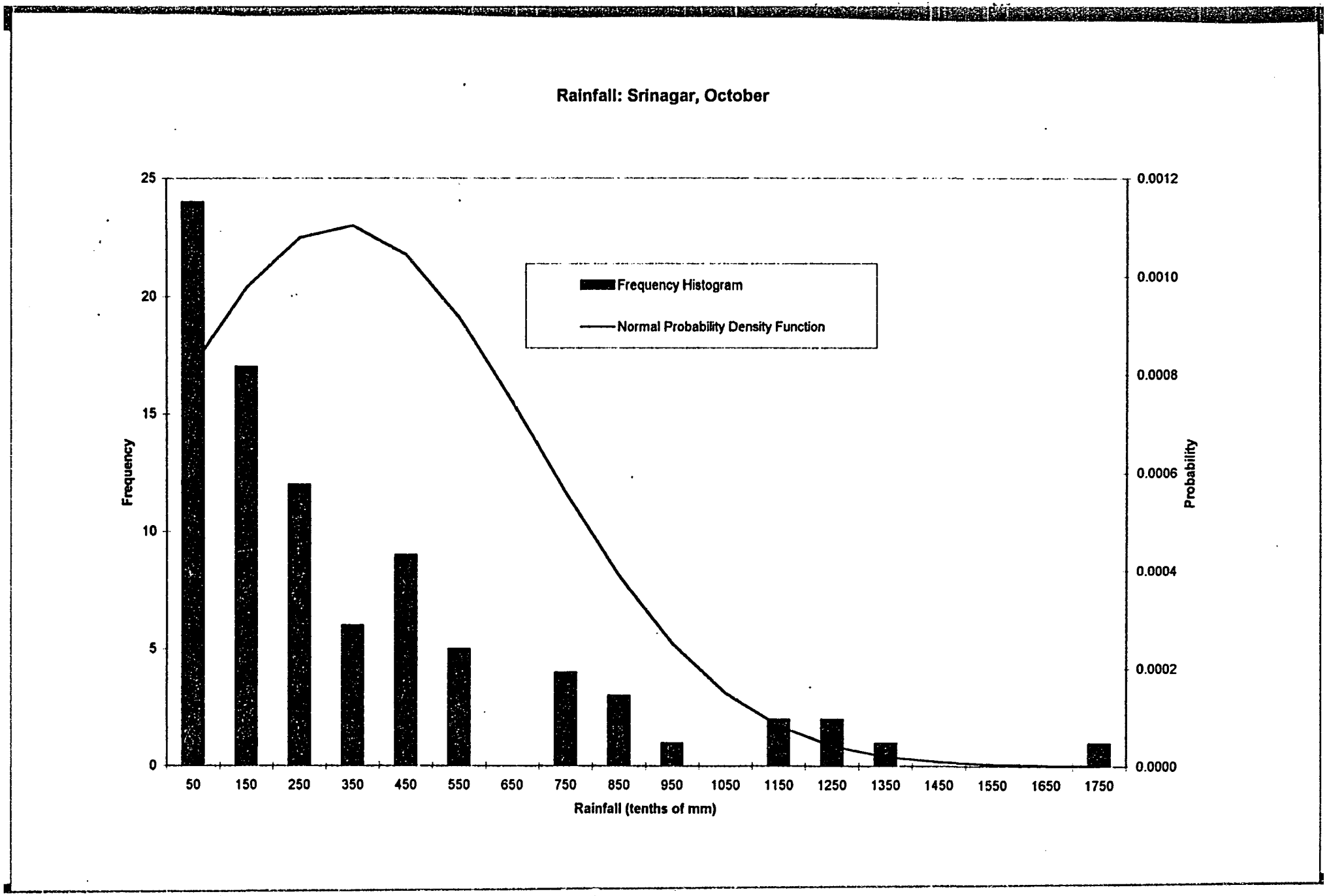

Cummulative Normal Distribution Function
Srinagar, March
Cummulative Frequency
Cummulative Normal Distribution Function
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
0
10
20
30
40
50
60
70
80
90
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
100
300
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700

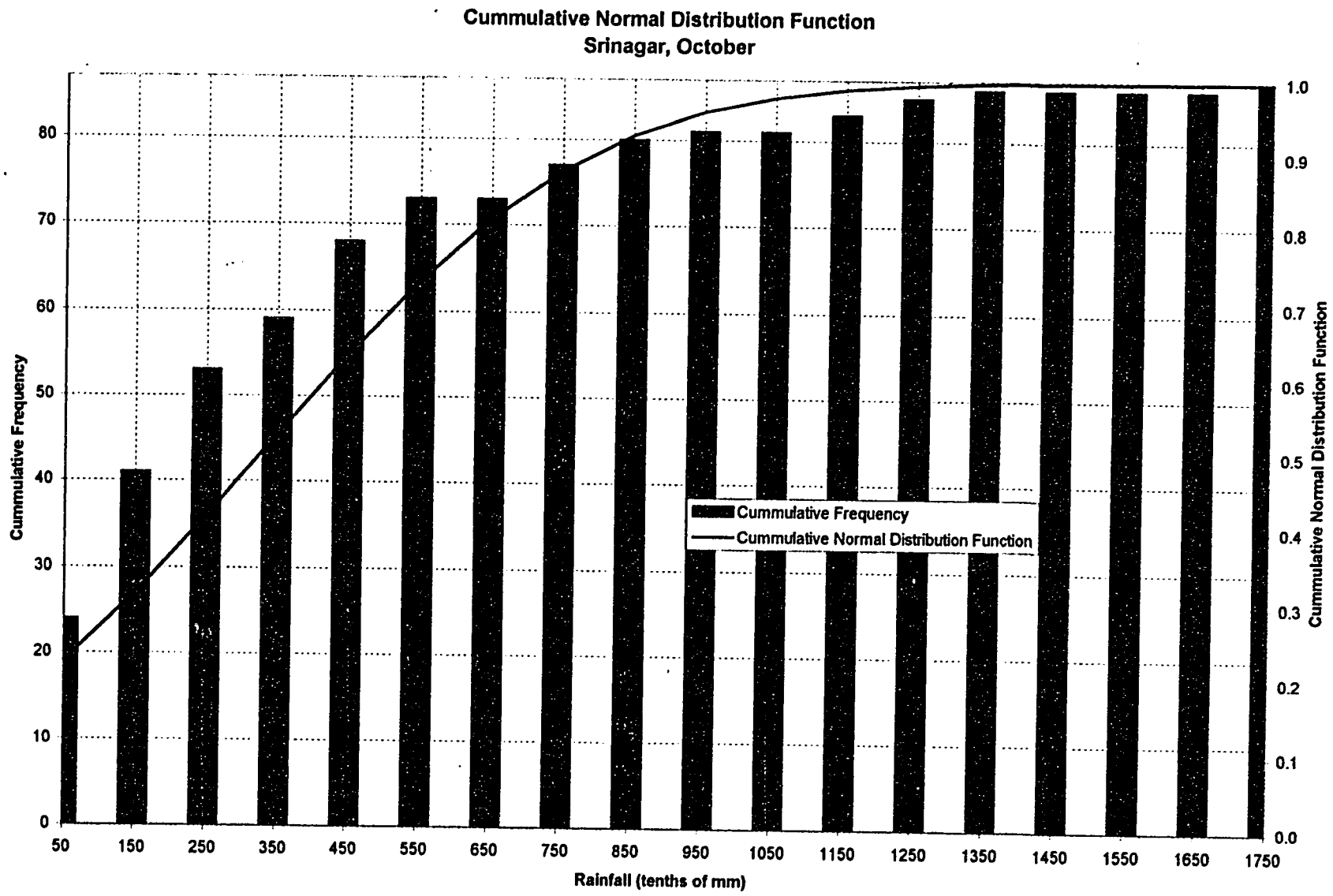
Frequency Histogram

min	0
max	1710
Mean	328.965517
St Dev	360.777695

Station 38 Srinagar, October

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 100	50	24	24	0.00082	0.21969
100 - 200	150	17	41	0.00098	0.30993
200 - 300	250	12	53	0.00108	0.41337
300 - 400	350	6	59	0.00110	0.52325
400 - 500	450	9	68	0.00105	0.63137
500 - 600	550	5	73	0.00092	0.72995
600 - 700	650	0	73	0.00074	0.81322
700 - 800	750	4	77	0.00056	0.87840
800 - 900	850	3	80	0.00039	0.92566
900 - 1000	950	1	81	0.00025	0.95741
1000 - 1100	1050	0	81	0.00015	0.97717
1100 - 1200	1150	2	83	0.00008	0.98857
1200 - 1300	1250	2	85	0.00004	0.99466
1300 - 1400	1350	1	86	0.00002	0.99767
1400 - 1500	1450	0	86	0.00001	0.99906
1500 - 1600	1550	0	86	0.00000	0.99964
1600 - 1700	1650	0	86	0.00000	0.99987
1700 - 1799	1750	1	87	0.00000	0.99996
		87			


Rainfall: Srinagar, October
Frequency Histogram
Normal Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
5
10
15
20
25
0.0000
0.0002
0.0004
0.0006
0.0008
0.0010
0.0012
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750

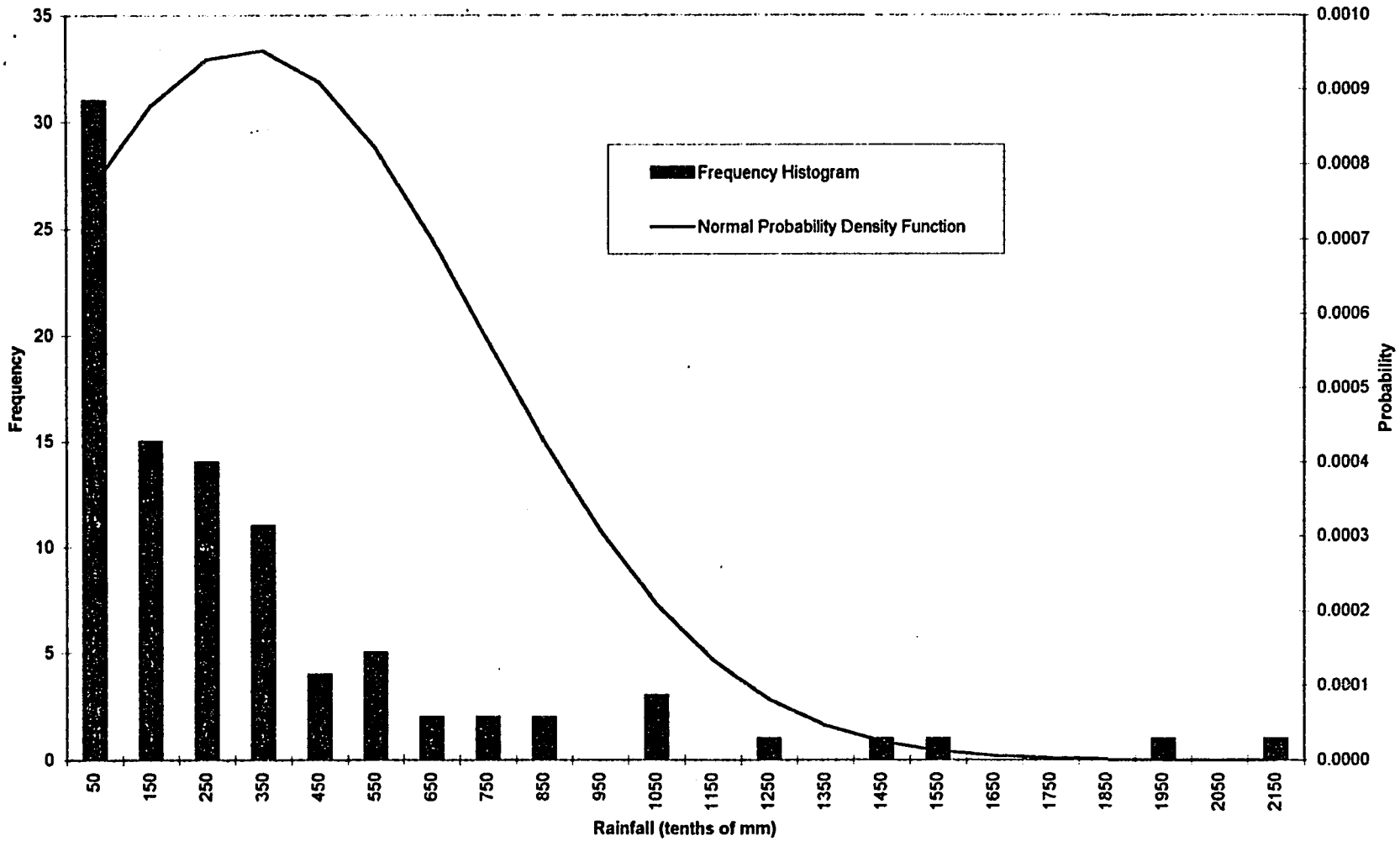

Cummulative Normal Distribution Function
Srinagar, October
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
0
10
20
30
40
50
60
70
80
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750

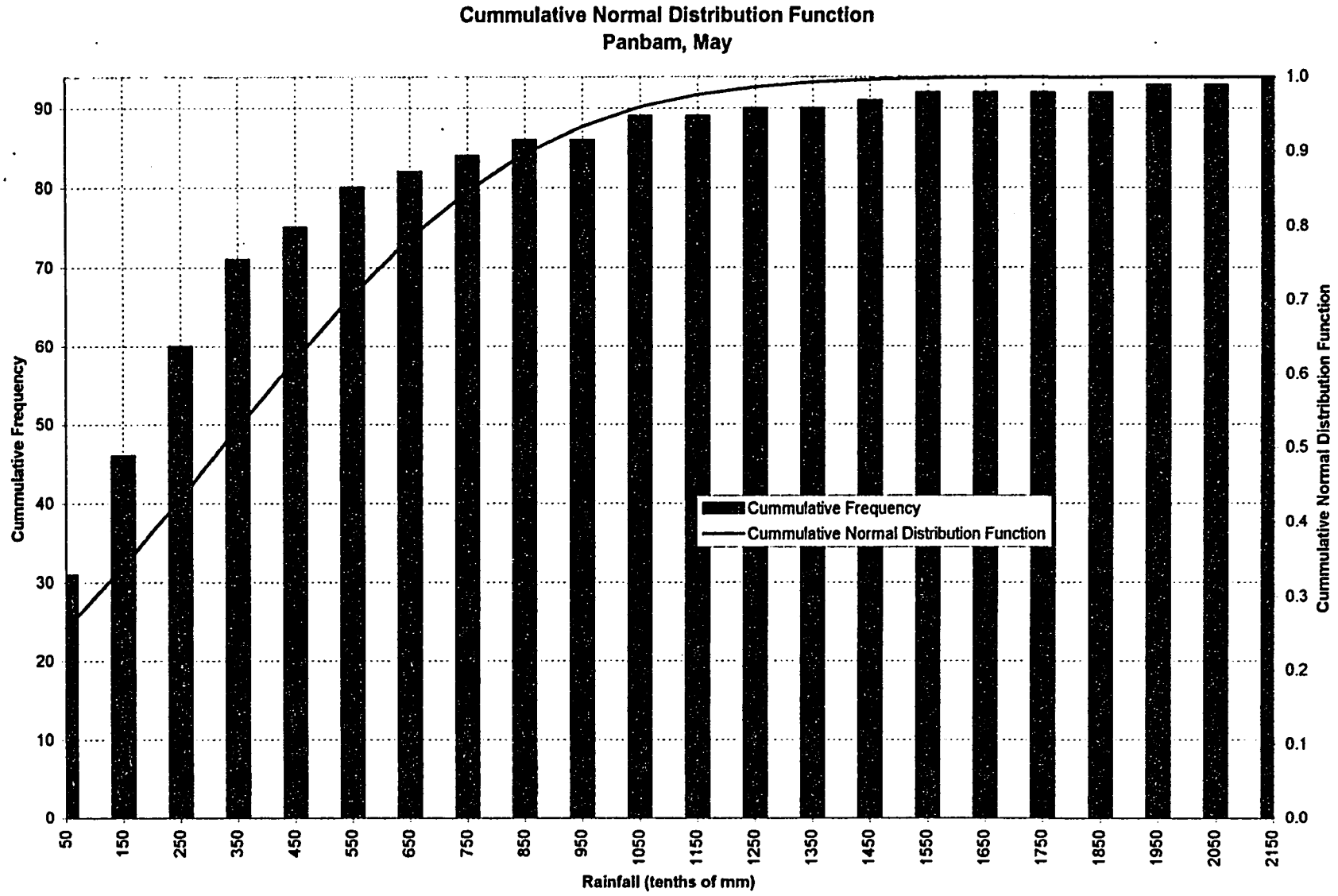
Frequency Histogram

min	0
max	2170
Mean	321.2765957
St Dev	417.8445305

Station 40 Panbam, May

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 99	50	31	31	0.00077	0.25810
100 - 199	150	15	46	0.00088	0.34094
200 - 299	250	14	60	0.00094	0.43228
300 - 399	350	11	71	0.00095	0.52740
400 - 499	450	4	75	0.00091	0.62098
500 - 599	550	5	80	0.00082	0.70794
600 - 699	650	2	82	0.00070	0.78427
700 - 799	750	2	84	0.00056	0.84756
800 - 899	850	2	86	0.00043	0.89713
900 - 999	950	0	86	0.00031	0.93380
1000 - 1099	1050	3	89	0.00021	0.95942
1100 - 1199	1150	0	89	0.00013	0.97633
1200 - 1299	1250	1	90	0.00008	0.98688
1300 - 1399	1350	0	90	0.00005	0.99309
1400 - 1499	1450	1	91	0.00002	0.99655
1500 - 1599	1550	1	92	0.00001	0.99836
1600 - 1699	1650	0	92	0.00001	0.99926
1700 - 1799	1750	0	92	0.00000	0.99969
1800 - 1899	1850	0	92	0.00000	0.99987
1900 - 1999	1950	1	93	0.00000	0.99995
2000 - 2099	2050	0	93	0.00000	0.99998
2100 - 2199	2150	1	94	0.00000	0.99999
		94			


Rainfall: Panbam, May
Frequency Histogram
Normal Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
5
10
15
20
25
30
35
0.0000
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
0.0007
0.0008
0.0009
0.0010
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1850
1950
2050
2150

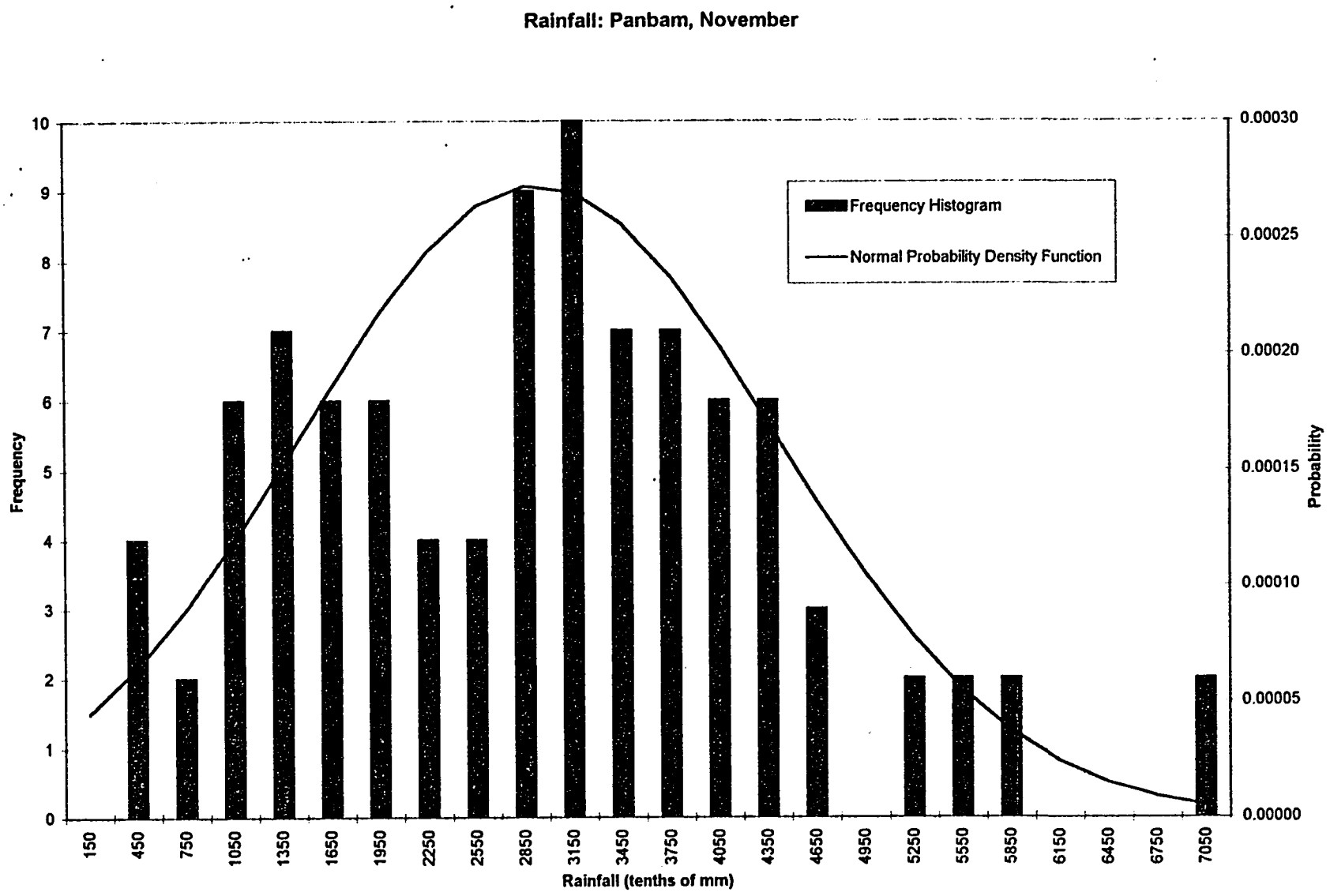

Cummulative Normal Distribution Function
Panbam, May
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
Cummulative Frequency
Cummulative Normal Distribution Function
0
10
20
30
40
50
60
70
80
90
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1850
1950
2050
2150

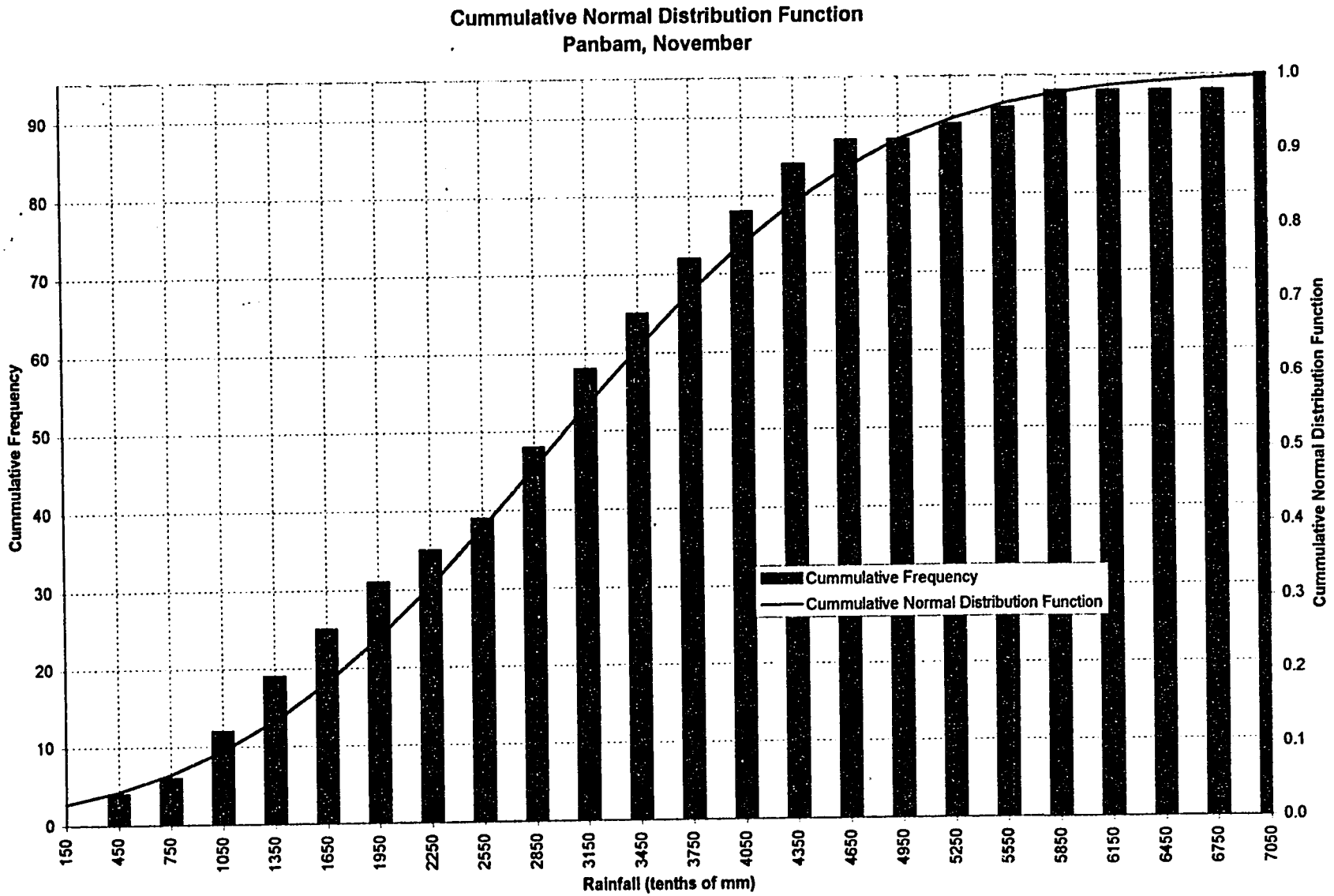
Frequency Histogram

min	0
max	6920
Mean	2930.210526
St Dev	1463.70121

Station 40 Panbam, November

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Normal Probability Density Function	Cummulative Normal Distribution Function
0 - 299	150	0	0	0.00004	0.02875
300 - 599	450	4	4	0.00006	0.04509
600 - 899	750	2	6	0.00009	0.06818
900 - 1199	1050	6	12	0.00012	0.09947
1200 - 1499	1350	7	19	0.00015	0.14016
1500 - 1799	1650	6	25	0.00019	0.19089
1800 - 2099	1950	6	31	0.00022	0.25153
2100 - 2399	2250	4	35	0.00024	0.32107
2400 - 2699	2550	4	39	0.00026	0.39752
2700 - 2999	2850	9	48	0.00027	0.47815
3000 - 3299	3150	10	58	0.00027	0.55968
3300 - 3599	3450	7	65	0.00026	0.63875
3600 - 3899	3750	7	72	0.00023	0.71229
3900 - 4199	4050	6	78	0.00020	0.77788
4200 - 4499	4350	6	84	0.00017	0.83398
4500 - 4799	4650	3	87	0.00014	0.87999
4800 - 5099	4950	0	87	0.00011	0.91619
5100 5399	5250	2	89	0.00008	0.94350
5400 5699	5550	2	91	0.00005	0.96326
5700 5999	5850	2	93	0.00004	0.97697
6000 6299	6150	0	93	0.00002	0.98609
6300 6599	6450	0	93	0.00002	0.99191
6600 6899	6750	0	93	0.00001	0.99547
6900 7199	7050	2	95	0.00001	0.99756
		95			


Rainfall: Panbam, November
Frequency Histogram
Normal Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
1
2
3
4
5
6
7
8
9
10
0.00000
0.00005
0.00010
0.00015
0.00020
0.00025
0.00030
150
450
750
1050
1350
1650
1950
2250
2550
2850
3150
3450
3750
4050
4350
4650
4950
5250
5550
5850
6150
6450
6750
7050


Cummulative Normal Distribution Function
Panbam, November
Cummulative Frequency
Cummulative Normal Distribution Function
Rainfall (tenths of mm)
Cummulative Frequency
Cummulative Normal Distribution Function
0
10
20
30
40
50
60
70
80
90
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
150
450
750
1050
1350
1650
1950
2250
2550
2850
3150
3450
3750
4050
4350
4650
4950
5250
5550
5850
6150
6450
6750
7050

APPENDIX R

EFFECTIVE PRECIPITATION

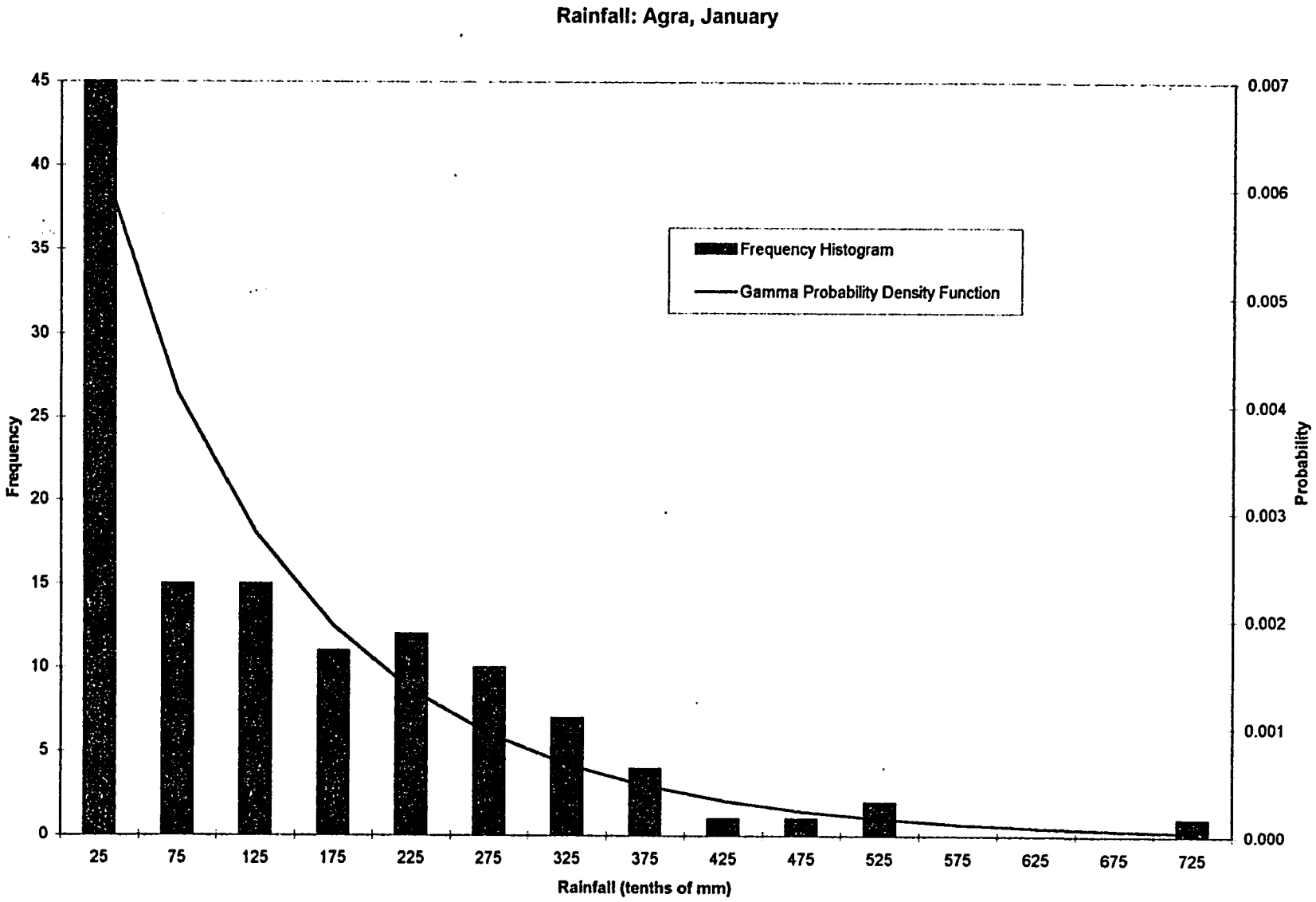
METHOD 4
GAMMA DISTRIBUTION

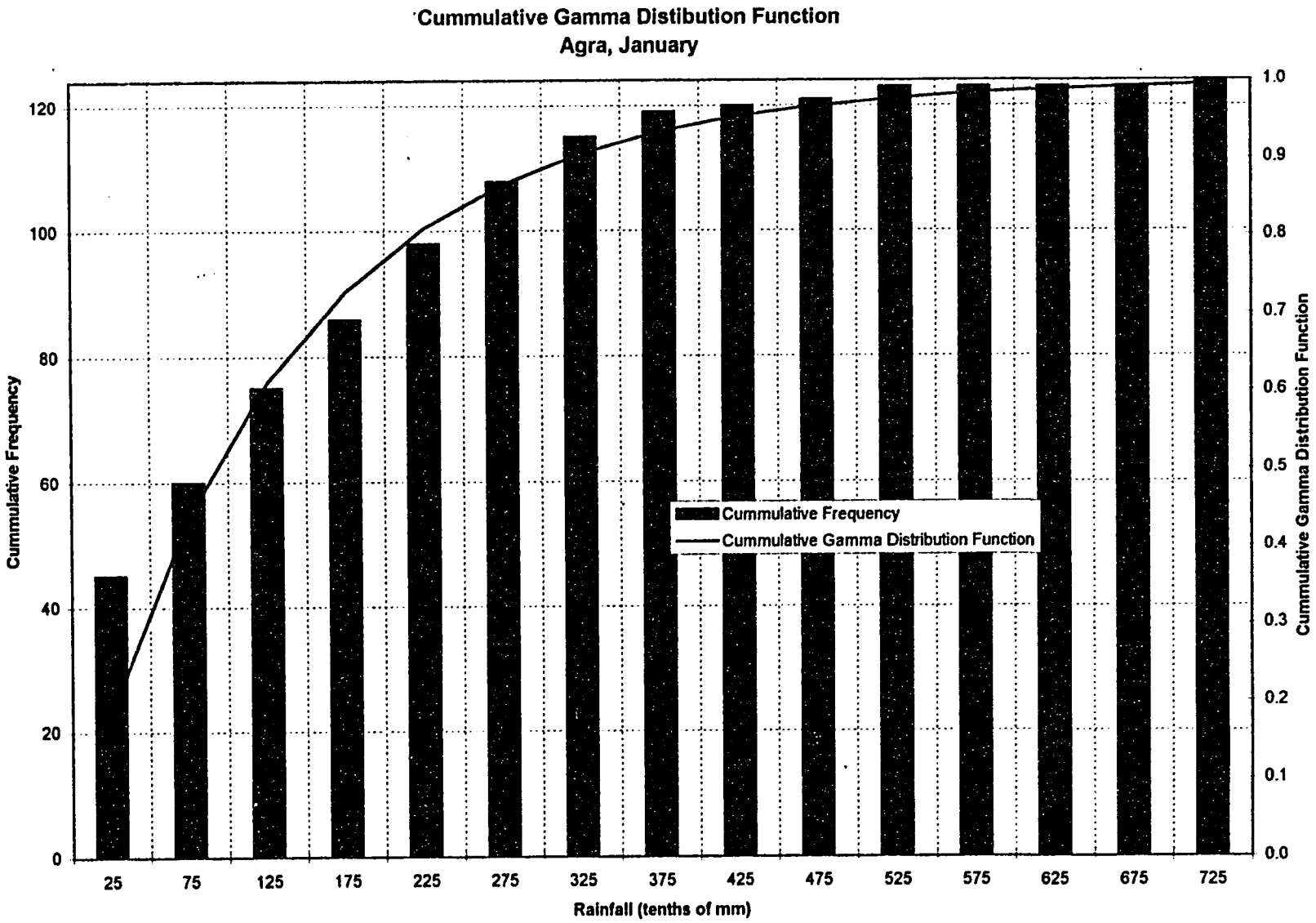
Rainfall Frequency Histograms
Gamma Probability Density Function
Cumulative Gamma Distribution Function

Frequency Histogram	
min	0
max	720
alpha	0.92843333
beta	144.711348

Station 1 Agra, January

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 - 49	25	45	45	0.00630	0.18572
50 - 99	75	15	60	0.00412	0.44053
100 - 149	125	15	75	0.00281	0.61152
150 - 199	175	11	86	0.00194	0.72900
200 - 249	225	12	98	0.00135	0.81044
250 - 299	275	10	108	0.00094	0.86716
300 - 349	325	7	115	0.00066	0.90679
350 - 399	375	4	119	0.00046	0.93453
400 - 449	425	1	120	0.00032	0.95398
450 - 499	475	1	121	0.00023	0.96763
500 - 549	525	2	123	0.00016	0.97722
550 - 599	575	0	123	0.00011	0.98396
600 - 649	625	0	123	0.00008	0.98870
650 - 699	675	0	123	0.00006	0.99204
700 - 749	725	1	124	0.00004	0.99439
		124			

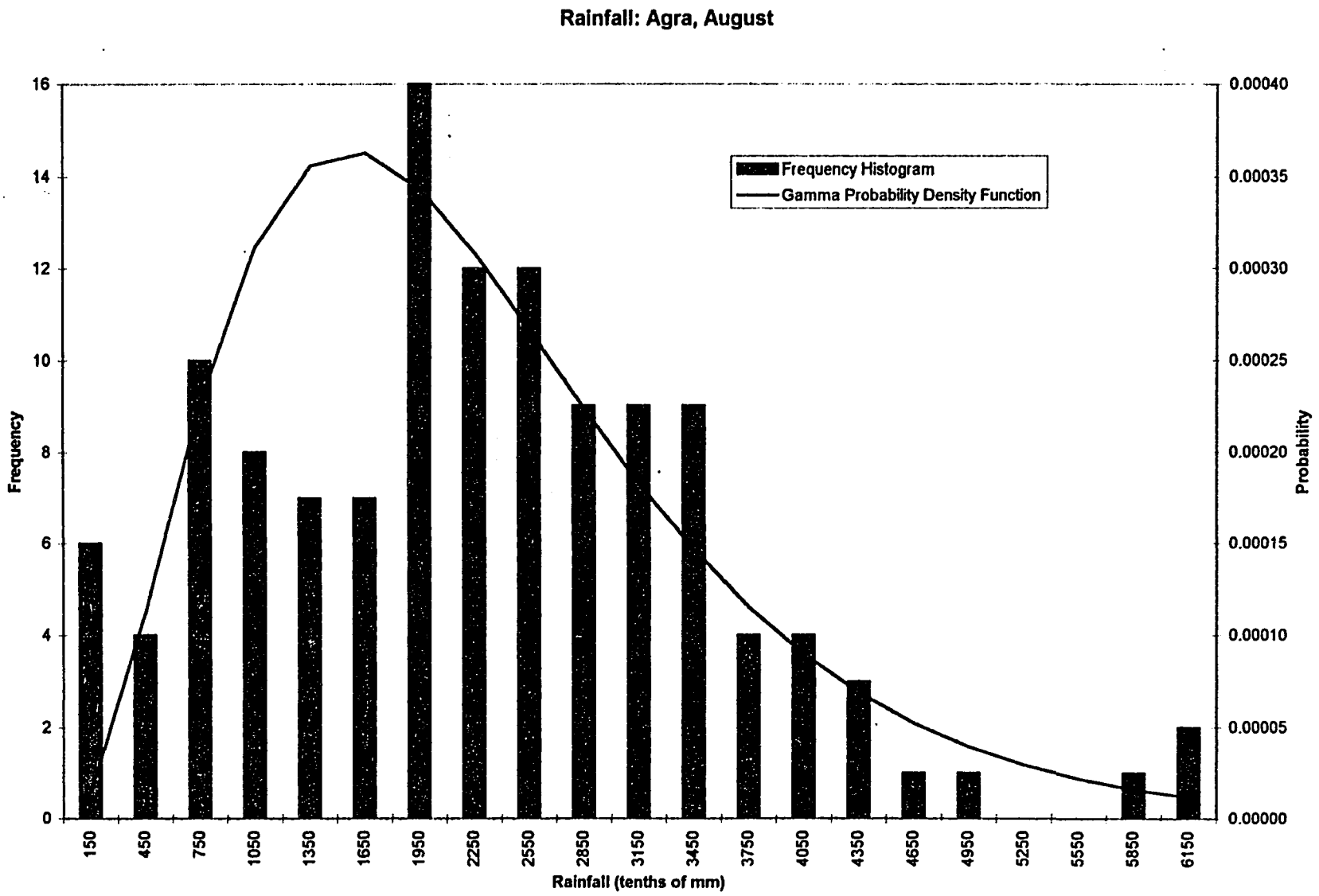

Rainfall: Agra, January
Frequency Histogram
Gamma Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
5
10
15
20
25
30
35
40
45
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
25
75
125
175
225
275
325
375
425
475
525
575
625
675
725

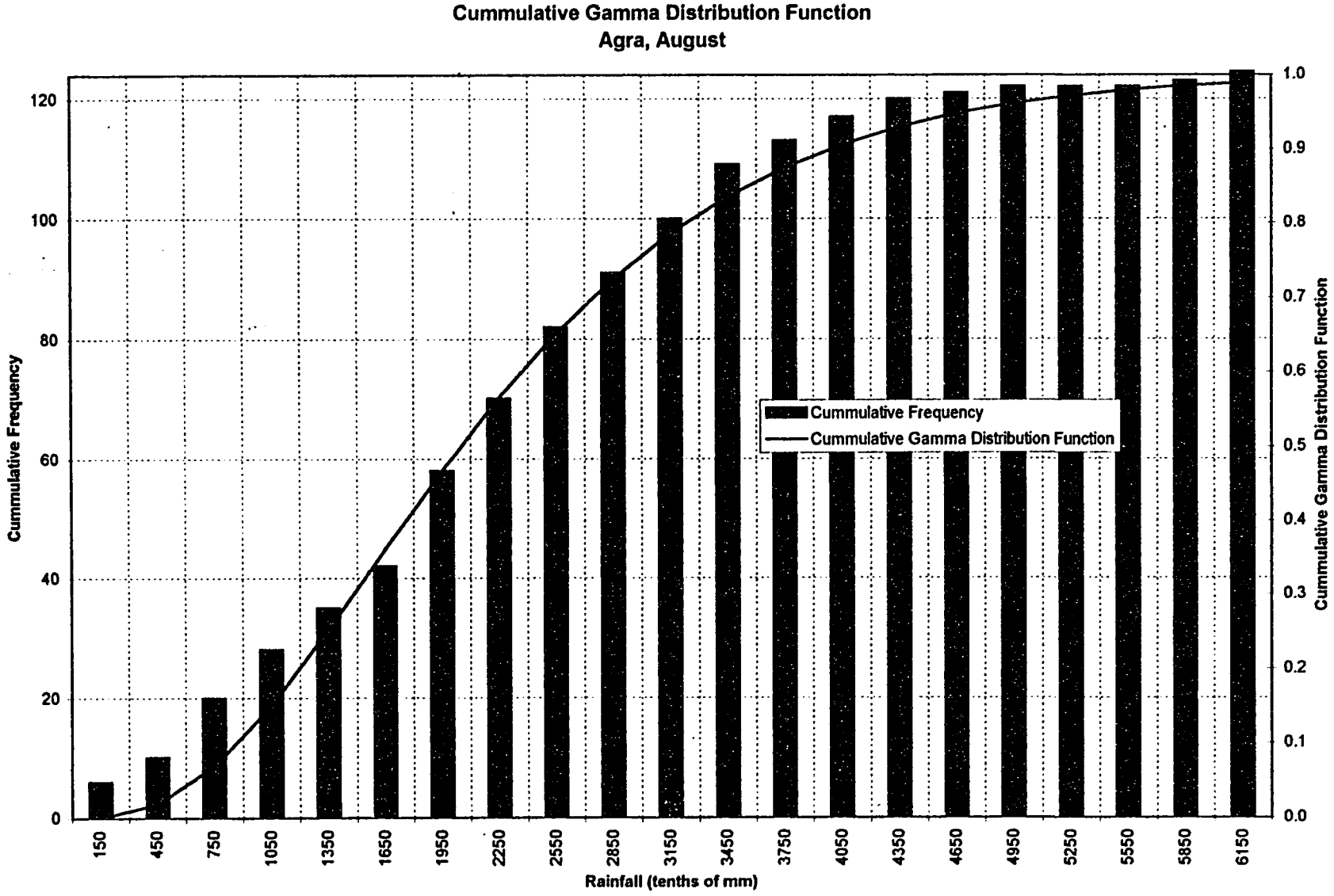

Cummulative Gamma Distibution Function
Agra, January
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
Cummulative Frequency
Cummulative Gamma Distribution Function
0
20
40
60
80
100
120
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
25
75
125
175
225
275
325
375
425
475
525
575
625
675
725

Frequency Histogram	
min	0
max	6180
alpha	3.194102463
beta	712.7385631

Station 1 Agra, August

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 - 299	150	6	6	0.00002	0.00076
300 - 599	450	4	10	0.00011	0.01862
600 - 899	750	10	20	0.00023	0.07002
900 - 1199	1050	8	28	0.00031	0.15195
1200 - 1499	1350	7	35	0.00036	0.25317
1500 - 1799	1650	7	42	0.00036	0.36174
1800 - 2099	1950	16	58	0.00034	0.46819
2100 - 2399	2250	12	70	0.00031	0.56629
2400 - 2699	2550	12	82	0.00027	0.65269
2700 - 2999	2850	9	91	0.00022	0.72618
3000 - 3299	3150	9	100	0.00018	0.78701
3300 - 3599	3450	9	109	0.00015	0.83625
3600 - 3899	3750	4	113	0.00012	0.87539
3900 - 4199	4050	4	117	0.00009	0.90603
4200 - 4499	4350	3	120	0.00007	0.92970
4500 - 4799	4650	1	121	0.00005	0.94779
4800 - 5099	4950	1	122	0.00004	0.96147
5100 - 5399	5250	0	122	0.00003	0.97173
5400 - 5699	5550	0	122	0.00002	0.97937
5700 - 5999	5850	1	123	0.00002	0.98502
6000 - 6299	6150	2	125	0.00001	0.98916
		125			


Rainfall: Agra, August
Frequency Histogram
Gamma Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
2
4
6
8
10
12
14
16
0.00000
0.00005
0.00010
0.00015
0.00020
0.00025
0.00030
0.00035
0.00040
150
450
750
1050
1350
1650
1950
2250
2550
2850
3150
3450
3750
4050
4350
4650
4950
5250
5550
5850
6150


Cummulative Gamma Distribution Function
Agra, August
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
Cummulative Frequency
Cummulative Gamma Distribution Function
0
20
40
60
80
100
120
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
150
450
750
1050
1350
1650
1950
2250
2550
2850
3150
3450
3750
4050
4350
4650
4950
5250
5550
5850
6150

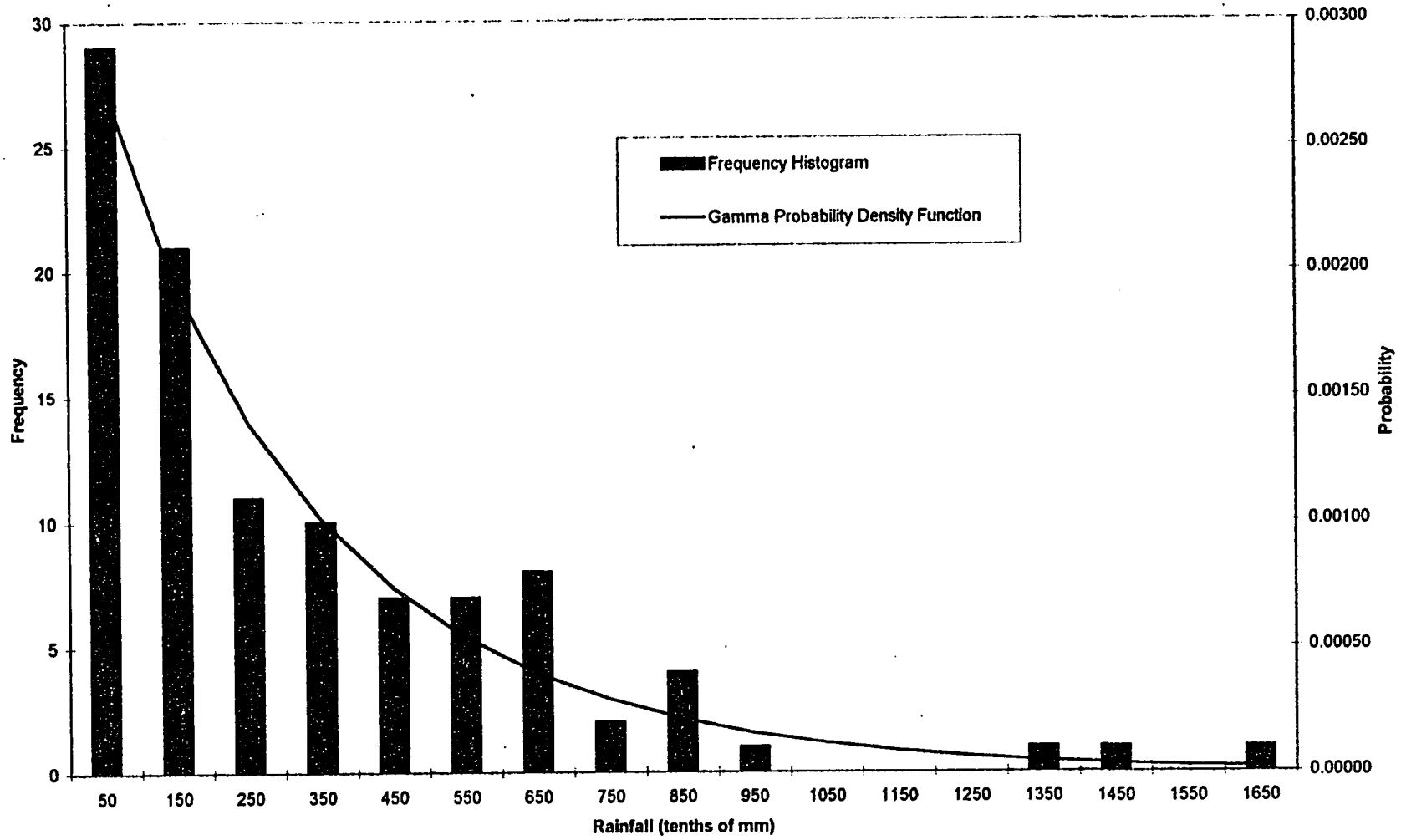
Frequency Histogram

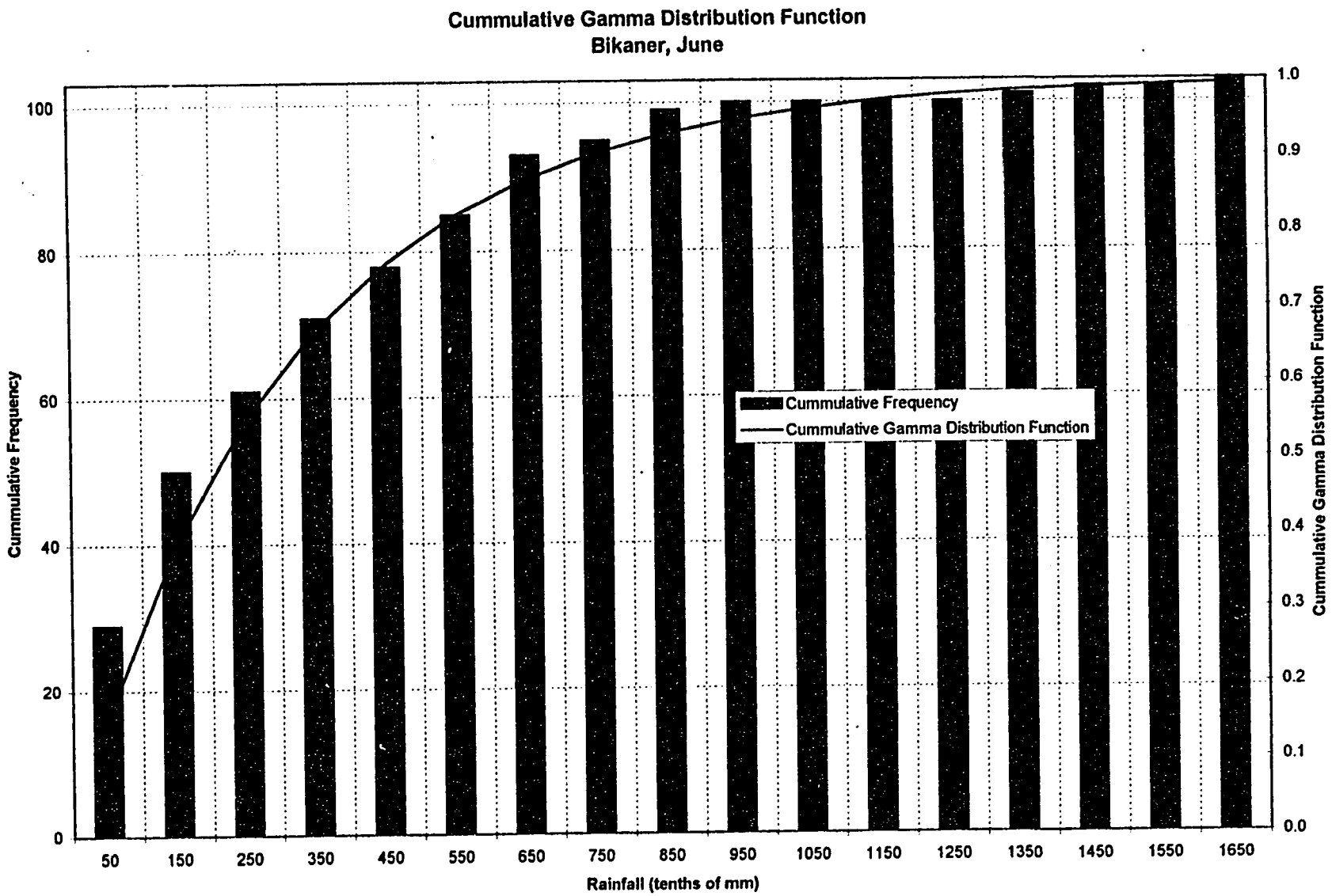
min	0
max	1630
alpha	0.950656315
beta	329.2564346

Station 9 Bikaner, June

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 - 99	50	29	29	0.00278	0.15806
100 - 199	150	21	50	0.00194	0.39039
200 - 299	250	11	61	0.00140	0.55569
300 - 399	350	10	71	0.00101	0.67521
400 - 499	450	7	78	0.00074	0.76216
500 - 599	550	7	85	0.00054	0.82563
600 - 699	650	8	93	0.00040	0.87205
700 - 799	750	2	95	0.00029	0.90606
800 - 899	850	4	99	0.00021	0.93099
900 - 999	950	1	100	0.00016	0.94928
1000 - 1099	1050	0	100	0.00011	0.96271
1100 - 1199	1150	0	100	0.00008	0.97258
1200 - 1299	1250	0	100	0.00006	0.97983
1300 - 1399	1350	1	101	0.00005	0.98516
1400 - 1499	1450	1	102	0.00003	0.98908
1500 - 1599	1550	0	102	0.00002	0.99196
1600 - 1699	1650	1	103	0.00002	0.99408
		103			

Rainfall: Bikaner, June

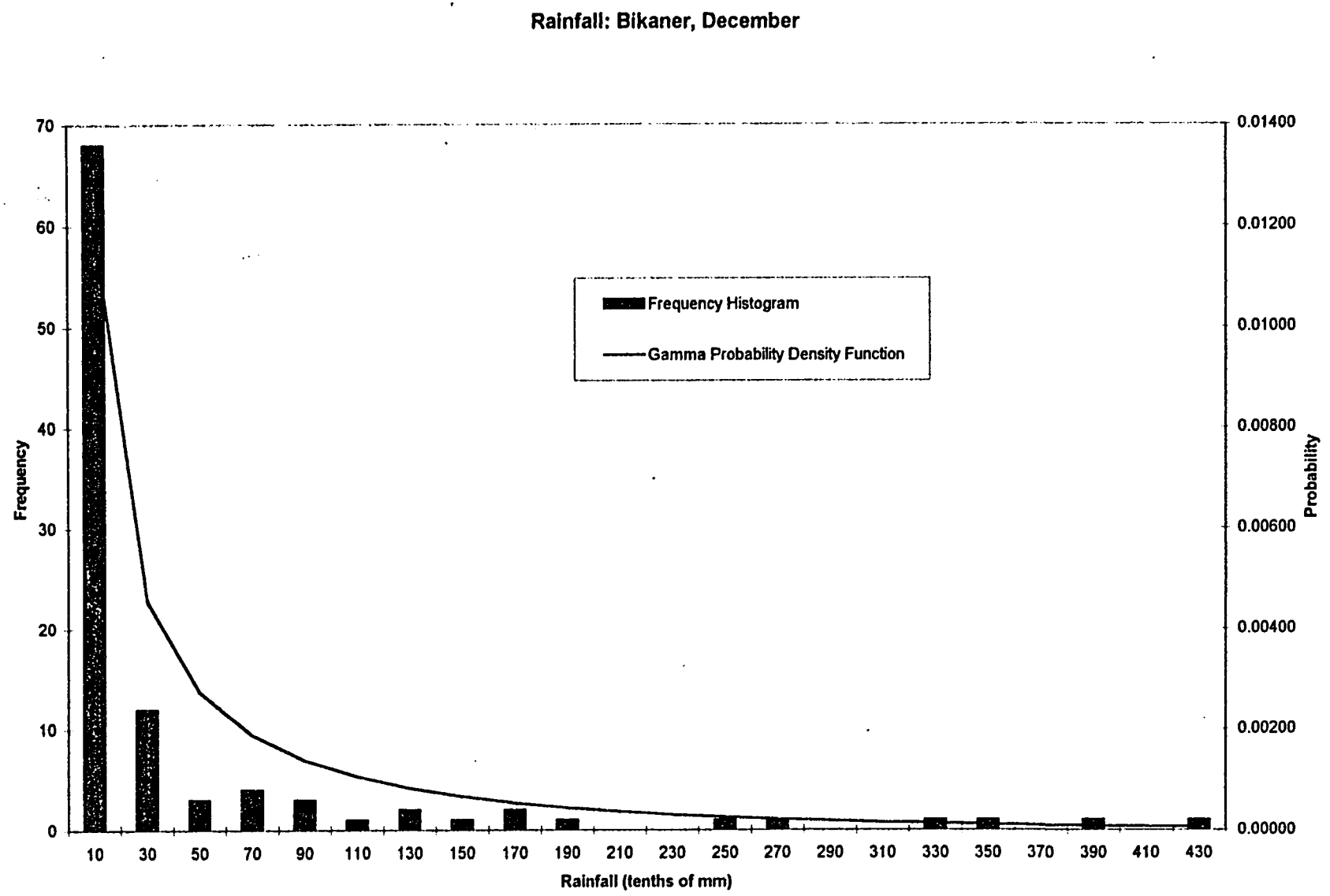


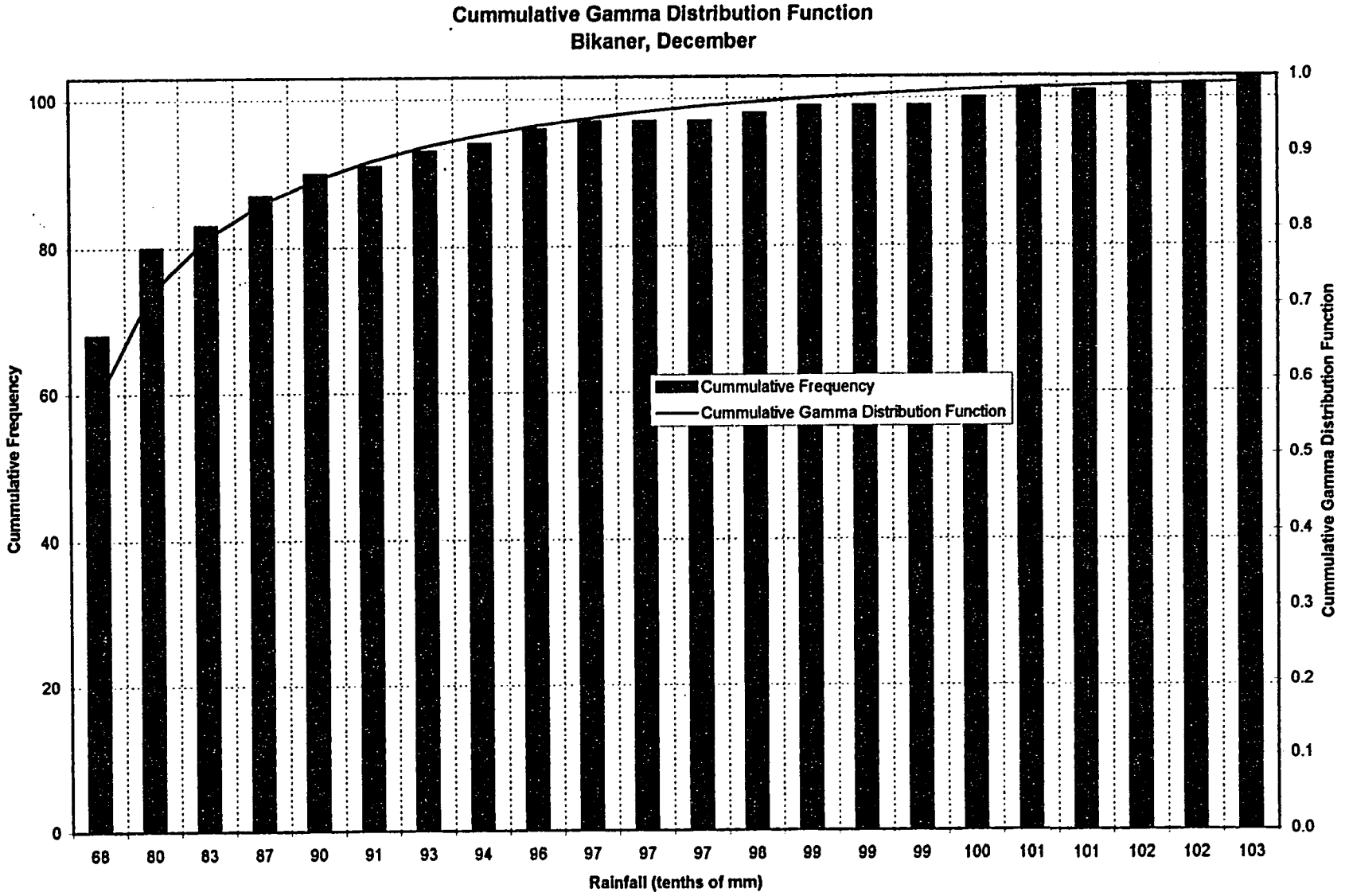

Cummulative Gamma Distribution Function
Bikaner, June
Cummulative Frequency
Cummulative Gamma Distribution Function
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650

Frequency Histogram	
min	0
max	1630
alpha	0.218865169
beta	180.5429494

Station 9 Bikaner, December

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 - 19	10	68	68	0.01204	0.57551
20 - 39	30	12	80	0.00457	0.71810
40 - 59	50	3	83	0.00274	0.78845
60 - 79	70	4	87	0.00189	0.83390
80 - 99	90	3	90	0.00139	0.86627
100 - 119	110	1	91	0.00106	0.89058
120 - 139	130	2	93	0.00083	0.90943
140 - 159	150	1	94	0.00067	0.92438
160 - 179	170	2	96	0.00054	0.93643
180 - 199	190	1	97	0.00045	0.94627
200 - 219	210	0	97	0.00037	0.95438
220 - 239	230	0	97	0.00031	0.96112
240 - 259	250	1	98	0.00026	0.96675
260 - 279	270	1	99	0.00022	0.97149
280 - 299	290	0	99	0.00018	0.97549
300 - 319	310	0	99	0.00016	0.97888
320 - 339	330	1	100	0.00013	0.98177
340 359	350	1	101	0.00011	0.98423
360 379	370	0	101	0.00010	0.98634
380 399	390	1	102	0.00008	0.98815
400 419	410	0	102	0.00007	0.98971
420 439	430	1	103	0.00006	0.99105
		103			


Rainfall: Bikaner, December
Frequency
Probability
Frequency Histogram
Gamma Probability Density Function
Rainfall (tenths of mm)
0
10
20
30
40
50
60
70
0.00000
0.00200
0.00400
0.00600
0.00800
0.01000
0.01200
0.01400
10 30 50 70 90 110 130 150 170 190 210 230 250 270 290 310 330 350 370 390 410 430

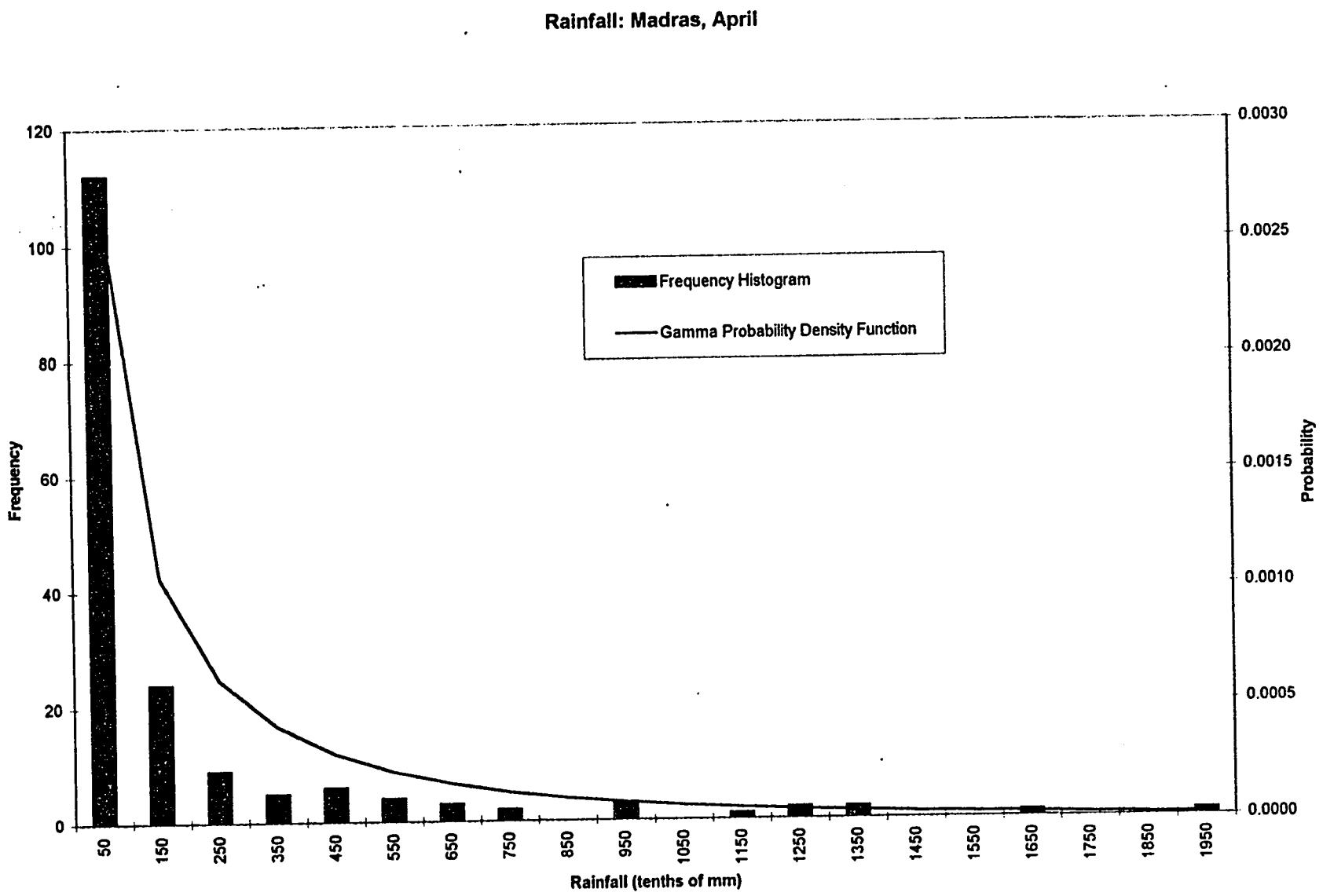

Cummulative Gamma Distribution Function
Bikaner, December
Cummulative Frequency
Cummulative Gamma Distribution Function
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
68 80 83 87 90 91 93 94 96 97 97 97 98 99 99 99 100 101 101 102 102 103

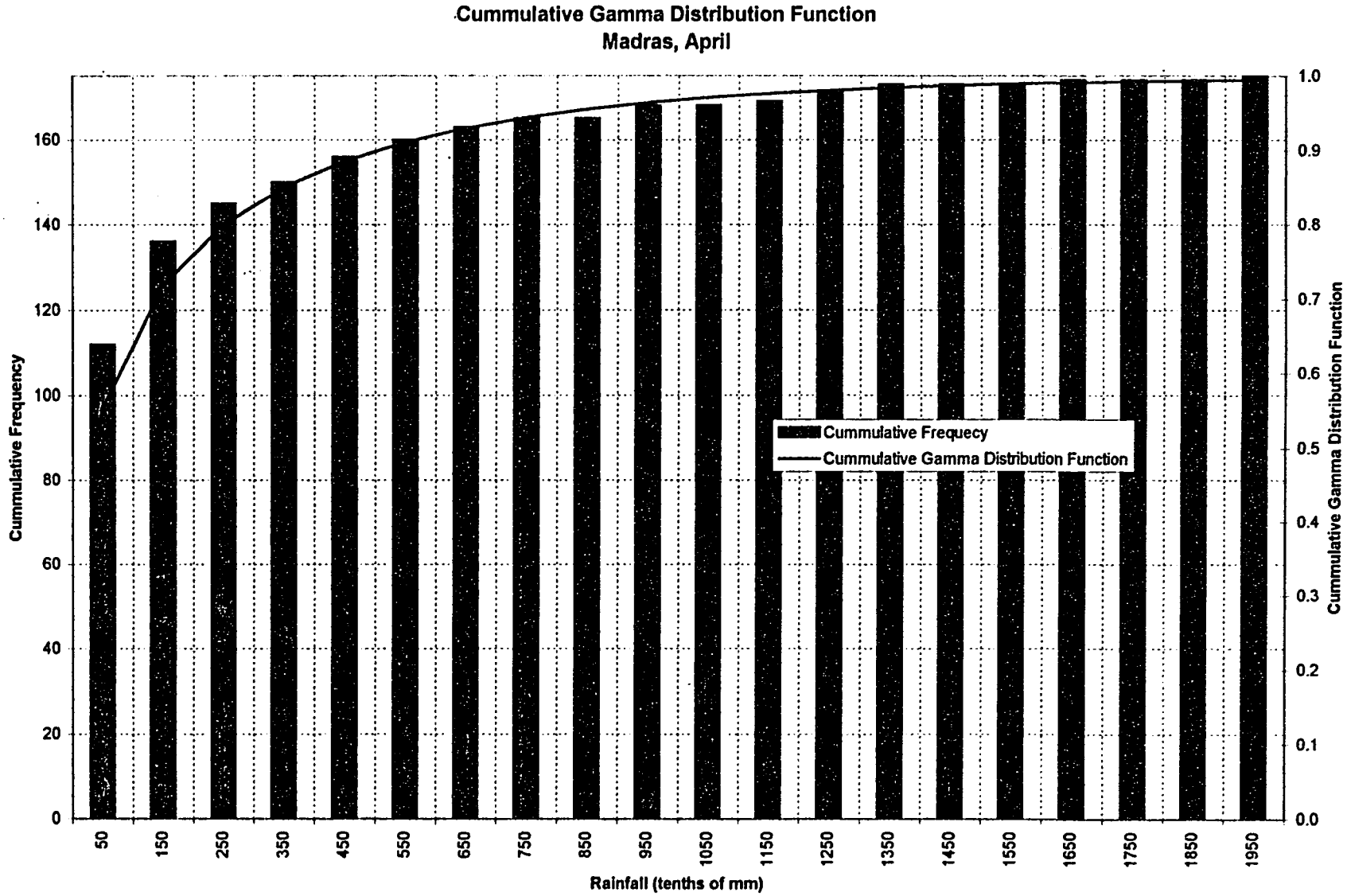
Frequency Histogram

min	0
max	1910
alpha	0.267037199
beta	628.4410696

Station 27 Madras, April

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 - 99	50	112	112	0.00278	0.55405
100 - 199	150	24	136	0.00106	0.71975
200 - 299	250	9	145	0.00062	0.80053
300 - 399	350	5	150	0.00041	0.85124
400 - 499	450	6	156	0.00029	0.88615
500 - 599	550	4	160	0.00022	0.91139
600 - 699	650	3	163	0.00016	0.93021
700 - 799	750	2	165	0.00013	0.94453
800 - 899	850	0	165	0.00010	0.95560
900 - 999	950	3	168	0.00008	0.96426
1000 - 1099	1050	0	168	0.00006	0.97110
1100 - 1199	1150	1	169	0.00005	0.97653
1200 - 1299	1250	2	171	0.00004	0.98088
1300 - 1399	1350	2	173	0.00003	0.98438
1400 - 1499	1450	0	173	0.00003	0.98721
1500 - 1599	1550	0	173	0.00002	0.98950
1600 - 1699	1650	1	174	0.00002	0.99136
1700 1799	1750	0	174	0.00001	0.99288
1800 1899	1850	0	174	0.00001	0.99412
1900 1999	1950	1	175	0.00001	0.99514
		175			


Rainfall: Madras, April
Frequency Histogram
Gamma Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
20
40
60
80
100
120
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025
0.0030
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1850
1950

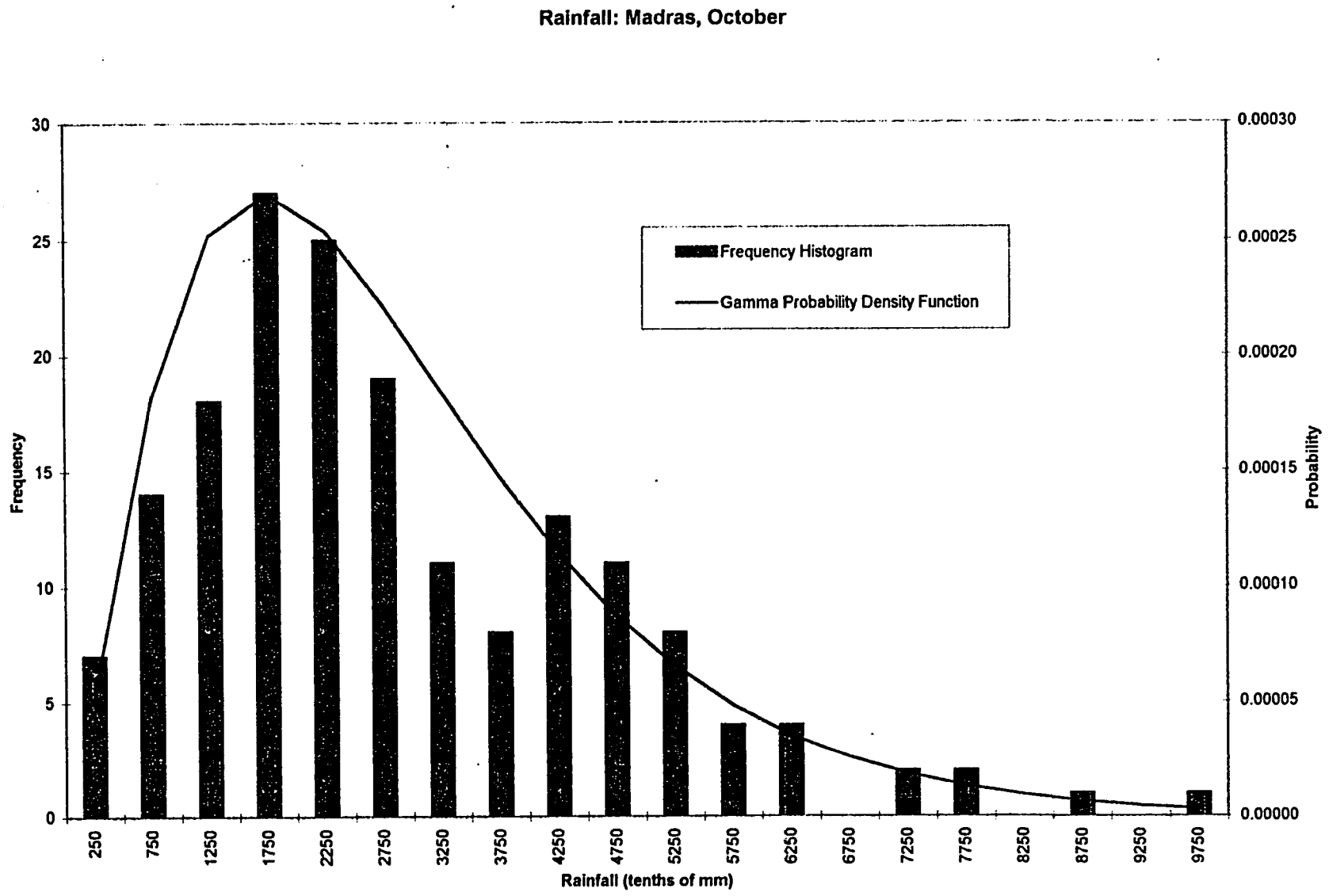

Cummulative Gamma Distribution Function
Madras, April
Cummulative Frequency
Cummulative Gamma Distribution Function
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
0
20
40
60
80
100
120
140
160
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1850
1950

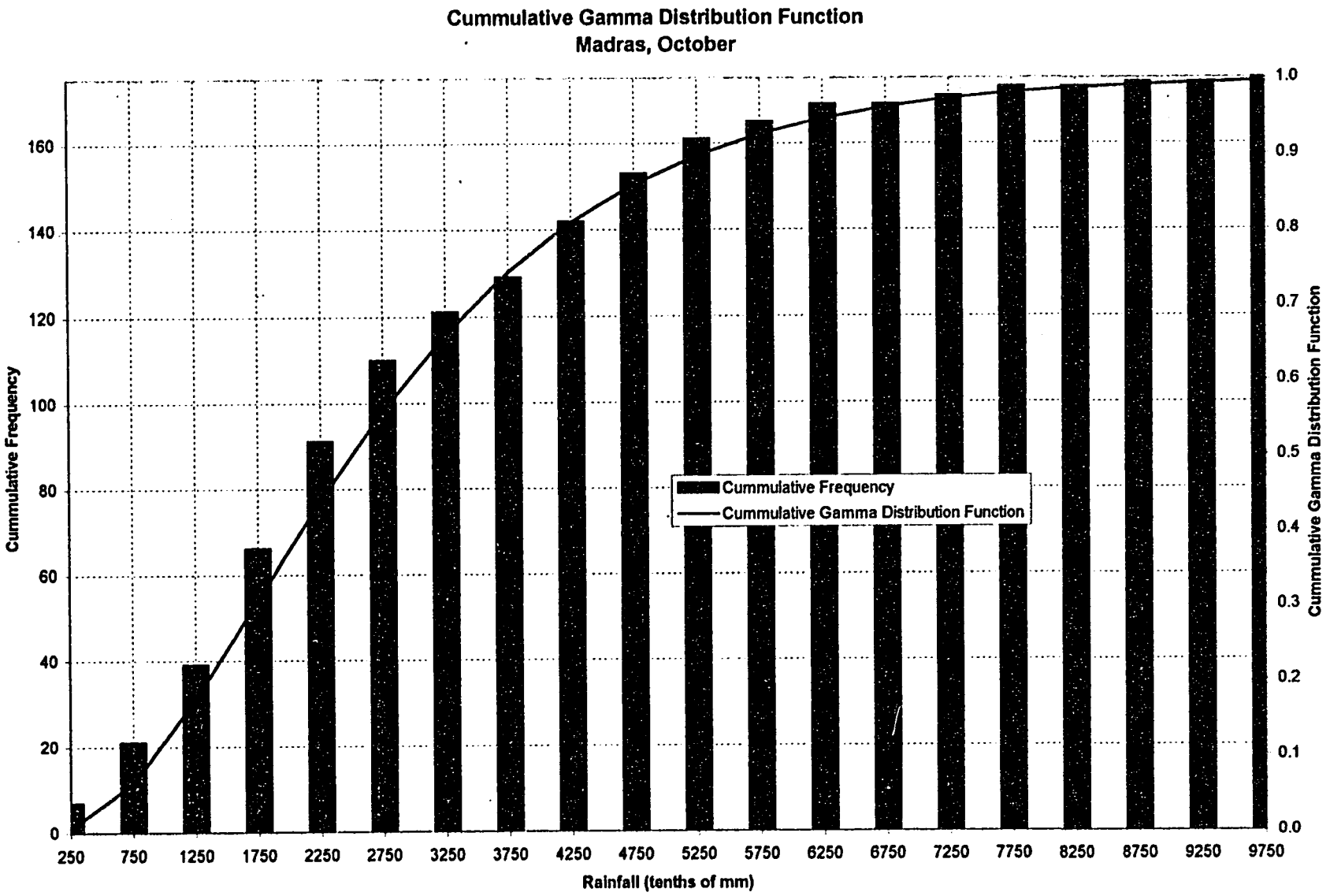
Frequency Histogram

min	0
max	9583
alpha	2.500758968
beta	1142.508007

Station 27 Madras, October

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 - 499	250	7	7	0.00005	0.00576
500 - 999	750	14	21	0.00018	0.06632
1000 - 1499	1250	18	39	0.00025	0.17731
1500 - 1999	1750	27	66	0.00027	0.30960
2000 - 2499	2250	25	91	0.00025	0.44152
2500 - 2999	2750	19	110	0.00022	0.56080
3000 - 3499	3250	11	121	0.00018	0.66218
3500 - 3999	3750	8	129	0.00015	0.74475
4000 - 4499	4250	13	142	0.00011	0.80994
4500 - 4999	4750	11	153	0.00009	0.86019
5000 - 5499	5250	8	161	0.00007	0.89821
5500 - 5999	5750	4	165	0.00005	0.92654
6000 - 6499	6250	4	169	0.00004	0.94739
6500 - 6999	6750	0	169	0.00003	0.96257
7000 - 7499	7250	2	171	0.00002	0.97352
7500 - 7999	7750	2	173	0.00001	0.98137
8000 - 8499	8250	0	173	0.00001	0.98695
8500 8999	8750	1	174	0.00001	0.99090
9000 9499	9250	0	174	0.00000	0.99368
9500 9999	9750	1	175	0.00000	0.99562
		175			


Rainfall: Madras, October
Frequency Histogram
Gamma Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
5
10
15
20
25
30
0.00000
0.00005
0.00010
0.00015
0.00020
0.00025
0.00030
250
750
1250
1750
2250
2750
3250
3750
4250
4750
5250
5750
6250
6750
7250
7750
8250
8750
9250
9750

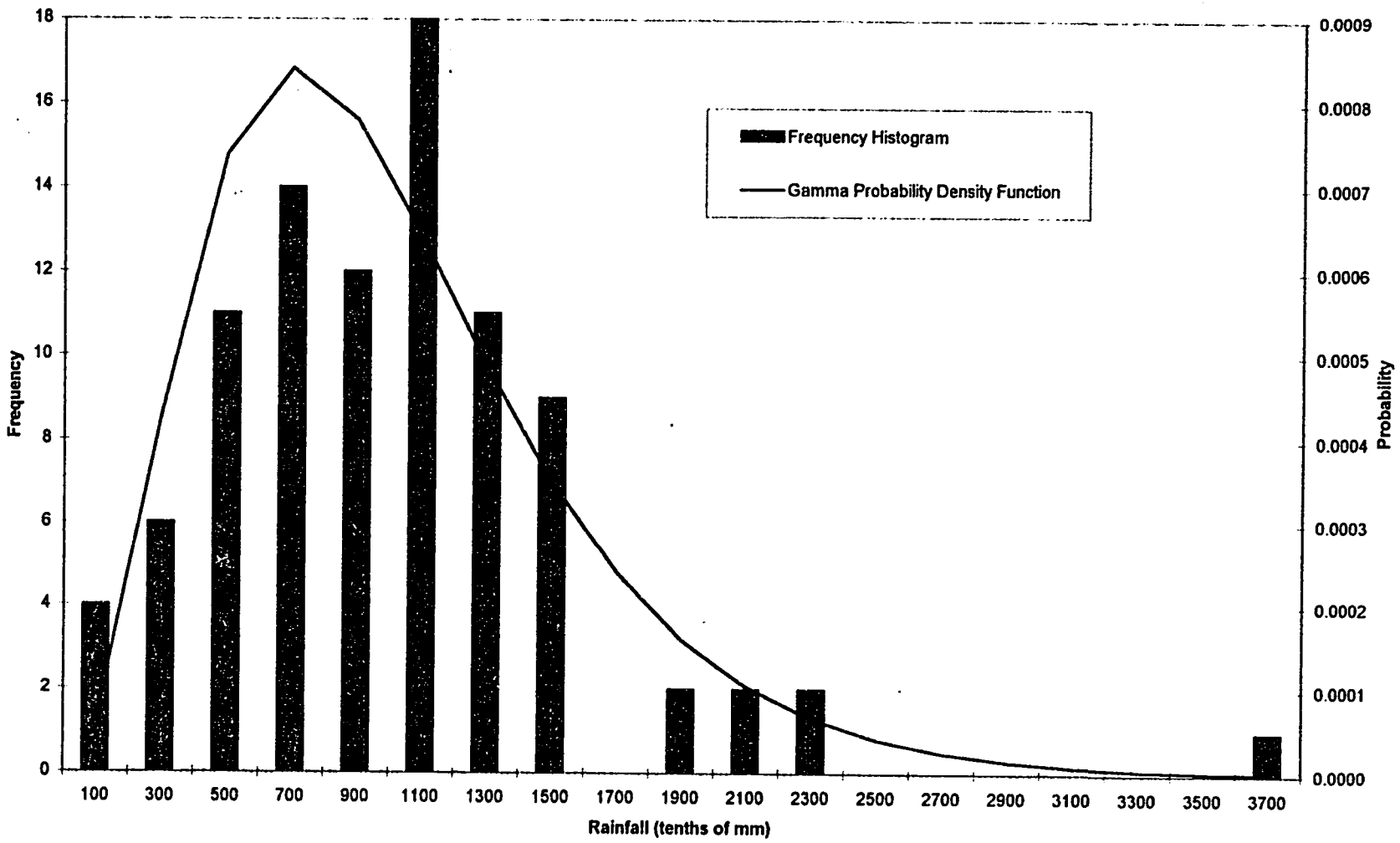

Cummulative Gamma Distribution Function
Madras, October
Cummulative Frequency
Cummulative Gamma Distribution Function
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
0
20
40
60
80
100
120
140
160
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
250
750
1250
1750
2250
2750
3250
3750
4250
4750
5250
5750
6250
6750
7250
7750
8250
8750
9250
9750

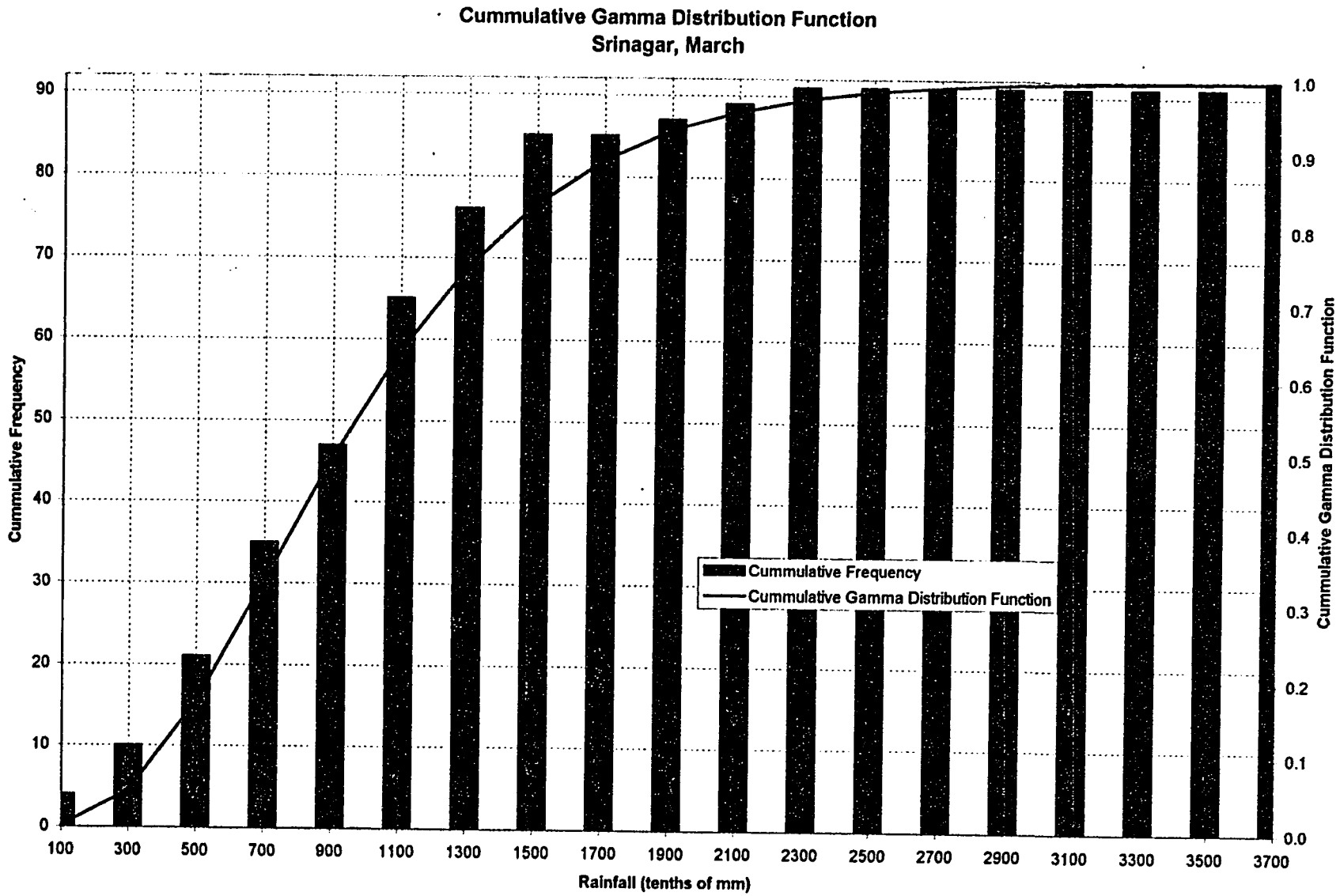
Frequency Histogram

min	0
max	3650
alpha	3.385614811
beta	296.5231131

Station 38 Srinagar, March

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 - 199	100	4	4	0.00006	0.00196
200 - 399	300	6	10	0.00043	0.04878
400 - 599	500	11	21	0.00074	0.16892
600 - 799	700	14	35	0.00084	0.33041
800 - 999	900	12	47	0.00078	0.49456
1000 - 1199	1100	18	65	0.00064	0.63747
1200 - 1399	1300	11	76	0.00049	0.75025
1400 - 1599	1500	9	85	0.00035	0.83342
1600 - 1799	1700	0	85	0.00024	0.89178
1800 - 1999	1900	2	87	0.00016	0.93121
2000 - 2199	2100	2	89	0.00010	0.95707
2200 - 2399	2300	2	91	0.00007	0.97362
2400 - 2599	2500	0	91	0.00004	0.98401
2600 - 2799	2700	0	91	0.00002	0.99042
2800 - 2999	2900	0	91	0.00001	0.99432
3000 - 3199	3100	0	91	0.00001	0.99666
3200 - 3399	3300	0	91	0.00001	0.99805
3400 3599	3500	0	91	0.00000	0.99887
3600 3799	3700	1	92	0.00000	0.99935
		92			


Rainfall: Srinagar, March
Frequency Histogram
Gamma Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
2
4
6
8
10
12
14
16
18
0.0000
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
0.0007
0.0008
0.0009
100
300
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700


Cummulative Gamma Distribution Function
Srinagar, March
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
0
10
20
30
40
50
60
70
80
90
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
100
300
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700

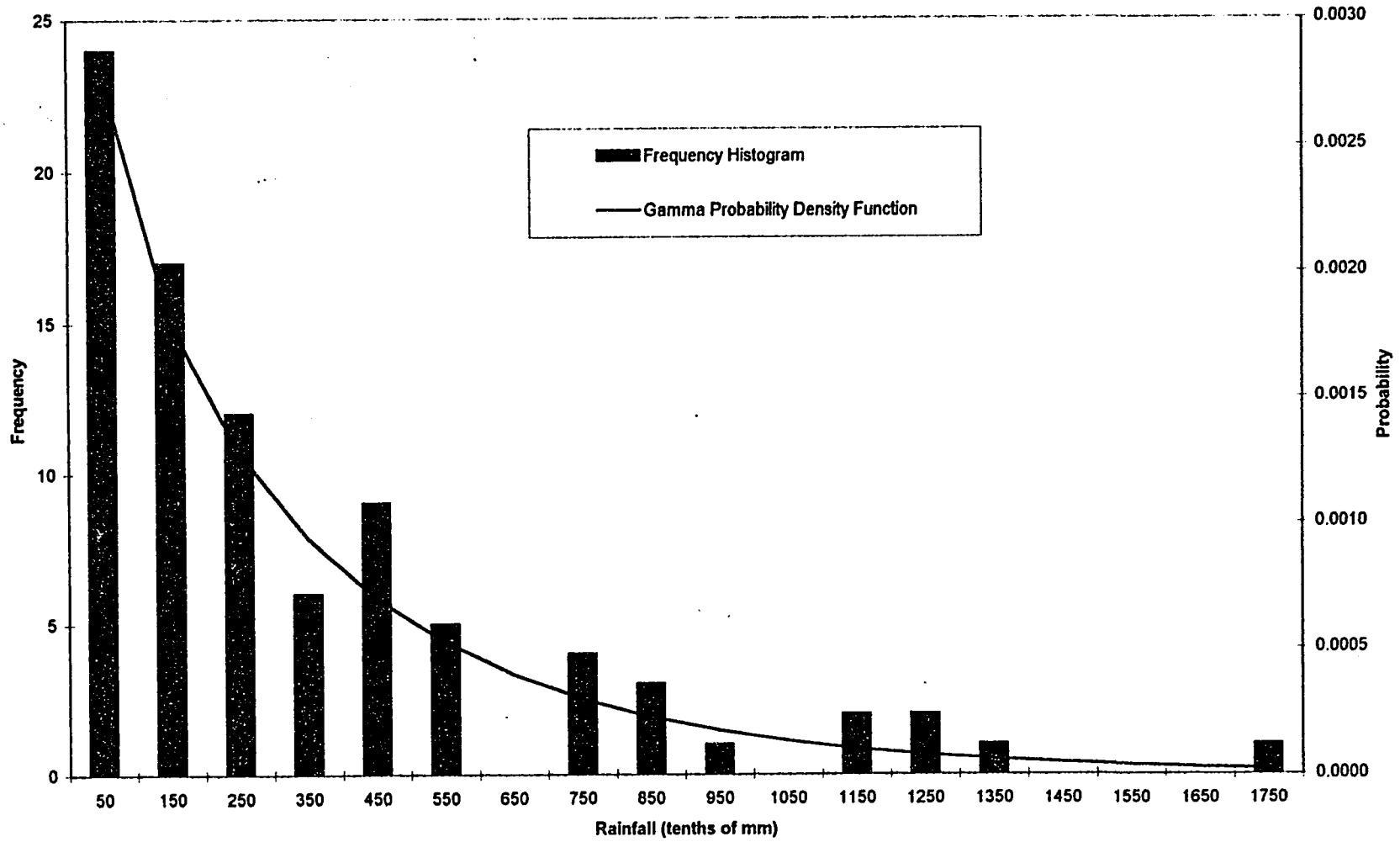
Frequency Histogram

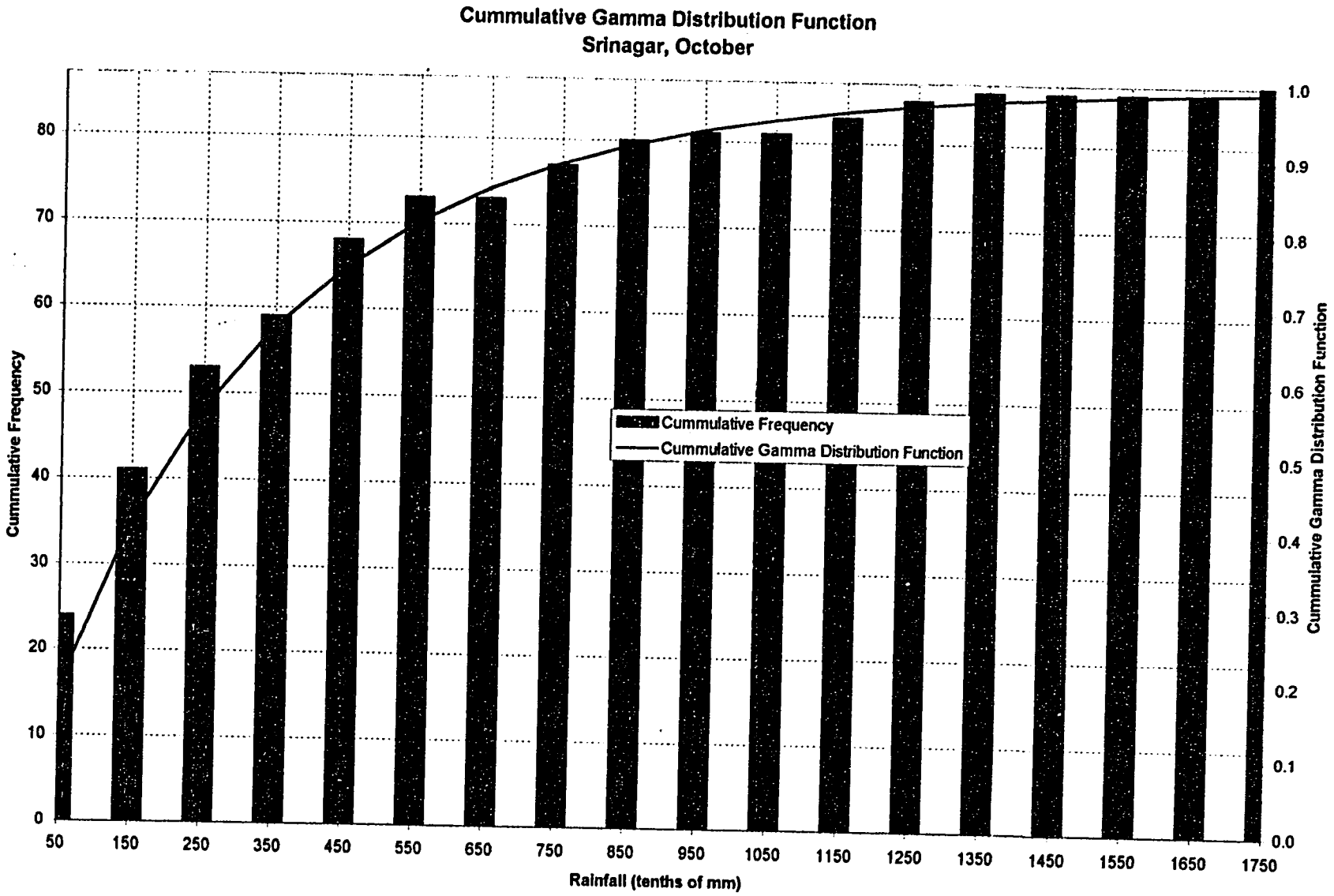
min	0
max	1710
alpha	0.831421774
beta	395.6662279

Station 38 Srinagar, October

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 - 100	50	24	24	0.00279	0.18001
100 - 200	150	17	41	0.00180	0.40232
200 - 300	250	12	53	0.00128	0.55458
300 - 400	350	6	59	0.00094	0.66482
400 - 500	450	9	68	0.00070	0.74634
500 - 600	550	5	73	0.00053	0.80729
600 - 700	650	0	73	0.00040	0.85318
700 - 800	750	4	77	0.00030	0.88791
800 - 900	850	3	80	0.00023	0.91428
900 - 1000	950	1	81	0.00017	0.93435
1000 - 1100	1050	0	81	0.00013	0.94967
1100 - 1200	1150	2	83	0.00010	0.96137
1200 - 1300	1250	2	85	0.00008	0.97033
1300 - 1400	1350	1	86	0.00006	0.97720
1400 - 1500	1450	0	86	0.00005	0.98246
1500 - 1600	1550	0	86	0.00004	0.98650
1600 - 1700	1650	0	86	0.00003	0.98961
1700 - 1799	1750	1	87	0.00002	0.99200
		87			

Rainfall: Srinagar, October



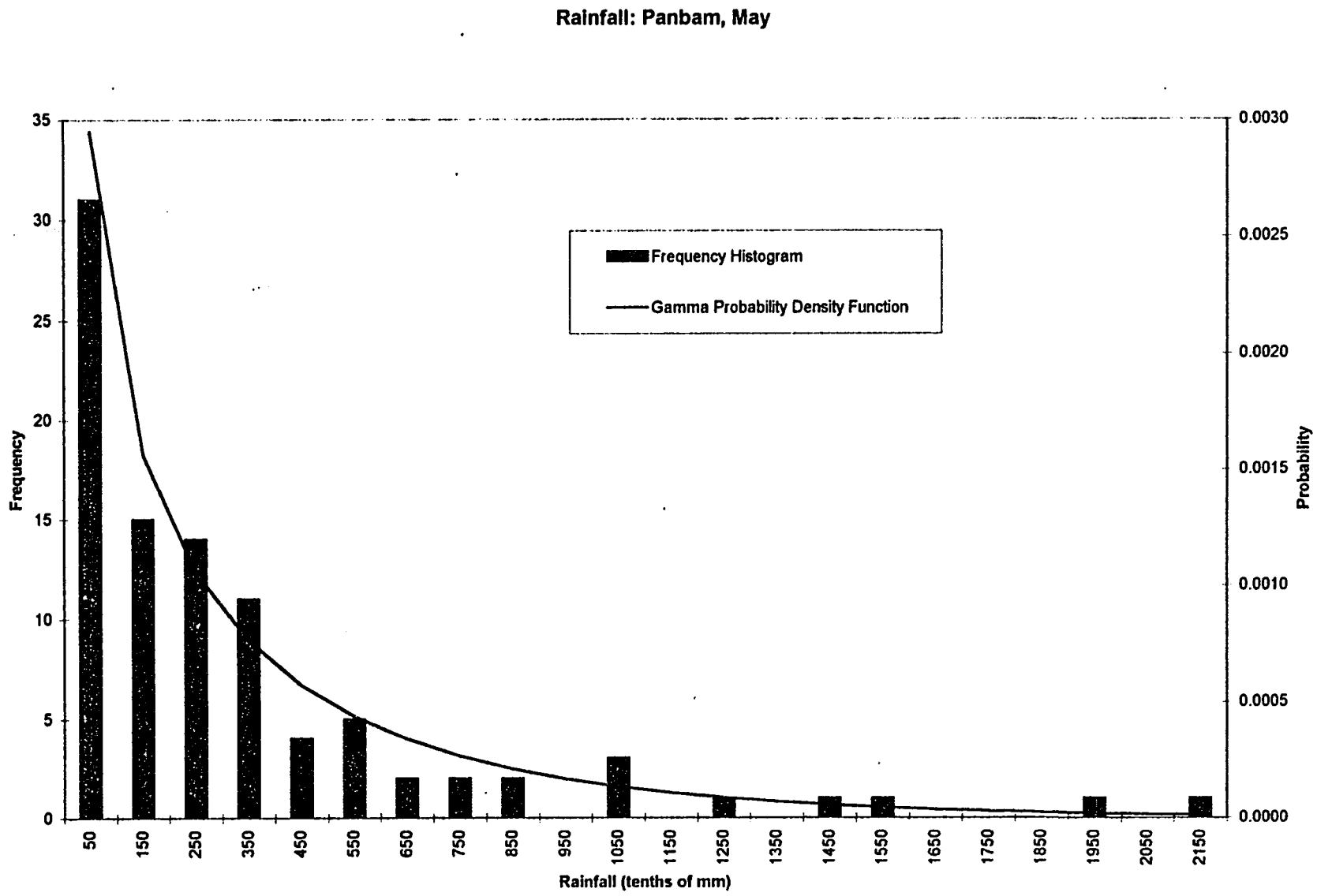

Cummulative Gamma Distribution Function
Srinagar, October
Cummulative Frequency
Cummulative Gamma Distribution Function
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
0
10
20
30
40
50
60
70
80
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750

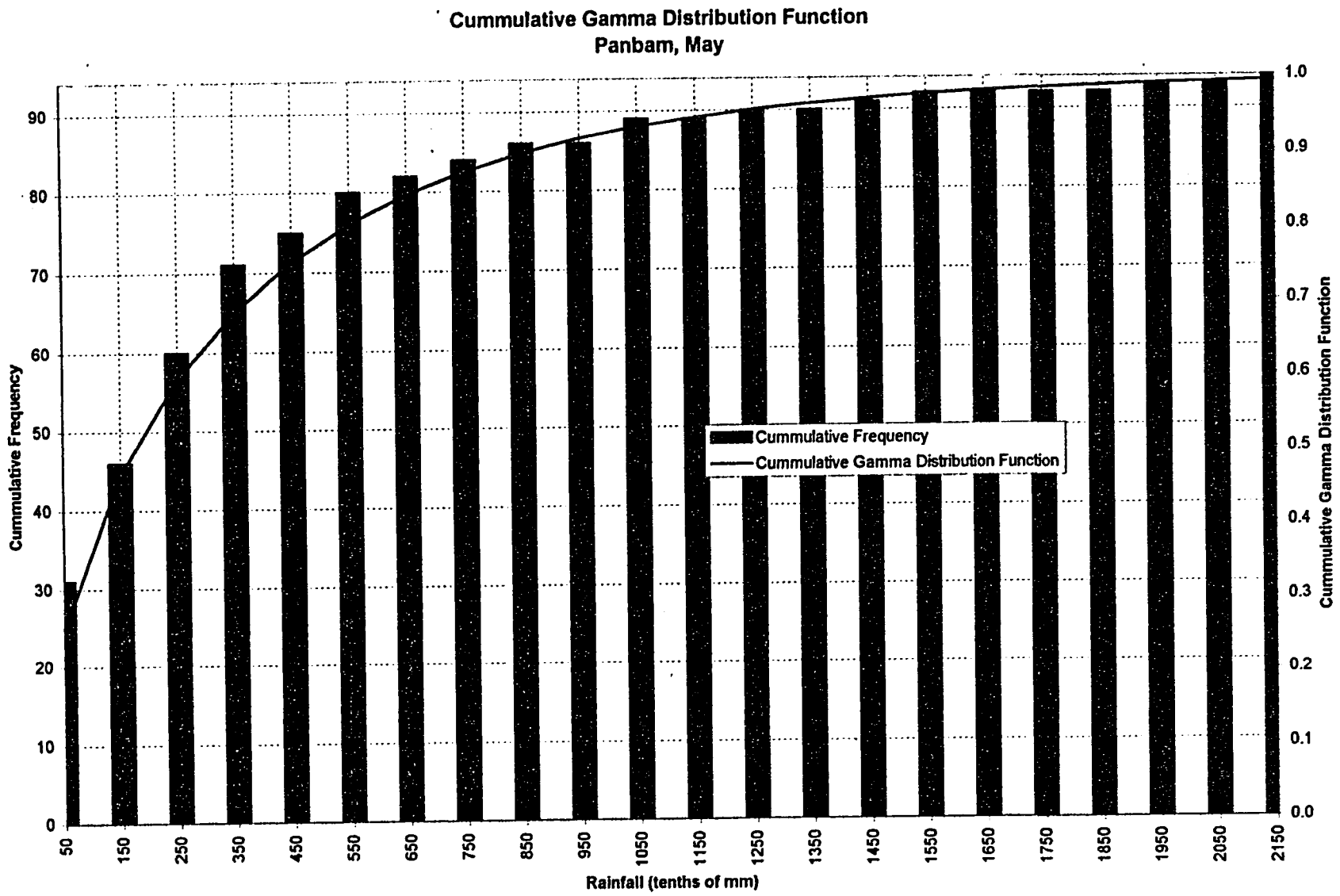
Frequency Histogram

min	0
max	2170
alpha	0.591192254
beta	543.4384391

Station 40 Panbam, May

Class Interval		Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 -	99	50	31	31	0.00295	0.26430
100 -	199	150	15	46	0.00157	0.47401
200 -	299	250	14	60	0.00106	0.60231
300 -	399	350	11	71	0.00077	0.69234
400 -	499	450	4	75	0.00058	0.75881
500 -	599	550	5	80	0.00044	0.80925
600 -	699	650	2	82	0.00034	0.84817
700 -	799	750	2	84	0.00027	0.87857
800 -	899	850	2	86	0.00021	0.90251
900 -	999	950	0	86	0.00017	0.92148
1000 -	1099	1050	3	89	0.00013	0.93660
1100 -	1199	1150	0	89	0.00011	0.94869
1200 -	1299	1250	1	90	0.00009	0.95840
1300 -	1399	1350	0	90	0.00007	0.96622
1400 -	1499	1450	1	91	0.00006	0.97253
1500 -	1599	1550	1	92	0.00005	0.97763
1600 -	1699	1650	0	92	0.00004	0.98177
1700	1799	1750	0	92	0.00003	0.98512
1800	1899	1850	0	92	0.00002	0.98785
1900	1999	1950	1	93	0.00002	0.99007
2000	2099	2050	0	93	0.00002	0.99188
2100	2199	2150	1	94	0.00001	0.99335
			94			

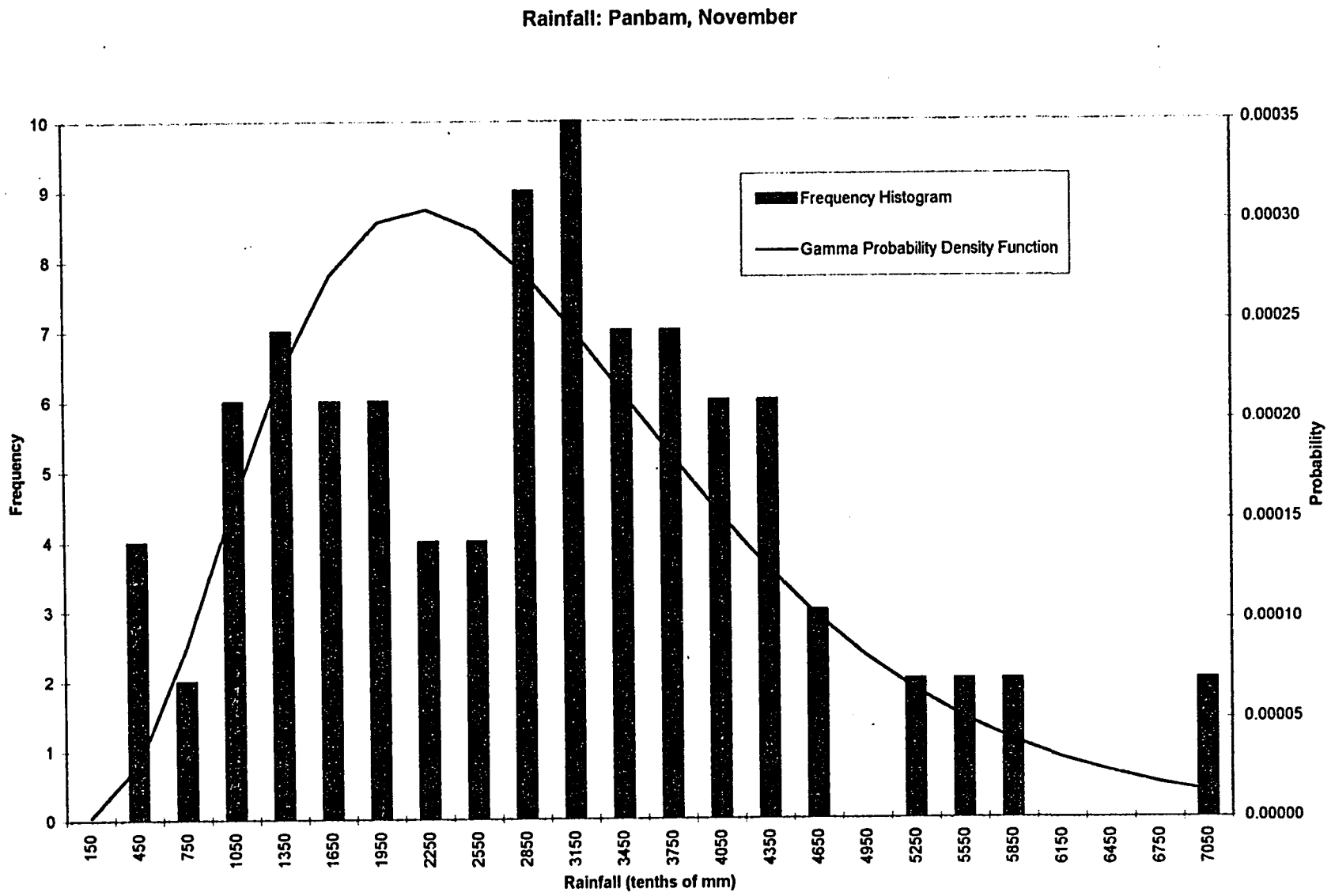

Rainfall: Panbam, May
Frequency Histogram
Gamma Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
5
10
15
20
25
30
35
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025
0.0030
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1850
1950
2050
2150

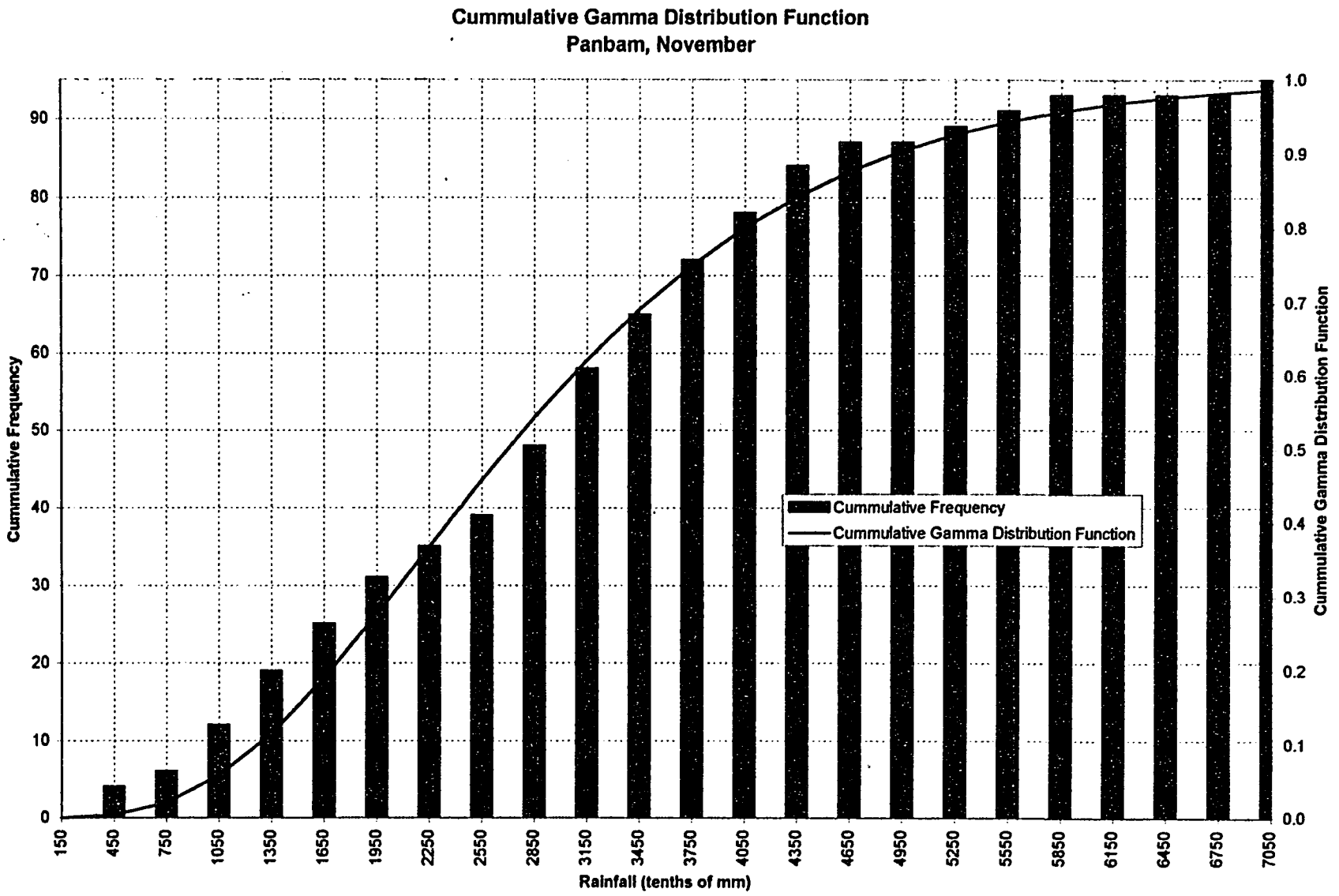

Cummulative Gamma Distribution Function
Panbam, May
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
0
10
20
30
40
50
60
70
80
90
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1850
1950
2050
2150

Frequency Histogram	
min	0
max	6920
alpha	4.007677669
beta	731.1492511

Station 40 Panbam, November

Class Interval	Interval Midpoint	Frequency	Cummulative Frequency	Gamma Probability Density Function	Cummulative Gamma Distribution Function
0 - 299	150	0	0	0.00000	0.00006
300 - 599	450	4	4	0.00003	0.00362
600 - 899	750	2	6	0.00009	0.02037
900 - 1199	1050	6	12	0.00016	0.05734
1200 - 1499	1350	7	19	0.00023	0.11540
1500 - 1799	1650	6	25	0.00027	0.19073
1800 - 2099	1950	6	31	0.00030	0.27723
2100 - 2399	2250	4	35	0.00031	0.36853
2400 - 2699	2550	4	39	0.00030	0.45909
2700 - 2999	2850	9	48	0.00027	0.54477
3000 - 3299	3150	10	58	0.00025	0.62284
3300 - 3599	3450	7	65	0.00021	0.69188
3600 - 3899	3750	7	72	0.00018	0.75140
3900 - 4199	4050	6	78	0.00015	0.80166
4200 - 4499	4350	6	84	0.00013	0.84335
4500 - 4799	4650	3	87	0.00010	0.87739
4800 - 5099	4950	0	87	0.00008	0.90483
5100 5399	5250	2	89	0.00006	0.92667
5400 5699	5550	2	91	0.00005	0.94389
5700 5999	5850	2	93	0.00004	0.95733
6000 6299	6150	0	93	0.00003	0.96774
6300 6599	6450	0	93	0.00002	0.97574
6600 6899	6750	0	93	0.00002	0.98184
6900 7199	7050	2	95	0.00001	0.98647
		95			


Rainfall: Panbam, November
Frequency Histogram
Gamma Probability Density Function
Frequency
Probability
Rainfall (tenths of mm)
0
1
2
3
4
5
6
7
8
9
10
0.00000
0.00005
0.00010
0.00015
0.00020
0.00025
0.00030
0.00035
150
450
750
1050
1350
1650
1950
2250
2550
2850
3150
3450
3750
4050
4350
4650
4950
5250
5550
5850
6150
6450
6750
7050


Cummulative Gamma Distribution Function
Panbam, November
Cummulative Frequency
Cummulative Gamma Distribution Function
Rainfall (tenths of mm)
Cummulative Frequency
Cummulative Gamma Distribution Function
0
10
20
30
40
50
60
70
80
90
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
150
450
750
1050
1350
1650
1950
2250
2550
2850
3150
3450
3750
4050
4350
4650
4950
5250
5550
5850
6150
6450
6750
7050

APPENDIX S

EFFECTIVE PRECIPITATION

ESTIMATES OF EFFECTIVE RAINFALL

20th Percentile
Normal Distribution
Gamma Distribution

Effective Rainfall, Pe (mm)

St# Eto	Station Name	Lat(N)	Long(E)	Elev(m)		Effective Rainfall, Pe (mm) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	Agra	27.2	78.0	169	20th %tile	0.0	0.0	0.0	0.0	1.0	14.6	114.8	112.4	29.6	0.0	0.0	0.0
					20% Prob (Normal)	1.7	0.0	0.0	0.0	0.0	6.9	121.5	120.4	35.5	0.0	0.0	0.0
					20% Prob (Gamma)	2.7	0.3	0.1	0.0	1.3	11.5	120.6	119.7	39.1	0.1	0.0	0.1
					Difference	1.0	0.3	0.1	0.0	1.3	4.6	0.9	0.7	3.6	0.1	0.0	0.1
					Minimun	1.7	0.0	0.0	0.0	0.0	6.9	120.6	119.7	35.5	0.0	0.0	0.0
2	Ahmadabad	23.1	72.6	55	20th %tile	0.0	0.0	0.0	0.0	0.0	26.8	141.8	93.4	19.7	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	1.7	95.4	65.5	1.2	0.0	0.0	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	0.0	0.0	14.5	104.0	71.0	19.0	0.0	0.0	0.0
					Difference	0.0	0.0	0.0	0.0	0.0	12.9	8.6	5.5	17.8	0.0	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	1.7	95.4	65.5	1.2	0.0	0.0	0.0
3	Akola	20.7	77.0	282	20th %tile	0.0	0.0	0.0	0.0	0.0	70.0	142.0	93.0	61.0	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	77.2	138.5	83.6	56.1	0.0	0.0	0.0
					20% Prob (Gamma)	0.3	0.1	0.1	0.0	0.1	76.6	137.3	83.3	57.8	4.8	0.0	0.0
					Difference	0.3	0.1	0.1	0.0	0.1	0.6	1.2	0.3	1.7	4.8	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	76.6	137.3	83.3	56.1	0.0	0.0	0.0
4	Allahabad/Bamhrauli	25.5	81.7	98	20th %tile	0.0	0.5	0.0	0.0	0.0	20.6	179.2	188.0	78.8	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	13.9	181.6	173.1	75.6	0.0	0.0	0.0
					20% Prob (Gamma)	2.2	1.2	0.2	0.0	0.1	20.7	180.0	171.6	76.4	1.0	0.0	0.0
					Difference	2.2	1.2	0.2	0.0	0.1	6.7	1.7	1.5	0.8	1.0	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	13.9	180.0	171.6	75.6	0.0	0.0	0.0
5	Amini	11.1	72.7	4	20th %tile	0.0	0.0	0.0	0.0	28.0	260.3	172.4	81.6	57.8	75.8	16.9	0.4
					20% Prob (Normal)	0.0	0.0	0.0	0.0	18.8	259.5	173.9	89.4	60.4	77.4	16.4	0.0
					20% Prob (Gamma)	0.1	0.0	0.0	1.0	27.9	257.6	172.4	89.5	61.3	77.0	19.9	0.5
					Difference	0.1	0.0	0.0	1.0	9.1	2.0	1.5	0.2	0.9	0.5	3.5	0.5
					Minimun	0.0	0.0	0.0	0.0	18.8	257.6	172.4	89.4	60.4	77.0	16.4	0.0
6	Amritsar/Rajasansi	31.6	74.9	234	20th %tile	3.0	6.2	9.2	2.6	3.0	7.8	125.4	96.2	5.2	0.0	0.0	0.0
					20% Prob (Normal)	6.4	10.5	6.7	0.0	2.1	5.5	118.0	89.7	8.5	0.0	0.0	0.0
					20% Prob (Gamma)	7.7	10.7	8.6	0.4	3.4	9.5	117.0	89.3	16.6	0.0	0.0	1.1
					Difference	1.3	0.2	1.9	0.4	1.3	4.0	1.0	0.4	8.1	0.0	0.0	1.1
					Minimun	6.4	10.5	6.7	0.0	2.1	5.5	117.0	89.3	8.5	0.0	0.0	0.0
7	Bangalore	13.0	77.6	921	20th %tile	0.0	0.0	0.0	8.1	61.2	43.2	48.8	61.0	94.5	71.0	11.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	7.0	62.9	42.4	50.6	69.6	88.0	75.1	0.0	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	9.2	62.5	42.1	50.6	69.3	87.6	75.1	3.8	0.7
					Difference	0.0	0.0	0.0	2.2	0.5	0.3	0.0	0.3	0.4	0.0	3.8	0.7
					Minimun	0.0	0.0	0.0	7.0	62.5	42.1	50.6	69.3	87.6	75.1	0.0	0.0
8	Sagar	23.9	78.8	551	20th %tile	0.0	0.0	0.0	0.0	0.0	50.6	250.0	230.2	80.0	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	50.3	250.1	225.6	77.0	0.0	0.0	0.0
					20% Prob (Gamma)	1.4	0.9	0.1	0.0	0.3	52.4	247.8	223.7	78.5	1.6	0.0	0.0
					Difference	1.4	0.9	0.1	0.0	0.3	2.1	2.3	1.9	1.6	1.6	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	50.3	247.8	223.7	77.0	0.0	0.0	0.0
9	Bikaner	28.0	73.3	224	20th %tile	0.0	0.0	0.0	0.0	0.0	5.0	25.0	24.6	0.0	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	4.3	24.5	24.2	0.0	0.0	0.0	0.0
					20% Prob (Gamma)	0.3	0.1	0.1	0.0	1.0	6.6	26.9	26.8	2.6	0.0	0.0	0.0
					Difference	0.3	0.1	0.1	0.0	1.0	2.3	2.4	2.6	2.6	0.0	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	4.3	24.5	24.2	0.0	0.0	0.0	0.0
10	Bombay/Colaba,India	18.9	72.8	11	20th %tile	0.0	0.0	0.0	0.0	0.0	329.4	409.0	176.8	119.4	0.3	0.0	0.0

Effective Rainfall, Pe (mm)

St# Eto	Station Name	Lat(N)	Long(E)	Elev(m)		Effective Rainfall, Pe (mm) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	322.9	412.9	189.7	111.9	0.0	0.0	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	0.0	0.0	319.9	409.2	189.2	113.9	3.9	0.0	0.0
					Difference	0.0	0.0	0.0	0.0	0.0	3.0	3.7	0.4	2.1	3.9	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	319.9	409.2	189.2	111.9	0.0	0.0	0.0
11	Bombay/Santa Cruz	19.1	72.9	14	20th %tile	0.0	0.0	0.0	0.0	0.0	407.0	831.0	277.0	110.0	15.2	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	354.8	752.4	314.9	113.3	17.4	0.0	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	0.0	0.4	351.7	749.2	313.4	119.9	23.8	0.1	0.0
					Difference	0.0	0.0	0.0	0.0	0.4	3.2	3.1	1.5	6.6	6.4	0.1	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	351.7	749.2	313.4	113.3	17.4	0.0	0.0
12	Calcutta/Alipore	22.5	88.3	6	20th %tile	0.0	0.0	1.8	14.7	62.6	164.4	234.0	247.4	169.0	64.5	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.6	16.1	57.5	161.3	234.0	239.0	143.8	55.2	0.0	0.0
					20% Prob (Gamma)	0.6	2.7	4.7	17.3	57.9	160.0	232.2	237.1	142.8	55.8	0.1	0.0
					Difference	0.6	2.7	4.1	1.3	0.4	1.3	1.8	1.8	1.0	0.7	0.1	0.0
					Minimun	0.0	0.0	0.6	16.1	57.5	160.0	232.2	237.1	142.8	55.2	0.0	0.0
13	Calcutta/Dum Dum	22.7	88.5	6	20th %tile	0.0	0.6	3.4	18.2	71.2	159.6	201.2	231.8	201.2	63.8	0.0	0.0
					20% Prob (Normal)	0.0	0.0	6.1	5.1	38.8	150.6	215.6	213.7	181.5	57.0	0.0	0.0
					20% Prob (Gamma)	0.8	1.6	7.5	8.7	41.0	149.3	213.8	212.5	179.9	57.4	0.5	0.0
					Difference	0.8	1.6	1.4	3.6	2.2	1.3	1.8	1.2	1.7	0.4	0.5	0.0
					Minimun	0.0	0.0	6.1	5.1	38.8	149.3	213.8	212.5	179.9	57.0	0.0	0.0
14	Cuttack	20.5	85.9	27	20th %tile	0.0	0.0	0.0	1.0	36.0	139.2	244.6	203.4	173.6	50.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	1.2	30.0	129.1	224.7	209.2	164.2	57.7	0.0	0.0
					20% Prob (Gamma)	0.2	1.5	1.3	4.8	31.3	128.4	222.7	207.3	162.8	59.2	1.0	0.0
					Difference	0.2	1.5	1.3	3.6	1.2	0.7	1.9	1.9	1.5	1.5	1.0	0.0
					Minimun	0.0	0.0	0.0	1.2	30.0	128.4	222.7	207.3	162.8	57.7	0.0	0.0
15	Belguam/Samra	15.9	74.6	747	20th %tile	0.0	0.0	0.0	10.2	38.4	108.6	142.2	87.6	63.6	30.2	20.6	0.0
					20% Prob (Normal)	0.0	0.0	0.0	10.4	34.3	98.1	145.2	103.0	57.1	31.2	17.2	0.0
					20% Prob (Gamma)	0.0	0.0	0.6	11.9	34.5	97.7	144.0	102.1	56.9	31.7	18.1	0.0
					Difference	0.0	0.0	0.6	1.5	0.2	0.4	1.3	0.9	0.1	0.5	0.9	0.0
					Minimun	0.0	0.0	0.0	10.4	34.3	97.7	144.0	102.1	56.9	31.2	17.2	0.0
16	Dibrugarh/Mohanbari	27.5	95.0	111	20th %tile	15.0	23.0	50.0	147.0	192.4	345.2	406.4	313.6	224.6	74.4	5.0	1.2
					20% Prob (Normal)	12.8	29.0	51.3	140.8	199.4	346.1	406.0	331.6	223.1	69.7	3.0	0.5
					20% Prob (Gamma)	13.2	28.8	51.2	139.5	197.6	343.9	403.8	329.6	221.1	69.9	5.6	2.7
					Difference	0.4	0.2	0.1	1.3	1.8	2.2	2.2	2.1	2.0	0.3	2.6	2.2
					Minimun	12.8	28.8	51.2	139.5	197.6	343.9	403.8	329.6	221.1	69.7	3.0	0.5
17	Masulipatam	16.2	81.1	3	20th %tile	0.0	0.0	0.0	0.0	4.6	43.6	100.6	79.5	83.8	84.5	6.6	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	50.7	96.0	86.8	94.6	92.1	10.8	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	0.1	2.9	50.6	95.2	86.2	93.8	93.4	22.2	0.0
					Difference	0.0	0.0	0.0	0.1	2.9	0.1	0.8	0.6	0.8	1.3	11.4	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	50.6	95.2	86.2	93.8	92.1	10.8	0.0
18	Gauhti	26.1	91.6	54	20th %tile	0.0	3.3	13.0	89.0	169.8	220.9	218.2	172.9	105.8	29.1	0.0	0.0
					20% Prob (Normal)	0.0	2.7	16.6	83.8	161.3	224.5	220.1	178.6	104.0	28.3	0.7	0.0
					20% Prob (Gamma)	0.9	4.3	17.9	83.2	159.9	222.8	218.4	177.1	103.1	29.6	2.4	0.0
					Difference	0.9	1.6	1.3	0.7	1.4	1.7	1.7	1.5	0.9	1.3	1.7	0.0
					Minimun	0.0	2.7	16.6	83.2	159.9	222.8	218.4	177.1	103.1	28.3	0.7	0.0
19	Goa/Panjim	15.5	73.8	57	20th %tile	0.0	0.0	0.0	0.0	3.6	703.8	677.2	327.2	126.2	26.4	5.2	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	633.4	693.6	338.1	109.7	22.8	0.0	0.0

Effective Rainfall, Pe (mm)

St# Eto	Station Name	Lat(N)	Long(E)	Elev(m)		Effective Rainfall, Pe (mm) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
					20% Prob (Gamma)	0.0	0.0	0.0	0.1	2.2	629.6	689.9	335.0	110.1	29.2	3.5	0.0
					Difference	0.0	0.0	0.0	0.1	2.2	3.7	3.7	3.1	0.4	6.3	3.5	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	629.6	689.9	335.0	109.7	22.8	0.0	0.0
20	Begampet	17.5	78.5	545	20th %tile	0.0	0.0	0.0	2.0	4.0	51.6	108.8	84.2	82.4	23.8	3.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	3.9	55.6	104.3	84.0	84.7	24.5	0.0	0.0
					20% Prob (Gamma)	0.0	0.2	0.0	2.7	6.1	55.3	103.3	83.4	84.5	26.9	1.2	0.0
					Difference	0.0	0.2	0.0	2.7	2.2	0.4	1.0	0.7	0.3	2.4	1.2	0.0
					Minimun	0.0	0.0	0.0	0.0	3.9	55.3	103.3	83.4	84.5	24.5	0.0	0.0
21	Indore	22.7	75.8	567	20th %tile	0.0	0.0	0.0	0.0	0.0	63.0	179.0	139.8	58.0	0.6	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	59.8	171.6	138.6	68.9	0.0	0.0	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	0.0	0.3	60.3	170.0	137.6	71.0	4.1	0.1	0.0
					Difference	0.0	0.0	0.0	0.0	0.3	0.5	1.6	1.1	2.0	4.1	0.1	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	59.8	170.0	137.6	68.9	0.0	0.0	0.0
22	Jogdalapur	19.1	82.0	553	20th %tile	0.0	0.0	0.0	23.2	25.2	136.2	258.4	285.8	172.0	39.8	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.2	23.4	28.0	146.6	266.6	263.4	159.3	36.3	0.0	0.0
					20% Prob (Gamma)	0.1	0.1	2.2	23.5	28.2	145.2	264.6	261.3	157.9	37.8	1.6	0.0
					Difference	0.1	0.1	1.9	0.1	0.3	1.3	2.0	2.2	1.4	1.6	1.6	0.0
					Minimun	0.0	0.0	0.2	23.4	28.0	145.2	264.6	261.3	157.9	36.3	0.0	0.0
23	Jaipur/Sanganer	26.8	75.8	390	20th %tile	0.0	0.0	0.0	0.0	0.3	12.8	115.7	54.5	18.3	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	4.2	109.7	81.1	13.3	0.0	0.0	0.0
					20% Prob (Gamma)	0.8	0.3	0.2	0.0	1.8	10.1	108.9	82.8	18.8	0.0	0.0	0.1
					Difference	0.8	0.3	0.2	0.0	1.8	5.9	0.8	1.7	5.5	0.0	0.0	0.1
					Minimun	0.0	0.0	0.0	0.0	0.0	4.2	108.9	81.1	13.3	0.0	0.0	0.0
24	Jodhpur	26.3	73.0	224	20th %tile	0.0	0.0	0.0	0.0	0.0	4.8	39.0	27.8	3.0	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	0.3	38.5	33.4	0.0	0.0	0.0	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	0.0	0.2	4.5	40.4	37.7	5.7	0.0	0.0	0.0
					Difference	0.0	0.0	0.0	0.0	0.2	4.3	2.0	4.2	5.7	0.0	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	0.3	38.5	33.4	0.0	0.0	0.0	0.0
25	Kodaikanal	10.2	77.5	2343	20th %tile	8.9	3.6	7.4	75.4	96.0	63.2	71.0	101.0	96.0	149.9	117.3	30.5
					20% Prob (Normal)	0.0	0.0	6.1	63.8	101.4	63.2	66.4	95.4	99.6	164.8	125.9	43.6
					20% Prob (Gamma)	10.0	4.5	10.6	64.2	100.5	62.6	65.9	94.6	98.8	163.3	125.5	45.9
					Difference	10.0	4.5	4.5	0.3	0.9	0.6	0.5	0.8	0.8	1.5	0.5	2.2
					Minimun	0.0	0.0	6.1	63.8	100.5	62.6	65.9	94.6	98.8	163.3	125.5	43.6
26	Kota	25.2	75.9	257	20th %tile	0.0	0.0	0.0	0.0	0.0	19.0	152.2	137.6	35.0	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	19.3	153.0	128.8	33.9	0.0	0.0	0.0
					20% Prob (Gamma)	0.4	0.0	0.0	0.0	0.4	21.3	151.8	128.2	37.7	0.0	0.0	0.0
					Difference	0.4	0.0	0.0	0.0	0.4	2.0	1.1	0.6	3.8	0.0	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	19.3	151.8	128.2	33.9	0.0	0.0	0.0
27	Madras/Minambakkam	13.0	80.2	16	20th %tile	0.0	0.0	0.0	0.0	0.0	19.8	48.0	62.9	59.1	133.9	134.5	17.8
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	19.7	50.7	64.9	60.4	133.7	154.9	18.9
					20% Prob (Gamma)	0.9	0.0	0.0	0.1	0.1	20.3	50.5	64.5	60.3	133.9	155.7	28.9
					Difference	0.9	0.0	0.0	0.1	0.1	0.6	0.2	0.4	0.1	0.2	0.8	10.0
					Minimun	0.0	0.0	0.0	0.0	0.0	19.7	50.5	64.5	60.3	133.7	154.9	18.9
28	Minicoy	8.3	73.0	2	20th %tile	3.5	0.4	0.0	16.5	95.9	204.2	135.0	99.4	61.7	84.5	62.0	22.4
					20% Prob (Normal)	0.0	0.0	0.0	14.0	88.4	206.0	139.2	116.2	83.3	97.7	72.0	9.0
					20% Prob (Gamma)	3.9	0.9	2.3	16.4	88.4	204.5	137.9	115.3	83.0	97.0	71.7	16.7

Effective Rainfall, Pe (mm)

St# Eto	Station Name	Lat(N)	Long(E)	Elev(m)		Effective Rainfall, Pe (mm) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
					Difference	3.9	0.9	2.3	2.4	0.1	1.6	1.3	0.9	0.2	0.7	0.3	7.7
					Minimun	0.0	0.0	0.0	14.0	88.4	204.5	137.9	115.3	83.0	97.0	71.7	9.0
29	Nagpur/Sonegaon	21.1	79.1	310	20th %tile	0.0	0.0	0.0	0.0	1.0	110.7	220.9	177.1	91.7	1.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	114.2	239.3	173.4	98.5	0.0	0.0	0.0
					20% Prob (Gamma)	0.1	0.6	1.0	0.5	1.1	113.3	237.4	171.8	98.1	6.4	0.1	0.0
					Difference	0.1	0.6	1.0	0.5	1.1	0.9	1.9	1.6	0.4	6.4	0.1	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	113.3	237.4	171.8	98.1	0.0	0.0	0.0
30	New Dehli-Safarjung	28.6	77.2	216	20th %tile	1.0	0.0	0.0	0.0	1.1	18.3	110.5	81.7	19.6	0.0	0.0	0.0
					20% Prob (Normal)	1.0	0.0	0.0	0.0	0.2	9.0	106.4	84.6	30.5	0.0	0.0	0.0
					20% Prob (Gamma)	3.6	1.6	1.7	0.0	2.1	14.1	105.8	85.6	34.9	0.0	0.0	0.1
					Difference	2.5	1.6	1.7	0.0	1.9	5.1	0.6	0.9	4.4	0.0	0.0	0.1
					Minimun	1.0	0.0	0.0	0.0	0.2	9.0	105.8	84.6	30.5	0.0	0.0	0.0
31	Dwarka	22.4	69.1	11	20th %tile	0.0	0.0	0.0	0.0	0.0	1.0	49.0	13.0	1.0	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	0.0	34.1	7.2	0.0	0.0	0.0	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	0.0	0.0	3.3	44.7	14.4	1.4	0.0	0.0	0.0
					Difference	0.0	0.0	0.0	0.0	0.0	3.3	10.5	7.3	1.4	0.0	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	0.0	34.1	7.2	0.0	0.0	0.0	0.0
32	Fort Cochin	10.0	76.2	3	20th %tile	0.0	0.0	8.1	60.3	152.4	561.1	425.8	220.2	126.6	182.3	78.3	5.0
					20% Prob (Normal)	0.0	0.0	9.2	64.8	150.7	550.7	408.0	203.9	135.8	191.9	80.5	0.0
					20% Prob (Gamma)	0.4	1.9	11.8	64.6	150.8	547.2	404.4	202.1	134.9	190.2	80.3	5.7
					Difference	0.4	1.9	2.6	0.2	0.1	3.5	3.6	1.8	0.9	1.7	0.1	5.7
					Minimun	0.0	0.0	9.2	64.6	150.7	547.2	404.4	202.1	134.9	190.2	80.3	0.0
33	Patna	25.6	85.2	53	20th %tile	0.0	0.8	0.0	0.0	3.4	69.9	196.1	188.1	107.7	2.7	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.4	66.8	190.6	188.2	115.5	3.1	0.0	0.0
					20% Prob (Gamma)	1.8	2.3	0.3	0.4	4.9	68.4	188.9	186.5	114.8	10.0	0.0	0.0
					Difference	1.8	2.3	0.3	0.4	4.5	1.6	1.6	1.7	0.7	6.9	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.4	66.8	188.9	186.5	114.8	3.1	0.0	0.0
34	Port Blair	11.7	92.7	79	20th %tile	1.3	0.0	0.0	9.3	236.8	354.1	256.3	290.0	335.2	187.2	117.3	39.0
					20% Prob (Normal)	0.0	0.0	0.0	10.0	233.7	359.9	268.6	273.7	333.4	203.1	115.3	37.0
					20% Prob (Gamma)	0.8	0.5	0.1	14.4	231.5	357.4	266.2	271.3	330.8	201.5	114.8	43.4
					Difference	0.8	0.5	0.1	4.5	2.1	2.5	2.3	2.4	2.6	1.6	0.5	6.4
					Minimun	0.0	0.0	0.0	10.0	231.5	357.4	266.2	271.3	330.8	201.5	114.8	37.0
35	Poona	18.5	73.9	559	20th %tile	0.0	0.0	0.0	0.0	0.0	49.0	88.2	53.2	47.0	22.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	2.0	46.3	89.5	50.8	58.3	20.6	0.0	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	1.8	5.7	47.4	89.1	50.9	58.5	24.5	1.4	0.0
					Difference	0.0	0.0	0.0	1.8	3.7	1.2	0.4	0.0	0.1	3.9	1.4	0.0
					Minimun	0.0	0.0	0.0	0.0	2.0	46.3	89.1	50.8	58.3	20.6	0.0	0.0
36	Shillong	25.6	91.9	1500	20th %tile	0.7	4.1	13.7	57.8	183.5	321.0	217.5	206.9	209.3	81.9	3.8	0.0
					20% Prob (Normal)	0.0	5.6	15.1	58.6	175.2	294.4	214.7	220.7	204.6	84.2	0.0	0.0
					20% Prob (Gamma)	1.2	6.5	16.6	58.7	173.6	291.8	212.7	218.8	202.7	84.2	3.4	0.2
					Difference	1.2	0.9	1.5	0.1	1.6	2.7	1.9	1.9	1.9	0.0	3.4	0.2
					Minimun	0.0	5.6	15.1	58.6	173.6	291.8	212.7	218.8	202.7	84.2	0.0	0.0
37	Silchar	24.8	92.8	29	20th %tile	0.0	10.0	48.0	196.0	271.8	431.4	399.0	374.0	260.0	99.6	1.0	0.0
					20% Prob (Normal)	0.0	11.8	60.7	195.3	256.8	434.3	381.3	373.5	261.0	93.8	0.0	0.0
					20% Prob (Gamma)	1.0	13.6	62.9	193.8	254.5	431.5	378.6	371.2	259.0	93.6	2.7	0.0
					Difference	1.0	1.9	2.3	1.6	2.3	2.8	2.6	2.3	2.1	0.2	2.7	0.0

Effective Rainfall, Pe (mm)

St# Eto	Station Name	Lat(N)	Long(E)	Elev(m)		Effective Rainfall, Pe (mm) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
					Minimun	0.0	11.8	60.7	193.8	254.5	431.5	378.6	371.2	259.0	93.6	0.0	0.0
38	Srinagar	34.1	74.8	1587	20th %tile	31.4	35.0	58.0	47.6	35.0	13.4	22.4	27.0	9.0	4.2	0.0	6.0
					20% Prob (Normal)	29.3	36.2	54.5	49.3	32.8	13.8	18.7	27.0	7.3	2.5	0.0	6.0
					20% Prob (Gamma)	29.6	36.1	54.1	49.0	32.8	14.2	19.9	27.4	9.1	5.7	1.3	8.7
					Difference	0.3	0.1	0.4	0.3	0.1	0.3	1.2	0.4	1.9	3.2	1.3	2.7
					Minimun	29.3	36.1	54.1	49.0	32.8	13.8	18.7	27.0	7.3	2.5	0.0	6.0
39	Trivandrum	8.5	77.0	64	20th %tile	1.8	0.0	8.0	66.0	79.0	194.4	126.0	62.0	46.0	154.4	91.0	15.0
					20% Prob (Normal)	0.0	0.0	6.8	58.3	65.1	189.3	117.0	60.2	42.3	159.2	77.7	10.0
					20% Prob (Gamma)	1.7	2.2	9.3	58.1	69.7	187.7	116.0	60.5	45.0	157.8	78.4	14.5
					Difference	1.7	2.2	2.4	0.2	4.6	1.6	1.0	0.3	2.7	1.4	0.8	4.5
					Minimun	0.0	0.0	6.8	58.1	65.1	187.7	116.0	60.2	42.3	157.8	77.7	10.0
40	Panam	9.3	79.3	11	20th %tile	9.0	0.0	0.0	11.0	1.6	0.0	0.0	0.0	0.0	92.4	148.6	84.6
					20% Prob (Normal)	0.0	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	96.6	169.8	63.8
					20% Prob (Gamma)	7.5	0.3	0.9	10.0	3.1	0.0	0.0	0.2	2.5	96.5	168.4	67.7
					Difference	7.5	0.3	0.9	4.7	3.1	0.0	0.0	0.2	2.5	0.1	1.5	3.9
					Minimun	0.0	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	96.5	168.4	63.8
41	Veraval	20.9	70.4	8	20th %tile	0.0	0.0	0.0	0.0	0.0	11.4	85.6	28.8	9.0	0.0	0.0	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	10.0	90.8	13.5	0.0	0.0	0.0	0.0
					20% Prob (Gamma)	0.0	0.0	0.0	0.0	0.0	24.6	93.1	24.9	7.0	0.0	0.0	0.0
					Difference	0.0	0.0	0.0	0.0	0.0	14.6	2.3	11.4	7.0	0.0	0.0	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	10.0	90.8	13.5	0.0	0.0	0.0	0.0
42	Vishakhapatnam	17.7	83.2	3	20th %tile	0.0	0.0	0.0	0.0	0.0	8.2	48.3	71.5	71.7	97.0	88.1	5.1	0.0
					20% Prob (Normal)	0.0	0.0	0.0	0.0	0.0	44.1	69.5	68.0	93.6	101.1	5.6	0.0
					20% Prob (Gamma)	0.0	0.1	0.0	0.4	6.9	44.7	68.9	67.7	93.0	102.1	16.5	0.0
					Difference	0.0	0.1	0.0	0.4	6.9	0.6	0.6	0.3	0.6	1.0	10.8	0.0
					Minimun	0.0	0.0	0.0	0.0	0.0	44.1	68.9	67.7	93.0	101.1	5.6	0.0

APPENDIX T

EXCHANGE RATES
1985 - 1994

India / USA
India / Canada
Canada / USA

EXCHANGE RATES

Year	Average Exchange Rate for the Year		
	Indian Rs per US $	Can. $ per US $	Indian Rs per Can. $
1994	31.374	1.366	22.968
1993	30.493	1.290	23.638
1992	25.918	1.209	21.438
1991	22.742	1.146	19.845
1990	17.503	1.167	14.998
1989	16.225	1.184	13.704
1988	13.917	1.231	11.305
1987	12.961	1.326	9.775
1986	12.611	1.389	9.079
1985	12.369	1.365	9.062

APPENDIX U

SOLAR PUMPS

COST ESTIMATES
1993 US $ and Indian Rs

and

PUMPING OUTPUT
m^3/day

DAILY VOLUME OUTPUT FOR SURFACE DC PUMPS
BASED ON A STANDARD SOLAR DAY OF 6 kWh/m3

	PUMP OUTPUT IN GPD										
Head	NUMBER OF 53 W MODULES										
(m)	4	6	8	10	12	14	16	20	24	28	32
5	3499	7131	11226	14710	17173	21213	24068	27929			
7	2142	5893	9505	12511	14834	18831	21505	52101			
10	1375	4232	6712	9052	11128	15579	17839	21139	23689		
15		1350	4301	6602	8282	10284	12303	15584	18121	20344	
20		539	1778	4446	5919	7173	8115	9350	10382	11405	12263
25			937	1948	2862	3751	4466	5518	6255	7250	8164
30			179	1052	1868	2520	3227	4227	4896	5364	5852

	PUMP OUTPUT IN M3/DAY										
Head	NUMBER OF 53 W MODULES										
(m)	4	6	8	10	12	14	16	20	24	28	32
5	13.2	27.0	42.5	55.7	65.0	80.3	91.1	105.7			
7	8.1	22.3	36.0	47.4	56.1	71.3	81.4	197.2			
10	5.2	16.0	25.4	34.3	42.1	59.0	67.5	80.0	89.7		
15		5.1	16.3	25.0	31.3	38.9	46.6	59.0	68.6	77.0	
20		2.0	6.7	16.8	22.4	27.1	30.7	35.4	39.3	43.2	46.4
25			3.5	7.4	10.8	14.2	16.9	20.9	23.7	27.4	30.9
30			0.7	4.0	7.1	9.5	12.2	16.0	18.5	20.3	22.1

CAPITAL INVESTMENT - SURFACE DC PUMPS
RETAIL PRICING ($ US)
1.10(MODULE@(DEALER+30%)) + PUMP@(RETAIL)
TAX & SHIPPING NOT INCLUDED

	COST OF PUMPING SYSTEM ($ US)										
Head	NUMBER OF 53 W MODULES										
(m)	4	6	8	10	12	14	16	20	24	28	32
5	2,488	3,335	4,181	4,885	5,703	6,521	7,339	8,689			
7	2,488	3,335	4,181	4,885	5,703	6,521	7,339	8,689			
10	2,788	3,635	4,481	5,185	5,703	6,521	7,339	8,689	10,267		
15		3,715	4,481	5,185	5,703	6,521	7,339	8,689	10,267	11,846	
20		3,715	4,561	5,185	6,003	6,821	7,639	8,989	10,567	12,146	13,725
25			4,561	5,265	6,083	6,901	7,719	9,069	10,567	12,146	13,725
30			4,561	5,265	6,083	6,901	7,719	9,069	10,647	12,226	13,805

CAPITAL INVESTMENT - SURFACE DC PUMPS
RETAIL PRICING (Indian Rs)
1.10(MODULE@(DEALER+30%)) + PUMP@(RETAIL)
TAX & SHIPPING NOT INCLUDED

	COST OF PUMPING SYSTEM (Indian Rs)										
Head	NUMBER OF 53 W MODULES										
(m)	4	6	8	10	12	14	16	20	24	28	32
5	78,062	104,622	131,182	153,256	178,918	204,581	230,244	272,596			
7	78,062	104,622	131,182	153,256	178,918	204,581	230,244	272,596			
10	87,474	114,034	140,594	162,668	178,918	204,581	230,244	272,596	322,127		
15		116,544	140,594	162,668	178,918	204,581	230,244	272,596	322,127	371,658	
20		116,544	143,104	162,668	188,331	213,993	239,656	282,008	331,539	381,070	430,601
25			143,104	165,178	190,841	216,503	242,166	284,518	331,539	381,070	430,601
30			143,104	165,178	190,841	216,503	242,166	284,518	334,049	383,580	433,111

DAILY VOLUME OUTPUT FOR SUBMERSIBLE DC PUMPS
BASED ON A STANDARD SOLAR DAY OF 6 kWh/m3

	PUMP OUTPUT IN M3/DAY										
Head	NUMBER OF 53 W MODULES										
(m)	4	6	8	9	10	12	15	16	20	25	30
6	25.7	33.5	41.4	48.9	57.0	69.8	90.0	98.0	124.3	149.2	182.6
10	17.4	25.4	33.4	37.1	40.1	45.6	55.1	62.2	81.2	99.4	118.5
15	7.5	15.3	23.4	27.2	30.4	36.2	44.5	47.2	55.5	71.6	91.4
20	6.0	9.6	13.8	17.8	20.7	26.2	34.8	37.7	46.7	56.1	65.3
25	3.7	7.9	11.0	12.6	13.9	19.0	26.9	29.9	38.7	48.4	58.4
30		5.2	8.8	10.4	11.7	14.2	20.9	23.5	32.2	41.2	50.6
40		1.9	4.4	6.0	7.4	10.0	13.7	14.8	22.0	31.0	38.6
50			2.1	2.9	3.6	5.9	10.0	11.3	15.4	21.8	30.0
60						3.3	6.2	7.5	12.0	16.0	21.7
70						2.0	3.9	4.6	8.5	12.8	16.1
80						1.0	2.7	3.2	5.5	9.4	12.9
90							1.8	2.4	4.4	6.7	10.5
100									3.3	5.4	8.0
120									1.4	3.3	5.0
130										2.5	4.2

	PUMP OUTPUT IN M3/DAY											
Head	NUMBER OF 75 W MODULES											
(m)	2	3	4	5	6	8	9	10	12	15	16	20
6	21.0	26.6	32.1	37.7	43.2	65.4	74.3	82.8	96.0	110.4	115.3	137.6
10	12.7	18.4	24.0	29.6	35.3	43.8	48.0	52.2	67.4	85.6	86.9	85.8
15	5.3	8.4	13.9	19.5	25.3	34.3	38.8	42.2	49.5	57.8	60.2	85.1
20	3.8	6.4	9.0	11.5	15.8	24.1	28.1	32.2	40.1	49.1	51.7	62.3
25	1.7	4.2	6.6	9.2	11.8	17.1	19.8	24.6	32.3	41.0	43.7	55.1
30		2.1	4.6	7.0	9.6	12.2	15.0	18.4	25.8	33.9	36.7	47.2
40		1.6	3.8	6.2	7.9	9.1	10.8	12.6	15.8	24.4	27.0	36.1
50						8.1	9.3	10.7	12.4	16.5	17.5	27.3
60						6.1	7.4	8.7	10.6	13.2	14.3	18.2
70						4.2	5.5	6.8	8.8	9.7	11.0	15.0
80						2.5	3.4	4.1	5.9	6.4	7.6	11.8
90								3.1	5.1	8.1	9.1	7.7
100								1.6	3.3	6.2	6.5	6.7
120									1.3	3.3	4.1	4.5

CAPITAL INVESTMENT - SUBMERSIBLE DC PUMPS
RETAIL PRICING ($ US)
1.10(MODULES@(DEALER+30%)) + PUMP@(RETAIL)
TAX & SHIPPING NOT INCLUDED

	COST OF PUMPING SYSTEM ($ US)											
Head	NUMBER OF 53 W MODULES											
(m)	2	4	6	8	9	10	12	15	16	20	25	30
3	4737	5583	7025	7871	8295	8575	9393	10520	10929	12279	14252	16225
6	4737	5583	6430	7276	8060	8340	9158	10620	11029	12379	14252	16225
10	4737	5583	6430	7276	7700	7980	8798	10385	10794	12144	14352	16325
15		5583	6430	7276	7700	7980	8798	10025	10434	11784	14117	16090
20		5583	6430	7276	7700	7980	8798	10025	10434	11784	13757	15730
25		5583	6430	7276	7700	7980	8798	10025	10434	11784	13757	15730
30			6430	7276	7700	7980	8798	10025	10434	11784	13757	15730
40			6530	7276	7700	7980	8798	10025	10434	11784	13757	15730
50				7376	7800	8080	8798	10025	10434	11784	13757	15730
60							8898	10025	10434	11784	13757	15730
70							8898	10125	10534	11784	13757	15730
80							8898	10125	10534	11784	13757	15730
90								10125	10534	11884	13757	15730
100										11884	13857	15730
120										11884	13857	15830
130											13857	15830

	COST OF PUMPING SYSTEM ($ US)											
Head	NUMBER OF 75 W MODULES											
(m)	2	3	4	5	6	8	9	10	12	15	16	20
6	5085	5683	6281	6879	7476	9032	9630	10042	11200	12937	13516	15404
10	5085	5683	6281	6879	7476	8672	9270	9682	11200	12937	13516	15404
15	5085	5683	6281	6879	7476	8672	9270	9682	10840	12577	13156	15404
20	5085	5683	6281	6879	7476	8672	9270	9682	10840	12577	13156	15044
25	5085	5683	6281	6879	7476	8672	9270	9682	10840	12577	13156	15044
30		5683	6281	6879	7476	8672	9270	9682	10840	12577	13156	15044
40		-	-	-	-	8672	9270	9682	10840	12577	13156	15044
50						-	-	-	10840	12577	13156	15044
60						-	-	-	10840	12577	13156	15044
70						-	-	-	-	12577	13156	15044
80						-	-	-	-	12577	13156	15044
90								-	-	-	-	15144
100									-	-	-	15144
120										-	-	15144

CAPITAL INVESTMENT - SUBMERSIBLE DC PUMPS
RETAIL PRICING (Indian Rs)
1.10(MODULES@(DEALER+30%)) + PUMP@(RETAIL)
TAX & SHIPPING NOT INCLUDED

	COST OF PUMPING SYSTEM (Rs)											
Head	NUMBER OF 53 W MODULES											
(m)	2	4	6	8	9	10	12	15	16	20	25	30
3	148,605	175,165	220,392	246,952	260,232	269,026	294,688	330,045	342,876	385,229	447,142	509,056
6	148,605	175,165	201,725	228,285	252,859	261,653	287,316	333,182	346,014	388,366	447,142	509,056
10	148,605	175,165	201,725	228,285	241,565	250,358	276,021	325,810	338,641	380,993	450,280	512,193
15		175,165	201,725	228,285	241,565	250,358	276,021	314,515	327,346	369,699	442,907	504,820
20		175,165	201,725	228,285	241,565	250,358	276,021	314,515	327,346	369,699	431,612	493,526
25		175,165	201,725	228,285	241,565	250,358	276,021	314,515	327,346	369,699	431,612	493,526
30			201,725	228,285	241,565	250,358	276,021	314,515	327,346	369,699	431,612	493,526
40			204,862	228,285	241,565	250,358	276,021	314,515	327,346	369,699	431,612	493,526
50				231,422	244,702	253,496	276,021	314,515	327,346	369,699	431,612	493,526
60							279,158	314,515	327,346	369,699	431,612	493,526
70							279,158	317,652	330,484	369,699	431,612	493,526
80							279,158	317,652	330,484	369,699	431,612	493,526
90								317,652	330,484	372,836	431,612	493,526
100										372,836	434,750	493,526
120										372,836	434,750	496,663
130											434,750	496,663

	COST OF PUMPING SYSTEM (Rs)											
Head	NUMBER OF 75 W MODULES											
(m)	2	3	4	5	6	8	9	10	12	15	16	20
6	159,552	178,305	197,059	215,812	234,566	283,367	302,121	315,042	351,383	405,893	424,064	483,285
10	159,552	178,305	197,059	215,812	234,566	272,073	290,826	303,747	351,383	405,893	424,064	483,285
15	159,552	178,305	197,059	215,812	234,566	272,073	290,826	303,747	340,088	394,599	412,769	483,285
20	159,552	178,305	197,059	215,812	234,566	272,073	290,826	303,747	340,088	394,599	412,769	471,990
25	159,552	178,305	197,059	215,812	234,566	272,073	290,826	303,747	340,088	394,599	412,769	471,990
30		178,305	197,059	215,812	234,566	272,073	290,826	303,747	340,088	394,599	412,769	471,990
40		-	-	-	-	272,073	290,826	303,747	340,088	394,599	412,769	471,990
50						-	-	-	340,088	394,599	412,769	471,990
60						-	-	-	340,088	394,599	412,769	471,990
70						-	-	-	-	394,599	412,769	471,990
80						-	-	-	-	394,599	412,769	471,990
90								-	-	-	-	475,128
100									-	-	-	475,128
120										-	-	475,128

DAILY VOLUME OUTPUT FOR SUBMERSIBLE AC PUMPS
Six Peak Sun Hours per Day

	PUMP OUTPUT (m3/day)										
Head	ARRAY SIZE (Wp)										
(m)	420W	448W	512W	840W	896W	960W	1024W	1440W	1536W	1680W	1920W
6	32.2	36.0	44.2	86.5	93.9	99.8	106.8	142.6	150.7	159.5	174.6
10	17.8	20.2	24.5	47.7	51.8	55.1	59.8	91.0	99.7	109.4	125.2
15	14.4	16.4	19.9	35.8	38.7	41.5	44.9	65.0	69.9	75.5	88.1
20	8.3	9.8	12.8	27.9	30.6	32.8	35.5	50.3	54.3	59.1	68.5
25	4.8	6.0	8.6	21.9	24.4	26.6	29.2	42.6	45.7	49.2	56.2
30	4.0	5.0	7.0	16.3	18.0	19.5	21.7	33.6	36.6	40.2	46.1
40	1.4	1.9	3.8	12.0	13.5	14.8	16.4	25.1	27.5	30.3	35.4
50	0.7	1.1	1.8	7.8	9.0	10.3	11.8	19.8	21.8	24.0	27.6
60			1.0	5.8	6.8	7.5	8.6	14.0	15.7	17.7	21.2
70				3.8	4.7	5.5	6.5	11.4	12.9	14.7	17.8
80				3.4	4.1	4.6	5.3	9.2	10.4	11.7	14.0
90				1.6	1.9	3.1	3.7	7.6	8.7	10.0	12.2
100				1.2	1.5	1.8	2.9	6.6	7.6	9.4	10.7
120					0.8	1.1	1.4	4.6	5.5	6.5	8.2

DAILY VOLUME OUTPUT FOR GRUNDFOS PUMPS

Head (m)	Peak Sun hr/day	PUMP OUTPUT (m3/day) ARRAY SIZE (Wp) 420W	448W	512W	840W	896W	960W	1024W	1440W	1536W	1680W	1920W
6	4.5	22.0	25.7	30.5	63.1	69.9	74.9	81.0	111.0	117.7	124.5	136.6
	7.5	42.5	46.2	57.9	109.9	117.9	124.6	132.6	174.2	183.7	194.4	212.6
10	4.5	11.7	13.5	16.7	34.8	38.5	41.3	44.7	64.3	72.1	80.5	94.5
	7.5	23.8	26.9	32.3	60.6	65.1	68.8	74.9	117.6	127.4	138.2	155.9
15	4.5	9.6	11.0	13.6	27.1	29.3	31.0	33.1	48.4	52.4	57.0	64.8
	7.5	19.3	21.8	26.3	44.5	48.1	52.0	56.8	81.6	87.5	94.0	111.4
20	4.5	4.7	5.9	8.2	19.9	22.2	24.0	26.3	37.5	40.0	43.3	51.0
	7.5	11.8	13.7	17.4	35.9	39.0	41.5	44.7	63.1	68.7	75.0	86.1
25	4.5	2.2	3.0	4.9	14.8	17.0	18.7	20.9	32.0	34.5	37.4	42.2
	7.5	7.3	9.0	12.4	29.0	31.9	34.4	37.5	53.3	57.0	61.1	70.2
30	4.5	1.9	2.5	4.1	11.4	12.9	14.0	15.4	24.3	26.8	29.8	34.7
	7.5	6.1	7.5	10.0	21.2	23.1	25.1	28.0	43.0	46.4	50.7	57.6
40	4.5			1.7	8.0	9.2	10.1	11.3	18.4	19.9	21.8	25.7
	7.5	2.8	3.9	5.8	16.0	17.9	19.5	21.4	31.8	35.1	38.9	45.2
50	4.5				4.6	5.7	6.6	7.7	13.9	15.6	17.6	20.7
	7.5	1.4	2.2	3.6	11.0	12.2	14.0	15.8	25.7	27.9	30.4	34.4
60	4.5				3.5	4.3	5.0	5.8	9.3	10.5	12.2	15.2
	7.5			2.0	8.1	9.2	10.1	11.4	18.7	20.9	23.3	27.3
70	4.5				1.9	2.5	3.1	3.9	7.9	8.7	10.0	12.2
	7.5				5.8	6.9	7.8	9.0	15.0	17.1	19.5	23.4
80	4.5				1.8	2.4	2.9	3.5	6.2	7.0	8.1	9.9
	7.5				5.0	5.8	6.4	7.2	12.3	13.7	15.4	18.1
90	4.5						1.6	2.0	4.9	5.8	6.7	8.4
	7.5				3.2	3.9	4.5	5.3	10.4	11.6	13.2	15.9
100	4.5				2.3			1.5	4.0	4.8	5.8	7.4
	7.5					3.0	3.5	4.2	9.1	10.3	13.1	14.1
120	4.5								2.7	3.3	4.1	5.4
	7.5					1.6	2.1	2.8	6.4	7.6	8.9	11.0

ASSUMING FIXED ARRAY AT 35 DEGREES N LAT

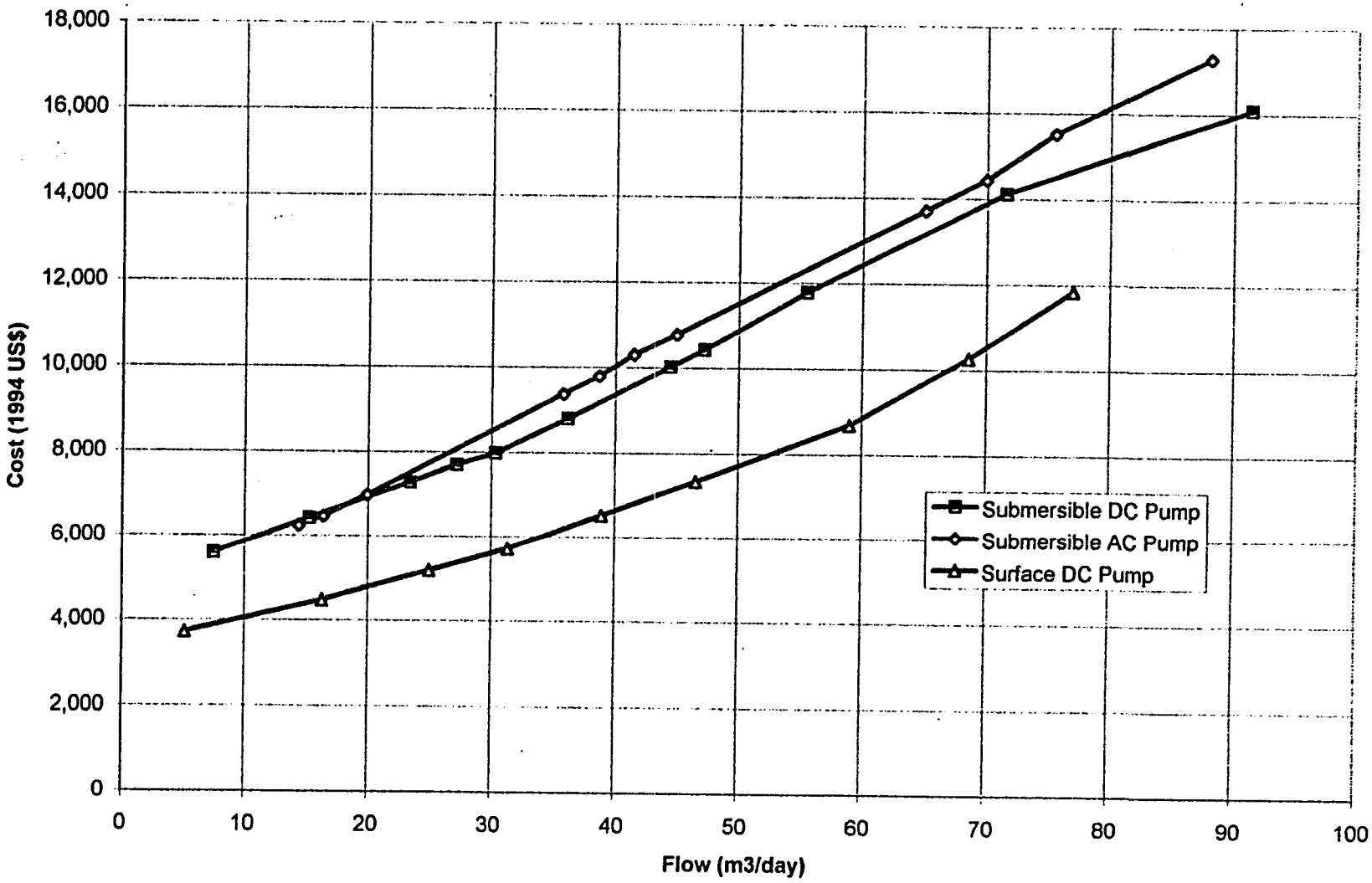
CAPITAL INVESTMENT - SUBMERSIBLE AC PUMPS
RETAIL PRICING ($US)
1.10(MODULES @(Dealer+30%)) + PUMP@(Retail)
TAX AND SHIPPING NOT INCLUDED

	COST OF PUMPING SYSTEM ($ US)										
Head	ARRAY SIZE (Wp)										
(m)	420	448	512	840	896	960	1024	1440	1536	1680	1920
6	6,363	6,584	7,094	9,546	9,967	10,473	10,954	13,768	14,489	15,552	17,337
10	6,243	6,464	6,974	9,496	9,917	10,423	10,904	13,768	14,489	15,552	17,337
15	6,243	6,464	6,974	9,376	9,797	10,303	10,784	13,718	14,439	15,502	17,287
20	6,243	6,464	6,974	9,376	9,797	10,303	10,784	13,598	14,319	15,502	17,287
25	6,243	6,464	6,974	9,376	9,797	10,303	10,784	13,598	14,319	15,382	17,167
30	6,188	6,409	6,919	9,321	9,742	10,248	10,729	13,598	14,319	15,382	17,167
40	6,188	6,409	6,919	9,321	9,742	10,248	10,729	13,543	14,264	15,327	17,167
50	6,318	6,539	7,049	9,321	9,742	10,248	10,729	13,543	14,264	15,327	17,112
60			7,049	9,451	9,872	10,378	10,859	13,543	14,264	15,327	17,112
70				9,451	9,872	10,378	10,859	13,673	14,394	15,457	17,112
80				9,701	10,122	10,628	11,109	13,673	14,394	15,457	17,242
90				9,701	10,122	10,628	11,109	13,673	14,394	15,457	17,242
100				9,701	10,122	10,628	11,109	13,673	14,394	15,457	17,242
120					10,122	10,628	11,109	13,923	14,644	15,707	17,242

CAPITAL INVESTMENT - SUBMERSIBLE AC PUMPS
RETAIL PRICING ($ Indian Rs)
1.10(MODULES @(Dealer+30%)) + PUMP@(Retail)
TAX AND SHIPPING NOT INCLUDED

	COST OF PUMPING SYSTEM ($ Indian Rs.)										
Head	ARRAY SIZE (Wp)										
(m)	420	448	512	840	896	960	1024	1440	1536	1680	1920
6	199,644	206,553	222,570	299,511	312,702	328,584	343,658	431,952	454,564	487,944	543,935
10	195,879	202,788	218,805	297,943	311,133	327,015	342,090	431,952	454,564	487,944	543,935
15	195,879	202,788	218,805	294,178	307,368	323,250	338,325	430,384	452,995	486,375	542,366
20	195,879	202,788	218,805	294,178	307,368	323,250	338,325	426,619	449,231	486,375	542,366
25	195,879	202,788	218,805	294,178	307,368	323,250	338,325	426,619	449,231	482,610	538,601
30	194,153	201,062	217,079	292,452	305,642	321,525	336,599	426,619	449,231	482,610	538,601
40	194,153	201,062	217,079	292,452	305,642	321,525	336,599	424,893	447,505	480,884	538,601
50	198,232	205,141	221,158	292,452	305,642	321,525	336,599	424,893	447,505	480,884	536,876
60			221,158	296,531	309,721	325,603	340,678	424,893	447,505	480,884	536,876
70				296,531	309,721	325,603	340,678	428,972	451,584	484,963	536,876
80				304,374	317,564	333,447	348,521	428,972	451,584	484,963	540,954
90				304,374	317,564	333,447	348,521	428,972	451,584	484,963	540,954
100				304,374	317,564	333,447	348,521	428,972	451,584	484,963	540,954
120					317,564	333,447	348,521	436,815	459,427	492,806	540,954

Cost vs. Flow for 15 m Head



APPENDIX V

INTEREST AND INFLATION RATES

India

Interest Rates for India

Year	Bank Rate end of period	Money Market Rate	Lending Rate	Consumer Price Index	Estimated Inflation Rate
1994	12.00	7.14		149.2	10.19
1993	12.00	8.64	16.25	135.4	6.36
1992	12.00	15.23	18.92	127.3	11.76
1991	12.00	19.35	17.88	113.9	13.90
1990	10.00	15.57	16.50	100.0	8.93
1989	10.00		16.50	91.8	6.25
1988	10.00		16.50	86.4	9.37
1987	10.00	9.83	16.50	79.0	8.82
1986	10.00	9.97	16.50	72.6	8.68
1985	10.00	10.00	16.50	66.8	5.53
1984	10.00	9.95	16.50	63.3	8.39
1983	10.00	8.30	16.50	58.4	11.88
1982	10.00	7.27	16.50	52.2	7.85
1981	10.00	8.61	16.50	48.4	13.08
1980	9.00	7.24	16.50	42.8	11.46
1979	9.00	8.47	14.50	38.4	6.08
1978	9.00	8.05	13.50	36.2	2.55
1977	9.00	10.18		35.3	8.28
1976	9.00	11.28		32.6	-7.65
1975	9.00	10.40		35.3	6.01
AVG	10.10	10.30	16.41		7.89

Index of Consumer Prices - India
1980=100

Year	** Consumer Price Index	Estimated Inflation Rate	* Consumer Price Index All Items	Estimated Inflation Rate All Items	* Consumer Price Index Food	Estimated Inflation Rate Food	* Consumer Price Index Fuel & Light	Estimated Inflation Rate Fuel & Light	Wages Unskilled Agricultural Labourer Male (Rs./day)	Wages Unskilled Agricultural Labourer Male % Increase
1993	135.4	6.36	319	6.33	325	5.52				
1992	127.3	11.76	300	11.94	308	13.24	301	7.50		
1991	113.9	13.90	268	14.04	272	16.24	280	11.55	23.31	11.58
1990	100.0	8.93	235	8.80	234	8.84	251	6.36	20.89	10.76
1989	91.8	6.25	216	6.93	215	5.91	236	8.76	18.86	13.61
1988	86.4	9.37	202	9.78	203	9.73	217	7.96	16.60	11.11
1987	79.0	8.82	184	8.24	185	9.47	201	5.24	14.94	11.58
1986	72.6	8.68	170	8.97	169	9.74	191	6.70	13.39	11.21
1985	66.8	5.53	156	5.41	154	3.36	179	10.49	12.04	16.67
1984	63.3	8.39	148	8.82	149	7.19	162	13.29	10.32	6.94
1983	58.4		136		139		143		9.65	
AVG		8.80		8.93		8.92		8.65		11.68

* Statistical Yearbook for Asia and the Pacific
United Nations 1994

**

APPENDIX W

GRAPES

CROP EVAPOTRANSPIRATION

(ET_{grape})

Tables for Identification of Climatic Regions for Crop Coefficients

Type of Station

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Strong Winds	Dry	Light Frost	Area Type
1	3	Agra Airport	27.2	78.0	169.0				5
2	5	Ahmadabad Airport	23.1	72.6	55.0				5
3	9	Akola Airport	20.7	77.1	309.0				5
4	13	Allahabad Airport	25.5	81.7	98.0				5
5	19	Amini Divi	11.1	72.7	4.0	S			6
6	21	Amritsar Airport	31.6	74.9	234.0				5
7	37	Bangalore Airport	13.0	77.6	897.0				5
8	59	Bhopal Airport	23.3	77.4	523.0				5
9	64	Bikaner	28.0	73.3	224.0		D		7
10	69	Bombay-Colaba	18.9	72.8	11.0				5
11	70	Bombay-Santacruz	19.1	72.9	14.0				5
12	75	Calcutta-Alipore	22.5	88.3	6.0				5
13	76	Calcutta-Dum Dum	22.7	88.5	6.0				5
14	97	Cuttack	20.5	85.9	27.0				5
15	48	Belgaum Airport	15.9	74.6	747.0				5
16	112	Dibrugarh Airport	27.5	95.0	111.0				5
17	126	Gannavaram Airport	16.5	80.8	24.0				5
18	127	Gauhati Airport	26.1	91.6	54.0				5
19	131	Gao-Panjim	15.5	73.8	60.0				5
20	153	Hyderabad-Begumpet	17.5	78.5	545.0				5
21	156	Indore Airport	22.7	75.8	567.0	S			6
22	158	Jagdalpur	19.1	82.0	553.0				5
23	159	Jaipur Airport	26.8	75.8	390.0		D		7
24	172	Jodhpur	26.3	73.0	217.0		D		7
25	194	Kodaikanal	10.2	77.5	2343.0	S			6
26	200	Kota Airport	25.2	75.9	274.0		D		7
27	209	Madras- Minambakkam	13.0	80.2	16.0				5
28	231	Minicoy	8.3	73.0	2.0				5
29	239	Nagpur Airport	21.1	79.1	310.0				5
30	250	New Dehli - Safdarjung	28.6	77.2	216.0				5
31	256	Okha	22.5	69.1	7.0	S			6
32	122	Fort Cochin	10.0	76.2	3.0				5
33	271	Patna Airport	25.6	85.1	60.0				5
34	278	Port Blair	11.7	92.7	79.0				5
35	281	Pune Airport	18.6	73.9	593.0	S			6
36	314	Shillong	25.6	91.9	1600.0				5
37	320	Silchar - Khumbhigram	24.9	93.0	97.0				5
38	325	Srinagar Airport	34.0	74.8	1666.0			F	5
39	340	Trivandrum Airport	8.5	77.0	8.0				5
40	342	Tuticorin	8.8	78.2	4.0	S			6
41	352	Veraval	20.9	70.4	8.0	S			6
42	353	Vishakhapatnam	17.7	83.2	3.0				5

Area Type	Description
1	Areas with light frosts, humid, light-moderate wind
2	Areas with light frosts, humid, strong wind
3	Areas with light frosts, dry, light-moderate wind
4	Areas with light frosts, dry, strong wind
5	Hot, humid areas, light-moderate wind
6	Hot, humid areas, strong wind
7	Hot, dry areas, light-moderate wind
8	Hot, dry areas, strong wind

Average Relative Humidity (%) - Sorted by Combined Ranking for Annual Average Relative Humidity and Total Annual Precipitation

Eto St#	Sun St#	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Dry	Rank RH	Rank Rain	Rank Total
34	107	Port Blair	11.7	92.7	79	78.1	78.4	78.0	79.0	85.8	86.9	88.2	88.6	89.8	88.0	84.6	80.7	83.8		1	2	3
32	100	Ollukara	10.5	76.3	22	74.3	74.8	76.2	78.5	83.0	87.8	89.2	88.3	86.7	85.3	81.0	77.2	81.9		3	1	4
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	80.5	77.7	71.3	76.2	83.6	85.6	86.9	87.4	85.8	84.3	81.9	81.8	81.9		2	6	8
39	134	Trivandrum	8.5	77.0	64	72.9	71.5	74.5	79.3	82.6	86.1	87.7	85.9	85.0	85.8	83.2	77.8	81.0		4	8	12
37	124	Silicuri	24.8	92.9	40	68.5	65.3	60.0	68.3	76.5	84.8	85.0	85.0	83.3	80.5	73.8	71.8	75.2		12	3	15
28	89	Minicoy	8.3	73.0	2	76.2	76.8	77.5	74.6	76.6	80.2	80.7	80.3	79.7	80.8	79.7	79.8	78.6		6	10	16
18	40	Gauhati	26.1	91.6	54	78.8	71.5	63.8	69.9	79.9	84.3	84.7	85.7	85.5	84.3	82.4	82.0	79.4		5	13	18
25	76	Kodaikanal	10.2	77.5	2345	72.3	65.5	63.9	75.1	78.8	80.7	86.0	85.9	85.4	87.8	84.1	76.4	78.5		7	11	18
19	41	Goa	15.5	73.8	55	63.8	66.3	67.9	68.9	70.9	80.8	86.8	84.6	84.5	77.5	64.4	67.9	73.7		16	5	21
36	123	Shillong	25.6	91.9	1598	67.8	62.0	55.2	66.5	76.0	85.5	86.7	86.4	87.3	80 8	73.5	70.8	74.9		13	9	22
13	27	Calcutta	22.7	88.5	6	69.8	66.3	64.9	68.0	73.3	81.1	84.8	85.4	85.6	80.3	72.6	71.3	75.3		11	12	23
12	27	Calcutta	22.7	88.5	6	69.8	66.3	64.9	68.0	73.3	81.1	84.8	85.4	85.6	80.3	72.6	71.3	75.3		10	14	24
5	8	Amini Divi	11.1	72.7	4	72.0	72.5	72.5	75.4	77.3	81.9	83.2	84.1	80.8	79.8	77.4	75.1	77.7		8	17	25
11	26	Bombay	19.1	72.9	14	56.8	57.2	63.7	69.1	70.4	78.3	86.0	85.7	83.0	73.3	63.5	61.8	70.7		23	4	27
10	26	Bombay	19.1	72.9	14	56.8	57.2	63.7	69.1	70.4	78.3	86.0	85.7	83.0	73.3	63.5	61.8	70.7		22	7	29
27	86	Madras	13.0	80.2	16	76.7	74.9	73.7	74.1	66.8	63.3	67.8	73.7	76.5	81.3	82.3	79.9	74.2		15	19	34
15	36	Dharwar	15.4	75.1	679	64.0	61.8	63.3	67.1	70.1	77.9	84.9	85.0	83.8	76.6	67.8	66.3	72.4		19	15	34
42	144	Vishakhapatnam	17.7	83.2	3	73.0	71.3	72.1	74.1	72.7	72.2	79.2	79.4	81.8	78.7	71.9	69.7	74.7		14	25	39
17	39	Gannavaram	16.5	80.8	24	73.0	68.2	68.0	69.4	61.4	63.9	76.3	78.4	80.8	79.9	74.8	71.3	72.1		20	22	42
14	34	Cuttack	20.5	85.9	24	67.0	62.0	59.5	61.5	63.0	70.5	82.5	83.0	81.5	76.0	67.0	65.5	69.9		24	18	42
22	61	Jagadalpur	19.1	82.0	553	63.3	55.0	46.5	51.3	52.3	71.2	85.3	86.7	83.8	77.0	70.5	67.5	67.5		26	16	42
41	142	Veraval	20.9	70.4	8	52.9	61.5	71.1	75.7	81.6	83.0	87.4	87.6	82.9	72.5	60.5	54.6	72.6		17	27	44
7	14	Bangalor	13.0	77.6	897	65.5	63.0	50.8	53.5	64.4	78.4	80.8	80.4	82.5	80.5	81.6	75.9	71.4		21	26	47
31	99	Okha	22.5	69.1	7	63.7	74.0	77.8	83.5	81.0	82.9	84.6	86.0	81.8	83.5	67.5	60.3	77.2		9	40	49
33	105	Patna	25.5	85.3	52	66.5	53.3	45.2	40.5	47.9	63.8	81.7	84.3	82.5	76.9	70.6	70.8	65.3		27	24	51
29	92	Nagpur	21.2	79.1	311	56.1	40.3	34.3	30.5	28.6	57.2	77.9	83.9	80.3	66.6	59.7	61.3	56.4		32	21	53
38	127	Srinagar	34.1	74.8	1587	81.1	80.3	74.0	72.3	66.8	60.8	67.3	69.4	70.3	70.3	76.1	81.1	72.5		18	36	54
40	135	Tuticorin	8.8	78.2	4	78.5	76.0	75.0	72.0	64.0	56.5	56.5	57.0	58.0	71.0	78.0	79.0	68.5		25	29	54
8	21	Bhopal	23.3	77.4	503	50.2	37.0	28.5	25.9	26.7	51.7	80.2	85.2	77.8	54.6	49.4	50.6	51.5		36	20	56
4	7	Allahabad	25.5	81.7	98	67.3	54.6	38.5	28.2	28.9	46.0	76.6	83.5	78.1	68.7	63.2	68.0	58.5		31	28	59
21	59	Indore	22.7	75.8	567	45.5	30.1	28.7	22.7	26.8	54.7	78.4	83.8	72.6	44.6	40.5	45.6	47.8		38	23	61
20	56	Hyderabad	17.5	78.5	545	58.9	45.2	40.4	41.6	38.5	60.5	75.4	77.5	77.9	72.0	66.3	61.6	59.7		30	33	63
35	108	Pune	18.5	73.9	583	51.0	39.8	36.7	40.1	53.8	69.9	82.8	83.7	81.0	67.7	61.9	59.4	60.6		29	35	64
1	3	Agra	27.2	78.1	169	59.5	48.5	40.0	36.0	34.5	43.0	70.0	79.5	71.0	56.0	53.5	62.5	54.5		34	30	64
30	97	New Dehli	28.6	77.2	216	66.3	53.1	46.2	33.5	31.9	42.2	69.3	79.3	71.9	59.3	57.3	65.9	56.3		33	32	65
6	9	Amritsar	31.6	74.9	234	74.0	66.9	60.9	47.8	37.4	44.8	72.0	78.9	74.5	65.8	66.2	71.6	63.4		28	39	67
3	5	Akola	20.7	77.0	282	43.4	27.8	27.2	25.2	29.6	56.0	77.4	79.8	75.2	56.0	48.0	50.4	49.7		37	31	68
2	4	Ahmadabad	23.1	72.6	55	41.3	35.6	30.5	31.8	41.0	60.8	79.1	80.5	76.3	56.3	48.6	47.9	52.5		35	34	69
23	62	Jaipur	26.8	75.8	390	50.5	39.5	30.4	24.3	24.3	41.8	70.1	78.1	71.9	47.9	44.9	48.9	47.7	D	39	37	76
26	79	Kota	25.2	75.5	257	47.2	36.2	29.0	23.2	23.0	43.8	69.2	77.6	70.6	47.0	45.0	52.2	47.0	D	41	38	79
9	24	Bikaner	28.0	73.3	224	50.8	43.5	39.0	33.0	30.3	43.5	60.5	65.5	60.0	41.8	45.0	52.5	47.1	D	40	42	82
24	69	Jodhpur	26.3	73.0	224	37.7	28.7	23.8	22.2	26.1	45.8	66.3	71.0	68.4	39.1	34.0	40.0	41.9	D	42	41	83

Precipitation (mm) - Sorted by Combined Ranking for Total Annual Precipitation and Average Annual Relative Humidity

St# Eto		Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Dry	Rain Rank	RH Rank	Total Rank
34		Port Blair	11.7	92.7	79	67.6	27.1	11.0	56.2	490.4	449.1	476.5	486.2	547.8	323.9	239.1	199.8	3374.7		2	1	3
32		Fort Cochin	10.0	76.2	3	19.2	27.8	62.7	115.5	442.4	650.1	788.7	442.7	381.4	271.4	148.0	64.3	3414.2		1	3	4
16		Dibrugarh/Mohanbari	27.5	95.0	111	21.2	46.7	78.8	173.1	329.4	426.1	509.9	465.1	288.4	130.4	33.0	17.8	2519.9		6	2	8
39		Trivandrum	8.5	77.0	64	27.0	36.1	34.1	115.1	272.5	349.9	289.0	148.2	192.5	282.7	148.4	65.3	1960.8		8	4	12
37		Silchar	24.8	92.8	29	13.7	50.6	138.4	238.9	419.8	659.7	537.0	457.3	364.5	248.6	22.6	9.0	3160.1		3	12	15
28		Minicoy	8.3	73.0	2	35.1	26.2	4.8	70.3	256.6	262.5	230.5	231.7	181.6	191.0	130.7	118.4	1739.4		10	6	16
18		Gauhti	26.1	91.6	54	12.4	16.7	59.5	117.7	259.4	285.4	305.1	294.2	160.9	63.2	15.5	2.2	1592.2		13	5	18
25		Kodaikanal	10.2	77.5	2343	20.0	11.6	79.0	214.0	250.6	105.0	120.6	111.6	157.0	247.6	334.3	65.3	1716.6		11	7	18
19		Goa/Panjim	15.5	73.8	57	0.3	0.3	0.0	9.6	87.7	778.7	980.2	409.2	281.7	122.7	55.0	56.0	2781.4		5	16	21
36		Shillong	25.6	91.9	1500	5.0	11.3	39.0	61.0	203.6	314.0	282.3	201.0	435.0	213.0	14.0	3.0	1782.2		9	13	22
13		Calcutta/Dum Dum	22.7	88.5	6	16.0	10.6	22.6	33.3	83.0	179.6	315.0	334.3	447.6	160.6	4.0	0.3	1606.9		12	11	23
12		Calcutta/Alipore	22.5	88.3	6	23.3	17.7	18.9	43.0	93.7	224.9	308.3	295.9	313.3	147.5	9.6	1.9	1498.0		14	10	24
5		Amini	11.1	72.7	4	3.0	0.0	1.6	27.3	293.6	311.6	261.0	187.6	150.0	87.0	114.3	6.6	1443.6		17	8	25
11		Bombay/Santa Cruz	19.1	72.9	14	0.3	0.0	0.0	0.3	8.6	785.3	891.3	788.6	303.0	182.3	3.6	0.0	2963.3		4	23	27
10		Bombay/Colaba,India	18.9	72.8	11	1.4	2.0	0.0	1.6	9.0	616.6	798.1	489.5	237.6	86.6	1.2	8.4	2252.0		7	22	29
15		Belguam/Samra	15.9	74.6	747	0.2	3.2	15.2	53.2	152.8	149.0	556.6	260.1	129.4	110.3	42.6	14.1	1486.7		15	19	34
27		Madras/Minambakkam	13.0	80.2	16	24.5	6.8	5.2	18.0	36.9	72.7	107.9	168.4	137.5	262.9	408.6	109.5	1358.9		19	15	34
42		Vishakhapatnam	17.7	83.2	3	15.7	13.8	10.6	20.0	18.6	81.0	158.1	127.2	200.8	261.5	78.1	17.9	1003.3		25	14	39
14		Cuttack	20.5	85.9	27	23.3	26.4	14.8	45.5	56.6	176.9	376.1	290.0	236.5	141.1	18.6	1.0	1406.8		18	24	42
17		Masulipatam	16.2	81.1	3	4.2	10.1	12.3	20.3	15.6	134.0	260.2	172.5	223.2	138.0	91.3	13.7	1095.4		22	20	42
22		Jogdalapur	19.1	82.0	553	9.9	14.6	20.0	62.4	69.7	226.7	313.5	356.6	249.0	107.8	8.8	21.3	1460.3		16	26	42
41		Veraval	20.9	70.4	8	0.7	2.0	1.2	0.2	0.5	176.0	404.5	168.6	145.5	50.7	1.9	1.3	953.1		27	17	44
7		Bangalore	13.0	77.6	921	5.6	8.2	4.4	50.1	111.7	80.5	107.0	172.4	195.2	150.2	83.8	24.3	993.4		26	21	47
31		Dwarka	22.4	69.1	11	0.8	0.4	1.8	0.2	0.0	75.2	304.4	89.2	63.5	9.9	7.5	5.1	558.0		40	9	49
33		Patna	25.6	85.2	53	27.0	1.0	20.0	11.6	33.6	46.0	310.3	250.0	214.6	100.6	0.0	0.0	1014.7		24	27	51
29		Nagpur/Sonegaon	21.1	79.1	310	17.0	6.1	18.9	12.4	21.2	178.5	334.1	268.1	225.3	45.6	7.4	31.4	1166.0		21	32	53
38		Srinagar	34.1	74.8	1587	63.8	71.6	117.7	100.0	71.1	25.5	59.1	46.0	31.6	28.2	27.3	76.0	717.9		36	18	54
40		Panam	9.3	79.3	11	43.1	21.1	23.8	60.5	51.2	3.9	14.1	9.4	19.8	201.3	278.4	181.4	908.0		29	25	54
8		Sagar	23.9	78.8	551	20.0	5.6	12.0	2.7	10.7	86.3	343.0	486.0	226.6	63.2	8.7	16.9	1281.7		20	36	56
4		Allahabad/Bamhrauli	25.5	81.7	98	16.7	6.7	11.1	7.9	8.7	62.8	290.7	330.5	162.9	37.7	8.5	6.2	950.4		28	31	59
21		Indore	22.7	75.8	567	15.7	1.8	6.1	3.0	6.0	117.8	295.7	264.0	257.4	35.2	21.0	18.0	1041.7		23	38	61
20		Begampet	17.5	78.5	545	0.6	4.3	13.6	30.2	26.0	87.9	216.0	143.3	198.9	76.8	15.0	14.5	827.1		33	30	63
1		Agra	27.2	78.0	169	11.1	6.0	8.7	2.0	15.9	25.9	235.0	353.1	156.8	21.1	4.6	8.3	848.5		30	34	64
35		Poona	18.5	73.9	559	0.1	0.0	5.5	20.7	66.7	97.2	263.2	98.3	105.4	55.5	23.8	11.6	748.0		35	29	64
30		New Dehli-Safarjung	28.6	77.2	216	13.4	10.4	11.1	3.7	15.3	51.2	224.2	316.0	152.9	23.6	1.9	15.1	838.8		32	33	65
6		Amritsar/Rajasansi	31.6	74.9	234	25.5	18.2	28.5	12.3	16.2	32.2	199.9	171.3	129.1	11.0	10.2	26.1	680.5		39	28	67
3		Akola	20.7	77.0	282	9.8	1.4	13.8	6.6	7.0	114.9	243.3	157.3	194.1	58.3	14.9	26.6	848.0		31	37	68
2		Ahmadabad	23.1	72.6	55	2.6	0.1	2.1	2.5	3.0	89.2	304.4	150.8	242.7	17.4	6.8	1.7	823.3		34	35	69
23		Jaipur/Sanganer	26.8	75.8	390	1.0	1.3	3.3	5.0	36.3	62.0	151.0	316.3	112.6	12.6	13.3	3.0	717.7	D	37	39	76
26		Kota	25.2	75.9	257	7.0	0.2	4.6	1.3	10.5	52.8	262.7	220.8	115.6	6.4	3.0	1.1	686.0	D	38	41	79
9		Bikaner	28.0	73.3	224	5.4	6.9	10.1	0.6	15.5	23.3	78.8	74.9	72.1	4.2	4.4	6.9	303.1	D	42	40	82
24		Jodhpur	26.3	73.0	224	0.7	2.7	14.7	1.2	8.2	28.4	117.9	97.8	78.5	3.2	3.6	1.0	357.9	D	41	42	83

Mean Daily Wind Speed Corrected to 2 m Height, u (km/day) - Sorted by Mean Annual Wind Speed (km//hr)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean (km/hr)	Strong Wind
31	256	Okha	22.5	69.1	7.0	378.4	370.6	392.2	417.7	480.4	480.4	519.6	507.9	347.1	296.1	323.5	339.2	16.9	W
41	352	Veraval	20.9	70.4	8.0	262.4	283.0	322.4	361.7	386.1	492.9	635.4	507.9	384.2	264.3	236.2	254.9	15.2	W
40	342	Tuticorin	8.8	78.2	4.0	402.2	412.3	341.9	265.5	271.5	341.9	370.1	364.0	325.8	241.3	315.8	394.2	14.1	W
35	281	Pune Airport	18.6	73.9	593.0	150.7	175.6	222.1	268.6	401.8	442.7	416.3	394.7	305.4	177.4	156.2	133.9	11.3	W
21	156	Indore Airport	22.7	75.8	567.0	159.0	187.1	226.4	271.3	374.2	467.7	430.3	387.3	308.7	159.0	127.2	134.7	11.2	W
5	19	Amini Divi	11.1	72.7	4.0	118.8	155.9	168.9	187.5	271.0	458.4	527.1	477.0	378.6	200.4	109.5	100.2	10.9	W
25	194	Kodaikanal	10.2	77.5	2343.0	222.7	243.0	241.1	217.2	224.6	254.0	325.8	266.9	222.7	211.7	237.5	254.0	10.1	W
20	153	Hyderabad-Begumpet	17.5	78.5	545.0	150.3	154.2	167.9	185.5	259.7	423.7	464.7	376.8	259.7	140.6	128.9	128.9	9.9	
7	37	Bangalore Airport	13.0	77.6	897.0	176.2	165.3	162.8	159.1	232.2	353.9	385.5	322.3	263.4	152.2	166.0	165.7	9.4	
17	126	Gannavaram Airport	16.5	80.8	24.0	185.4	175.8	200.7	227.4	273.3	328.7	294.3	259.9	200.7	168.2	198.8	183.5	9.4	
34	278	Port Blair	11.7	92.7	79.0	181.8	148.2	118.5	116.6	241.0	359.6	365.5	349.7	296.3	171.9	154.1	187.7	9.3	
8	59	Bhopal Airport	23.3	77.4	523.0	158.4	171.5	193.9	223.7	307.6	372.8	333.7	303.8	229.3	139.8	124.9	115.6	9.3	
11	70	Bombay-Santacruz	19.1	72.9	14.0	151.9	165.5	183.0	204.4	247.3	319.3	416.7	348.5	222.0	138.2	136.3	140.2	9.3	
42	353	Vishakhapatnam	17.7	83.2	3.0	158.6	156.7	191.1	275.2	292.4	288.6	317.3	254.2	177.7	131.9	166.3	151.0	8.9	
19	131	Gao-Panjim	15.5	73.8	60.0	173.1	185.6	196.3	203.4	235.6	242.7	340.9	305.2	180.2	146.3	158.8	169.5	8.8	
26	200	Kota Airport	25.2	75.9	274.0	118.0	148.6	150.6	223.9	309.4	358.2	327.7	270.7	201.5	134.3	116.0	111.9	8.6	
15	48	Belgaum Airport	15.9	74.6	747.0	100.2	133.0	169.6	188.9	256.3	335.3	335.3	294.8	202.3	121.4	117.6	117.6	8.2	
27	209	Madras- Minambakkam	13.0	80.2	16.0	169.3	162.0	180.2	205.7	236.6	265.8	236.6	216.6	194.8	151.1	172.9	172.9	8.2	
24	172	Jodhpur	26.3	73.0	217.0	137.3	135.4	170.2	181.8	259.2	348.2	288.2	239.9	181.8	119.9	135.4	135.4	8.1	
29	239	Nagpur Airport	21.1	79.1	310.0	134.0	154.4	163.7	186.1	258.6	275.4	243.8	221.4	201.0	150.7	135.8	124.7	7.8	
3	9	Akola Airport	20.7	77.1	309.0	167.1	165.2	144.3	182.3	262.0	301.9	237.3	191.8	176.6	146.2	151.9	108.2	7.8	
30	250	New Dehli - Safdarjung	28.6	77.2	216.0	156.8	196.4	200.0	214.4	245.1	293.7	185.6	160.4	164.0	113.5	113.5	146.0	7.6	
28	231	Minicoy	8.3	73.0	2.0	107.4	109.2	118.3	127.4	227.5	282.2	296.7	271.2	234.8	169.3	123.8	92.8	7.5	
10	69	Bombay-Colaba	18.9	72.8	11.0	146.3	144.4	169.7	178.8	173.3	209.4	261.8	229.3	180.6	128.2	121.0	128.2	7.2	
32	122	Fort Cochin	10.0	76.2	3.0	157.4	174.5	193.5	178.3	189.7	161.2	172.6	180.2	178.3	153.6	140.4	136.6	7.0	
1	3	Agra Airport	27.2	78.0	169.0	105.5	140.4	156.1	181.0	213.3	274.5	247.7	186.5	164.2	102.6	78.8	86.9	6.7	
6	21	Amritsar Airport	31.6	74.9	234.0	108.0	145.3	174.8	182.6	206.2	214.0	221.9	164.9	133.5	113.9	98.2	102.1	6.5	
39	340	Trivandrum Airport	8.5	77.0	8.0	115.5	123.5	145.4	135.5	185.3	173.3	183.3	215.1	179.3	135.5	103.6	101.6	6.2	
9	64	Bikaner	28.0	73.3	224.0	66.5	86.7	121.0	135.1	181.4	268.1	239.9	201.6	163.3	96.8	74.6	72.6	5.9	
13	76	Calcutta-Dum Dum	22.7	88.5	6.0	62.2	85.6	126.4	200.3	243.1	204.2	190.6	163.3	126.4	93.3	56.4	52.5	5.6	
23	159	Jaipur Airport	26.8	75.8	390.0	113.6	113.1	125.2	137.5	170.9	199.2	167.9	129.7	119.7	91.3	95.1	89.1	5.4	
37	320	Silchar - Khumbhigram	24.9	93.0	97.0	146.9	156.3	169.5	156.3	139.4	118.6	105.5	97.9	101.7	111.1	109.2	128.1	5.3	
2	5	Ahmadabad Airport	23.1	72.6	55.0	117.3	109.4	119.3	133.2	175.0	196.9	169.0	123.3	107.4	75.6	89.5	107.4	5.3	
33	271	Patna Airport	25.6	85.1	60.0	71.4	91.0	114.2	151.7	166.0	162.4	151.7	123.1	114.2	71.4	48.2	58.9	4.6	
12	75	Calcutta-Alipore	22.5	88.3	6.0	62.7	87.8	112.9	155.9	186.4	150.5	132.6	116.5	103.9	78.8	62.7	62.7	4.6	
14	97	Cuttack	20.5	85.9	27.0	57.6	87.3	117.0	161.6	183.9	150.5	130.0	115.2	100.3	72.4	53.9	46.4	4.4	
4	13	Allahabad Airport	25.5	81.7	98.0	63.9	79.9	95.8	121.8	129.8	155.8	155.8	117.8	111.8	67.9	49.9	51.9	4.2	
22	158	Jagdalpur	19.1	82.0	553.0	50.5	71.1	84.2	101.0	108.5	121.6	136.6	119.7	93.5	69.2	54.3	44.9	3.7	
18	127	Gauhati Airport	26.1	91.6	54.0	55.3	79.0	108.7	118.5	124.5	108.7	96.8	94.8	86.9	67.2	57.3	49.4	3.6	
16	112	Dibrugarh Airport	27.5	95.0	111.0	56.5	90.9	115.5	130.3	118.0	118.0	93.4	78.6	71.3	54.1	46.7	46.7	3.5	
38	325	Srinagar Airport	34.0	74.8	1666.0	44.2	53.8	93.7	96.2	99.4	105.8	100.8	88.4	77.7	68.4	46.0	37.8	3.2	
36	314	Shillong	25.6	91.9	1600.0	42.9	55.9	93.2	136.1	139.8	102.5	63.4	52.2	46.6	54.1	37.3	29.8	3.0	

Minimum Temperature (C) - Sorted by Annual Minimum Temperature

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Min	Frost
5	8	Amini Divi	11.1	72.7	4	24.7	25.5	26.5	27.8	28.3	27.9	27.4	27.2	26.8	26.5	25.6	25.4	24.7	
28	89	Minicoy	8.3	73.0	2	24.0	24.3	25.7	26.6	27.5	27.0	26.7	26.5	26.2	25.6	24.9	24.5	24.0	
34	107	Port Blair	11.7	92.7	79	23.7	23.3	23.5	24.9	25.6	25.5	25.4	25.2	24.7	24.4	24.5	24.1	23.3	
39	134	Trivandrum	8.5	77.0	64	23.3	23.8	25.0	25.8	25.6	24.6	24.1	24.1	24.1	24.1	23.9	23.5	23.3	
32	100	Ollukara	10.5	76.3	22	22.3	23.2	24.9	25.3	25.3	24.2	23.6	23.7	23.6	23.9	23.5	22.7	22.3	
40	135	Tuticorin	8.8	78.2	4	21.9	22.7	24.5	25.9	26.5	25.9	25.8	25.9	25.4	24.4	23.4	22.0	21.9	
27	86	Madras	13.0	80.2	16	21.8	22.2	24.2	26.6	28.5	28.1	27.1	26.3	26.1	25.1	23.5	22.3	21.8	
19	41	Goa	15.5	73.8	55	20.8	21.4	23.7	25.7	26.8	25.7	25.5	25.3	24.7	24.4	22.8	21.9	20.8	
31	99	Okha	22.5	69.1	7	20.1	21.3	23.3	25.1	27.2	28.5	28.1	27.1	26.4	25.9	24.9	21.5	20.1	
17	39	Gannavaram	16.5	80.8	24	19.8	20.7	23.5	26.1	28.4	28.3	26.7	26.5	26.1	24.7	22.4	19.6	19.6	
42	144	Vishakhapatnam	17.7	83.2	3	19.1	20.3	23.4	26.5	28.6	28.5	26.7	26.7	26.4	24.9	22.1	19.7	19.1	
10	26	Bombay	19.1	72.9	14	18.3	19.1	21.9	24.6	27.2	27.2	26.5	26.0	25.3	24.2	22.2	20.1	18.3	
11	26	Bombay	19.1	72.9	14	18.3	19.1	21.9	24.6	27.2	27.2	26.5	26.0	25.3	24.2	22.2	20.1	18.3	
15	36	Dharwar	15.4	75.1	679	16.9	18.5	21.3	22.5	22.3	21.6	21.2	20.9	20.5	20.5	18.6	17.2	16.9	
41	142	Veraval	20.9	70.4	8	16.4	17.1	20.0	23.0	26.5	28.5	27.7	27.0	26.3	23.6	21.5	18.5	16.4	
14	34	Cuttack	20.5	85.9	24	15.7	18.5	22.2	25.0	27.0	26.7	25.7	25.8	25.6	23.7	19.3	15.8	15.7	
7	14	Bangalor	13.0	77.6	897	15.3	17.7	19.9	22.1	21.8	20.4	19.9	19.9	20.0	19.4	18.7	16.6	15.3	
20	56	Hyderabad	17.5	78.5	545	16.5	18.3	22.0	24.8	27.0	25.0	23.2	23.0	22.6	20.9	17.6	15.3	15.3	
29	92	Nagpur	21.2	79.1	311	13.7	15.9	20.4	25.2	29.1	27.5	25.0	24.4	23.8	20.6	16.1	13.4	13.4	
12	27	Calcutta	22.7	88.5	6	13.3	16.3	21.0	25.0	27.0	27.2	26.6	26.7	26.4	24.3	18.3	13.9	13.3	
13	27	Calcutta	22.7	88.5	6	13.3	16.3	21.0	25.0	27.0	27.2	26.6	26.7	26.4	24.3	18.3	13.9	13.3	
35	108	Pune	18.5	73.9	563	13.1	14.0	18.1	22.1	23.9	23.9	23.0	22.4	21.7	20.0	16.8	14.6	13.1	
2	4	Ahmadabad	23.1	72.6	55	13.0	15.1	19.5	24.1	27.2	27.9	26.5	25.8	24.9	21.5	17.3	14.5	13.0	
3	5	Akola	20.7	77.0	282	12.9	14.5	19.1	23.4	27.0	25.4	23.2	22.8	22.2	19.1	15.7	13.0	12.9	
18	40	Gauhati	26.1	91.6	54	17.0	13.3	16.8	21.6	23.7	25.8	26.8	26.7	25.9	22.8	17.4	12.9	12.9	
22	61	Jagadalpur	19.1	82.0	553	13.3	15.6	19.9	23.3	25.2	24.7	23.2	23.1	22.9	21.1	15.8	12.4	12.4	
8	21	Bhopal	23.3	77.4	503	12.2	14.1	19.0	23.4	26.5	26.7	24.4	23.6	22.5	19.9	16.5	13.2	12.2	
37	124	Silicuri	24.8	92.9	40	11.7	13.9	17.1	20.4	22.2	23.7	24.2	24.2	23.9	21.7	16.6	13.0	11.7	
24	69	Jodhpur	26.3	73.0	224	11.4	13.9	19.1	24.0	27.1	29.2	28.0	26.8	25.1	21.4	16.3	12.9	11.4	
21	59	Indore	22.7	75.8	567	11.0	13.4	17.1	22.0	24.8	25.5	23.9	22.5	21.6	19.4	15.2	12.6	11.0	
4	7	Allahabad	25.5	81.7	98	10.6	13.1	18.4	24.4	28.0	30.5	27.9	27.0	26.1	22.0	15.5	10.8	10.6	
33	105	Patna	25.5	85.3	52	10.6	13.1	17.8	23.6	26.3	28.1	27.3	27.0	26.3	22.1	16.0	11.6	10.6	
26	79	Kota	25.2	75.5	257	10.1	13.5	18.8	24.2	28.6	29.2	26.3	25.4	24.3	20.7	15.4	11.4	10.1	
23	62	Jaipur	26.8	75.8	390	9.5	13.0	17.7	23.3	26.4	29.1	27.4	25.7	24.2	20.1	14.8	10.5	9.5	
25	76	Kodaikanal	10.2	77.5	2345	9.5	9.8	11.1	12.6	14.0	13.5	12.7	12.8	12.6	12.1	11.1	10.1	9.5	
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	9.1	13.1	16.1	19.5	22.0	24.4	26.1	25.1	24.5	21.2	14.9	10.9	9.1	
30	97	New Dehli	28.6	77.2	216	8.6	12.0	16.6	22.6	26.3	29.6	28.4	27.1	25.5	20.8	14.3	9.5	8.6	
36	123	Shillong	25.6	91.9	1598	7.1	8.7	12.3	15.3	17.0	18.2	18.8	18.5	17.7	15.4	11.3	8.5	7.1	
1	3	Agra	27.2	78.1	169	6.9	10.8	15.8	21.7	26.0	29.5	29.0	22.7	24.4	19.3	12.6	8.1	6.9	
6	9	Amritsar	31.6	74.9	234	5.9	8.7	13.2	18.5	22.4	26.8	27.2	26.8	24.4	18.2	10.9	6.1	5.9	
9	24	Bikaner	28.0	73.3	224	4.4	8.7	14.6	20.8	25.3	28.9	27.8	26.8	24.8	18.6	10.7	5.5	4.4	
38	127	Srinagar	34.1	74.8	1587	-1.1	1.0	5.3	9.4	12.3	16.3	20.1	19.3	15.0	8.2	3.4	0.4	-1.1	F

APPENDIX X

GRAPES

Calculation of

Crop Water Requirements
and
Irrigation Water Requirements

Max 220.5
Min 0.0

GRAPES - Average Monthly Irrigation Requirement (mm/month)

St# Eto	St# Vind	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	3	Agra Airport	27.2	78.0	169	5	0.0	0.0	28.0	81.2	133.9	149.2	0.0	0.0	39.4	54.0	26.3	0.0	512.1
2	5	Ahmadabad Airport	23.1	72.6	55	5	0.0	0.0	30.7	83.6	143.9	137.1	0.0	7.3	67.2	62.2	35.9	0.0	568.0
3	9	Akola Airport	20.7	77.1	309	5	0.0	0.0	31.3	85.9	148.1	69.1	0.0	0.0	10.2	61.3	37.7	0.0	443.5
4	13	Allahabad Airport	25.5	81.7	98	5	0.0	0.0	28.5	80.1	130.1	124.7	0.0	0.0	0.0	52.4	26.7	0.0	442.4
5	19	Amini Divi	11.1	72.7	4	6	0.0	0.0	31.9	71.9	84.7	0.0	0.0	0.0	14.4	0.0	19.2	0.0	222.1
6	21	Amritsar Airport	31.6	74.9	234	5	0.0	0.0	14.4	72.0	131.6	150.5	7.3	10.0	63.3	48.0	21.1	0.0	518.2
7	37	Bangalore Airport	13.0	77.6	897	5	0.0	0.0	31.5	66.6	40.1	46.3	27.0	5.4	0.0	0.0	30.3	0.0	247.2
8	59	Bhopal Airport	23.3	77.4	523	5	0.0	0.0	31.9	87.1	163.7	109.2	0.0	0.0	0.0	61.6	34.1	0.0	487.7
9	64	Bikaner	28.0	73.3	224	7	0.0	0.0	44.8	104.3	177.6	220.5	159.7	121.8	115.3	78.1	37.4	0.0	1059.6
10	69	Bombay-Colaba	18.9	72.8	11	5	0.0	0.0	30.6	74.6	113.3	0.0	0.0	0.0	0.0	57.9	38.8	0.0	315.1
11	70	Bombay-Santacruz	19.1	72.9	14	5	0.0	0.0	32.2	82.4	125.6	0.0	0.0	0.0	0.0	41.3	39.2	0.0	320.7
12	75	Calcutta-Alipore	22.5	88.3	6	5	0.0	0.0	28.3	58.5	53.5	0.0	0.0	0.0	0.0	0.0	28.2	0.0	168.4
13	76	Calcutta-Dum Dum	22.7	88.5	6	5	0.0	0.0	21.4	70.0	73.8	0.0	0.0	0.0	0.0	0.0	28.7	0.0	193.8
14	97	Cuttack	20.5	85.9	27	5	0.0	0.0	28.6	71.9	88.7	0.0	0.0	0.0	0.0	0.0	30.1	0.0	219.3
15	48	Belgaum Airport	15.9	74.6	747	5	0.0	0.0	29.7	59.1	67.5	0.0	0.0	0.0	0.0	18.9	19.7	0.0	194.9
16	112	Dibrugarh Airport	27.5	95.0	111	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	18.2
17	126	Gannavaram Airport	16.5	80.8	24	5	0.0	0.0	31.7	78.4	130.3	71.8	3.6	4.3	0.0	0.0	25.6	0.0	345.7
18	127	Gauhati Airport	26.1	91.6	54	5	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	16.7	22.7	0.0	45.9
19	131	Gao-Panjim	15.5	73.8	60	5	0.0	0.0	31.3	76.4	112.4	0.0	0.0	0.0	0.0	33.4	42.4	0.0	295.9
20	153	Hyderabad-Begumpet	17.5	78.5	545	5	0.0	0.0	33.7	86.1	140.6	82.5	0.0	5.6	0.0	34.3	36.0	0.0	418.8
21	156	Indore Airport	22.7	75.8	567	6	0.0	0.0	32.5	91.5	191.0	117.0	0.0	0.0	1.8	62.5	33.6	0.0	529.8
22	158	Jagdalpur	19.1	82.0	553	5	0.0	0.0	29.9	51.8	85.7	0.0	0.0	0.0	0.0	13.1	31.2	0.0	211.6
23	159	Jaipur Airport	26.8	75.8	390	7	0.0	0.0	45.2	97.6	154.5	164.5	8.4	12.5	77.7	73.2	40.1	0.0	673.6
24	172	Jodhpur	26.3	73.0	217	7	0.0	0.0	49.1	107.1	188.7	210.5	114.2	88.9	107.1	82.2	48.3	0.0	996.1
25	194	Kodaikanal	10.2	77.5	2343	6	0.0	0.0	17.2	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	19.6
26	200	Kota Airport	25.2	75.9	274	7	0.0	0.0	49.5	118.0	194.2	186.6	0.0	0.0	60.1	80.2	46.8	0.0	735.3
27	209	Madras- Minambakkam	13.0	80.2	16	5	0.0	0.0	32.8	79.4	118.7	106.3	60.7	33.1	15.1	0.0	0.0	0.0	446.1
28	231	Minicoy	8.3	73.0	2	5	0.0	0.0	28.7	51.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	79.8
29	239	Nagpur Airport	21.1	79.1	310	5	0.0	0.0	32.5	86.4	153.9	23.3	0.0	0.0	0.0	59.5	35.0	0.0	390.6
30	250	New Dehli - Safdarjung	28.6	77.2	216	5	0.0	0.0	27.4	82.5	136.0	145.3	7.4	3.9	43.3	54.1	27.6	0.0	527.5
31	256	Okha	22.5	69.1	7	6	0.0	0.0	28.2	68.5	127.4	120.0	61.8	75.8	75.2	57.6	39.9	0.0	654.5
32	122	Fort Cochin	10.0	76.2	3	5	0.0	0.0	21.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.5
33	271	Patna Airport	25.6	85.1	60	5	0.0	0.0	29.2	87.6	137.7	65.2	0.0	0.0	0.0	48.7	29.3	0.0	397.7
34	278	Port Blair	11.7	92.7	79	5	0.0	0.0	28.9	56.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85.2
35	281	Pune Airport	18.6	73.9	593	6	0.0	0.0	36.2	94.5	162.8	88.6	0.0	29.3	7.3	41.4	37.8	0.0	497.9
36	314	Shillong	25.6	91.9	1600	5	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.9	0.0	20.4
37	320	Silchar - Khumbhigram	24.9	93.0	97	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.7	0.0	25.7
38	325	Srinagar Airport	34.0	74.8	1666	5	0.0	0.0	0.0	0.0	41.8	92.8	89.2	61.6	49.2	27.9	11.4	0.0	373.8
39	340	Trivandrum Airport	8.5	77.0	8	5	0.0	0.0	21.2	0.0	12.4	0.0	0.0	17.1	22.3	0.0	0.0	0.0	73.0
40	342	Tuticorin	8.8	78.2	4	6	0.0	0.0	32.3	70.1	121.2	143.4	151.1	139.9	98.0	0.0	0.0	0.0	755.9
41	352	Veraval	20.9	70.4	8	6	0.0	0.0	31.5	73.8	124.5	118.8	0.0	65.6	74.9	65.4	41.9	0.0	596.3
42	353	Vishakhapatnam	17.7	83.2	3	5	0.0	0.0	33.8	85.1	129.0	65.5	24.7	25.2	0.0	0.0	33.8	0.0	397.0

Effective Rainfall, Pe (mm/month)

St# Eto		Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1		Agra	27.2	78	169	1.7	0.0	0.0	0.0	0.0	6.9	120.6	119.7	35.5	0.0	0.0	0.0
2		Ahmadabad	23.1	72.6	55	0.0	0.0	0.0	0.0	0.0	1.7	95.4	65.5	1.2	0.0	0.0	0.0
3		Akola	20.7	77	282	0.0	0.0	0.0	0.0	0.0	76.6	137.3	83.3	56.1	0.0	0.0	0.0
4		Allahabad/Bamhrauli	25.5	81.7	98	0.0	0.0	0.0	0.0	0.0	13.9	180.0	171.6	75.6	0.0	0.0	0.0
5		Amini	11.1	72.7	4	0.0	0.0	0.0	0.0	18.8	257.6	172.4	89.4	60.4	77.0	16.4	0.0
6		Amritsar/Rajasansi	31.6	74.9	234	6.4	10.5	6.7	0.0	2.1	5.5	117.0	89.3	8.5	0.0	0.0	0.0
7		Bangalore	13	77.6	921	0.0	0.0	0.0	7.0	62.5	42.1	50.6	69.3	87.6	75.1	0.0	0.0
8		Sagar	23.9	78.8	551	0.0	0.0	0.0	0.0	0.0	50.3	247.8	223.7	77.0	0.0	0.0	0.0
9		Bikaner	28	73.3	224	0.0	0.0	0.0	0.0	0.0	4.3	24.5	24.2	0.0	0.0	0.0	0.0
10		Bombay/Colaba,India	18.9	72.8	11	0.0	0.0	0.0	0.0	0.0	319.9	409.2	189.2	111.9	0.0	0.0	0.0
11		Bombay/Santa Cruz	19.1	72.9	14	0.0	0.0	0.0	0.0	0.0	351.7	749.2	313.4	113.3	17.4	0.0	0.0
12		Calcutta/Alipore	22.5	88.3	6	0.0	0.0	0.6	16.1	57.5	160.0	232.2	237.1	142.8	55.2	0.0	0.0
13		Calcutta/Dum Dum	22.7	88.5	6	0.0	0.0	6.1	5.1	38.8	149.3	213.8	212.5	179.9	57.0	0.0	0.0
14		Cuttack	20.5	85.9	27	0.0	0.0	0.0	1.2	30.0	128.4	222.7	207.3	162.8	57.7	0.0	0.0
15		Belguam/Samra	15.9	74.6	747	0.0	0.0	0.0	10.4	34.3	97.7	144.0	102.1	56.9	31.2	17.2	0.0
16		Dibrugarh/Mohanbari	27.5	95	111	12.8	28.8	51.2	139.5	197.6	343.9	403.8	329.6	221.1	69.7	3.0	0.5
17		Masulipatam	16.2	81.1	3	0.0	0.0	0.0	0.0	0.0	50.6	95.2	86.2	93.8	92.1	10.8	0.0
18		Gauhti	26.1	91.6	54	0.0	2.7	16.6	83.2	159.9	222.8	218.4	177.1	103.1	28.3	0.7	0.0
19		Goa/Panjim	15.5	73.8	57	0.0	0.0	0.0	0.0	0.0	629.6	689.9	335.0	109.7	22.8	0.0	0.0
20		Begampet	17.5	78.5	545	0.0	0.0	0.0	0.0	3.9	55.3	103.3	83.4	84.5	24.5	0.0	0.0
21		Indore	22.7	75.8	567	0.0	0.0	0.0	0.0	0.0	59.8	170.0	137.6	68.9	0.0	0.0	0.0
22		Jogdalapur	19.1	82	553	0.0	0.0	0.2	23.4	28.0	145.2	264.6	261.3	157.9	36.3	0.0	0.0
23		Jaipur/Sanganer	26.8	75.8	390	0.0	0.0	0.0	0.0	0.0	4.2	108.9	81.1	13.3	0.0	0.0	0.0
24		Jodhpur	26.3	73	224	0.0	0.0	0.0	0.0	0.0	0.3	38.5	33.4	0.0	0.0	0.0	0.0
25		Kodaikanal	10.2	77.5	2343	0.0	0.0	6.1	63.8	100.5	62.6	65.9	94.6	98.8	163.3	125.5	43.6
26		Kota	25.2	75.9	257	0.0	0.0	0.0	0.0	0.0	19.3	151.8	128.2	33.9	0.0	0.0	0.0
27		Madras/Minambakkam	13	80.2	16	0.0	0.0	0.0	0.0	0.0	19.7	50.5	64.5	60.3	133.7	154.9	18.9
28		Minicoy	8.3	73	2	0.0	0.0	0.0	14.0	88.4	204.5	137.9	115.3	83.0	97.0	71.7	9.0
29		Nagpur/Sonegaon	21.1	79.1	310	0.0	0.0	0.0	0.0	0.0	113.3	237.4	171.8	98.1	0.0	0.0	0.0
30		New Dehli-Safarjung	28.6	77.2	216	1.0	0.0	0.0	0.0	0.2	9.0	105.8	84.6	30.5	0.0	0.0	0.0
31		Dwarka	22.4	69.1	11	0.0	0.0	0.0	0.0	0.0	0.0	34.1	7.2	0.0	0.0	0.0	0.0
32		Fort Cochin	10	76.2	3	0.0	0.0	0.0	9.2	64.6	150.7	547.2	404.4	202.1	134.9	190.2	80.3
33		Patna	25.6	85.2	53	0.0	0.0	0.0	0.0	0.4	66.8	188.9	186.5	114.8	3.1	0.0	0.0
34		Port Blair	11.7	92.7	79	0.0	0.0	0.0	10.0	231.5	357.4	266.2	271.3	330.8	201.5	114.8	37.0
35		Poona	18.5	73.9	559	0.0	0.0	0.0	0.0	2.0	46.3	89.1	50.8	58.3	20.6	0.0	0.0
36		Shillong	25.6	91.9	1500	0.0	5.6	15.1	58.6	173.6	291.8	212.7	218.8	202.7	84.2	0.0	0.0
37		Silchar	24.8	92.8	29	0.0	11.8	60.7	193.8	254.5	431.5	378.6	371.2	259.0	93.6	0.0	0.0
38		Srinagar	34.1	74.8	1587	29.3	36.1	54.1	49.0	32.8	13.8	18.7	27.0	7.3	2.5	0.0	6.0
39		Trivandrum	8.5	77	64	0.0	0.0	6.8	58.1	65.1	187.7	116.0	60.2	42.3	157.8	77.7	10.0
40		Panam	9.3	79.3	11	0.0	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	96.5	168.4	63.8
41		Veraval	20.9	70.4	8	0.0	0.0	0.0	0.0	0.0	10.0	90.8	13.5	0.0	0.0	0.0	0.0
42		Vishakhapatnam	17.7	83.2	3	0.0	0.0	0.0	0.0	0.0	44.1	68.9	67.7	93.0	101.1	5.6	0.0

Max 224.8
Min 0.0

GRAPES - Crop Evapotranspiration, ETcrop, (mm/month)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	3	Agra Airport	27.2	78.0	169	5	0.0	0.0	28.0	81.2	133.9	156.1	115.6	85.2	74.9	54.0	26.3	0.0	755.2
2	5	Ahmadabad Airport	23.1	72.6	55	5	0.0	0.0	30.7	83.6	143.9	138.8	90.6	72.8	68.4	62.2	35.9	0.0	726.9
3	9	Akola Airport	20.7	77.1	309	5	0.0	0.0	31.3	85.9	148.1	145.7	87.4	75.0	66.3	61.3	37.7	0.0	738.6
4	13	Allahabad Airport	25.5	81.7	98	5	0.0	0.0	28.5	80.1	130.1	138.6	99.8	77.5	68.9	52.4	26.7	0.0	702.5
5	19	Amini Divi	11.1	72.7	4	6	0.0	0.0	31.9	71.9	103.5	91.9	90.7	87.8	74.8	53.6	35.6	0.0	641.8
6	21	Amritsar Airport	31.6	74.9	234	5	0.0	0.0	21.1	72.0	133.7	156.0	124.4	99.2	71.7	48.0	21.1	0.0	747.3
7	37	Bangalore Airport	13.0	77.6	897	5	0.0	0.0	31.5	73.6	102.6	88.4	77.6	74.8	58.1	45.9	30.3	0.0	582.7
8	59	Bhopal Airport	23.3	77.4	523	5	0.0	0.0	31.9	87.1	163.7	159.5	85.3	64.7	64.8	61.6	34.1	0.0	752.8
9	64	Bikaner	28.0	73.3	224	7	0.0	0.0	44.8	104.3	177.6	224.8	184.2	145.9	115.3	78.1	37.4	0.0	1112.5
10	69	Bombay-Colaba	18.9	72.8	11	5	0.0	0.0	30.6	74.6	113.3	94.7	68.3	62.9	58.3	57.9	38.8	0.0	599.3
11	70	Bombay-Santacruz	19.1	72.9	14	5	0.0	0.0	32.2	82.4	125.6	99.7	71.0	64.0	59.2	58.7	39.2	0.0	632.0
12	75	Calcutta-Alipore	22.5	88.3	6	5	0.0	0.0	28.8	74.5	111.0	86.1	80.2	70.8	54.5	45.7	28.2	0.0	579.8
13	76	Calcutta-Dum Dum	22.7	88.5	6	5	0.0	0.0	27.4	75.1	112.6	87.2	81.8	71.1	55.2	45.9	28.7	0.0	584.9
14	97	Cuttack	20.5	85.9	27	5	0.0	0.0	28.6	73.1	118.7	97.6	75.9	71.0	57.8	48.4	30.1	0.0	601.2
15	48	Belgaum Airport	15.9	74.6	747	5	0.0	0.0	29.7	69.5	101.9	85.4	64.3	64.4	56.7	50.1	36.9	0.0	558.8
16	112	Dibrugarh Airport	27.5	95.0	111	5	0.0	0.0	19.5	44.3	68.2	73.4	77.9	75.9	50.9	39.1	21.2	0.0	470.4
17	126	Gannavaram Airport	16.5	80.8	24	5	0.0	0.0	31.7	78.4	130.3	122.4	98.9	90.5	67.7	54.5	36.4	0.0	710.6
18	127	Gauhati Airport	26.1	91.6	54	5	0.0	0.0	23.1	58.8	84.1	80.1	85.6	78.3	57.4	45.0	23.4	0.0	535.8
19	131	Gao-Panjim	15.5	73.8	60	5	0.0	0.0	31.3	76.4	112.4	81.5	70.4	72.4	61.2	56.2	42.4	0.0	604.2
20	153	Hyderabad-Begumpet	17.5	78.5	545	5	0.0	0.0	33.7	86.1	144.4	137.8	100.5	89.0	67.9	58.8	36.0	0.0	754.3
21	156	Indore Airport	22.7	75.8	567	6	0.0	0.0	32.5	91.5	191.0	176.8	97.6	73.6	70.7	62.5	33.6	0.0	829.7
22	158	Jagdalpur	19.1	82.0	553	5	0.0	0.0	30.2	75.1	113.6	96.8	69.1	61.9	53.7	49.3	31.2	0.0	581.0
23	159	Jaipur Airport	26.8	75.8	390	7	0.0	0.0	45.2	97.6	154.5	168.6	117.3	93.6	91.0	73.2	40.1	0.0	881.1
24	172	Jodhpur	26.3	73.0	217	7	0.0	0.0	49.1	107.1	188.7	210.8	152.7	122.4	107.1	82.2	48.3	0.0	1068.2
25	194	Kodaikanal	10.2	77.5	2343	6	0.0	0.0	23.3	47.5	67.4	65.1	56.5	57.1	42.3	30.8	21.0	0.0	410.9
26	200	Kota Airport	25.2	75.9	274	7	0.0	0.0	49.5	118.0	194.2	205.9	135.1	98.6	93.9	80.2	46.8	0.0	1022.2
27	209	Madras- Minambakkam	13.0	80.2	16	5	0.0	0.0	32.8	79.4	118.7	126.0	111.2	97.6	75.4	53.3	33.0	0.0	727.5
28	231	Minicoy	8.3	73.0	2	5	0.0	0.0	28.7	65.1	88.2	84.6	87.3	90.4	70.6	55.5	37.6	0.0	608.0
29	239	Nagpur Airport	21.1	79.1	310	5	0.0	0.0	32.5	86.4	153.9	136.6	86.9	70.7	64.2	59.5	35.0	0.0	725.6
30	250	New Dehli - Safdarjung	28.6	77.2	216	5	0.0	0.0	27.4	82.5	136.2	154.3	113.2	88.6	73.8	54.1	27.6	0.0	757.6
31	256	Okha	22.5	69.1	7	6	0.0	0.0	28.2	68.5	127.4	120.0	96.0	83.0	75.2	57.6	39.9	0.0	695.8
32	122	Fort Cochin	10.0	76.2	3	5	0.0	0.0	30.7	64.2	74.1	64.4	59.1	59.7	54.4	46.3	34.8	0.0	487.7
33	271	Patna Airport	25.6	85.1	60	5	0.0	0.0	29.2	87.6	138.1	132.0	101.2	85 9	67.7	51.8	29.3	0.0	722.6
34	278	Port Blair	11.7	92.7	79	5	0.0	0.0	28.9	66.2	72.5	71.3	71.7	66.6	52.0	46.8	34.0	0.0	510.1
35	281	Pune Airport	18.6	73.9	593	6	0.0	0.0	36.2	94.5	164.8	134.9	87.1	80.1	65.6	62.0	37.8	0.0	763.1
36	314	Shillong	25.6	91.9	1600	5	0.0	0.0	18.6	50.3	71.4	61.4	62.8	55.4	41.5	31.4	16.9	0.0	409.6
37	320	Silchar - Khumbhigram	24.9	93.0	97	5	0.0	0.0	25.1	59.2	81.9	76.7	81.8	73.5	57.7	43.1	25.7	0.0	524.7
38	325	Srinagar Airport	34.0	74.8	1666	5	0.0	0.0	11.0	36.8	74.5	106.7	107.9	88.6	56.5	30.4	11.4	0.0	523.8
39	340	Trivandrum Airport	8.5	77.0	8	5	0.0	0.0	28.0	57.0	77.6	68.3	70.9	77.2	64.6	46.3	30.9	0.0	520.9
40	342	Tuticorin	8.8	78.2	4	6	0.0	0.0	32.3	75.4	121.2	143.4	151.1	139.9	98.0	65.1	38.9	0.0	865.2
41	352	Veraval	20.9	70.4	8	6	0.0	0.0	31.5	73.8	124.5	128.7	89.3	79.1	74.9	65.4	41.9	0.0	709.1
42	353	Vishakhapatnam	17.7	83.2	3	5	0.0	0.0	33.8	85.1	129.0	109.6	93.6	92.9	68.1	57.4	39.4	0.0	708.9

Max 7.49
Min 0.00

GRAPES - Crop Evapotranspiration, ETcrop, (mm/day)

St# Eto	St# Wind	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	Agra Airport	27.2	78.0	169	5	0.00	0.00	0.90	2.71	4.32	5.20	3.73	2.75	2.50	1.74	0.88	0.00
2	5	Ahmadabad Airport	23.1	72.6	55	5	0.00	0.00	0.99	2.79	4.64	4.63	2.92	2.35	2.28	2.01	1.20	0.00
3	9	Akola Airport	20.7	77.1	309	5	0.00	0.00	1.01	2.86	4.78	4.86	2.82	2.42	2.21	1.98	1.26	0.00
4	13	Allahabad Airport	25.5	81.7	98	5	0.00	0.00	0.92	2.67	4.20	4.62	3.22	2.50	2.30	1.69	0.89	0.00
5	19	Amini Divi	11.1	72.7	4	6	0.00	0.00	1.03	2.40	3.34	3.06	2.93	2.83	2.49	1.73	1.19	0.00
6	21	Amritsar Airport	31.6	74.9	234	5	0.00	0.00	0.68	2.40	4.31	5.20	4.01	3.20	2.39	1.55	0.70	0.00
7	37	Bangalore Airport	13.0	77.6	897	5	0.00	0.00	1.02	2.45	3.31	2.95	2.50	2.41	1.94	1.48	1.01	0.00
8	59	Bhopal Airport	23.3	77.4	523	5	0.00	0.00	1.03	2.90	5.28	5.32	2.75	2.09	2.16	1.99	1.14	0.00
9	64	Bikaner	28.0	73.3	224	7	0.00	0.00	1.45	3.48	5.73	7.49	5.94	4.71	3.84	2.52	1.25	0.00
10	69	Bombay-Colaba	18.9	72.8	11	5	0.00	0.00	0.99	2.49	3.65	3.16	2.20	2.03	1.94	1.87	1.29	0.00
11	70	Bombay-Santacruz	19.1	72.9	14	5	0.00	0.00	1.04	2.75	4.05	3.32	2.29	2.07	1.97	1.89	1.31	0.00
12	75	Calcutta-Alipore	22.5	88.3	6	5	0.00	0.00	0.93	2.48	3.58	2.87	2.59	2.28	1.82	1.47	0.94	0.00
13	76	Calcutta-Dum Dum	22.7	88.5	6	5	0.00	0.00	0.88	2.50	3.63	2.91	2.64	2.29	1.84	1.48	0.96	0.00
14	97	Cuttack	20.5	85.9	27	5	0.00	0.00	0.92	2.44	3.83	3.25	2.45	2.29	1.93	1.56	1.00	0.00
15	48	Belgaum Airport	15.9	74.6	747	5	0.00	0.00	0.96	2.32	3.29	2.85	2.08	2.08	1.89	1.62	1.23	0.00
16	112	Dibrugarh Airport	27.5	95.0	111	5	0.00	0.00	0.63	1.48	2.20	2.45	2.51	2.45	1.70	1.26	0.71	0.00
17	126	Gannavaram Airport	16.5	80.8	24	5	0.00	0.00	1.02	2.61	4.20	4.08	3.19	2.92	2.26	1.76	1.21	0.00
18	127	Gauhati Airport	26.1	91.6	54	5	0.00	0.00	0.75	1.96	2.71	2.67	2.76	2.53	1.91	1.45	0.78	0.00
19	131	Gao-Panjim	15.5	73.8	60	5	0.00	0.00	1.01	2.55	3.63	2.72	2.27	2.34	2.04	1.81	1.41	0.00
20	153	Hyderabad-Begumpet	17.5	78.5	545	5	0.00	0.00	1.09	2.87	4.66	4.59	3.24	2.87	2.26	1.90	1.20	0.00
21	156	Indore Airport	22.7	75.8	567	6	0.00	0.00	1.05	3.05	6.16	5.89	3.15	2.37	2.36	2.01	1.12	0.00
22	158	Jagdalpur	19.1	82.0	553	5	0.00	0.00	0.97	2.50	3.67	3.23	2.23	2.00	1.79	1.59	1.04	0.00
23	159	Jaipur Airport	26.8	75.8	390	7	0.00	0.00	1.46	3.25	4.98	5.62	3.78	3.02	3.03	2.36	1.34	0.00
24	172	Jodhpur	26.3	73.0	217	7	0.00	0.00	1.58	3.57	6.09	7.03	4.93	3.95	3.57	2.65	1.61	0.00
25	194	Kodaikanal	10.2	77.5	2343	6	0.00	0.00	0.75	1.58	2.17	2.17	1.82	1.84	1.41	0.99	0.70	0.00
26	200	Kota Airport	25.2	75.9	274	7	0.00	0.00	1.60	3.93	6.26	6.86	4.36	3.18	3.13	2.59	1.56	0.00
27	209	Madras- Minambakkam	13.0	80.2	16	5	0.00	0.00	1.06	2.65	3.83	4.20	3.59	3.15	2.51	1.72	1.10	0.00
28	231	Minicoy	8.3	73.0	2	5	0.00	0.00	0.93	2.17	2.85	2.82	2.81	2.92	2.35	1.79	1.25	0.00
29	239	Nagpur Airport	21.1	79.1	310	5	0.00	0.00	1.05	2.88	4.96	4.55	2.80	2.28	2.14	1.92	1.17	0.00
30	250	New Dehli - Safdarjung	28.6	77.2	216	5	0.00	0.00	0.88	2.75	4.39	5.14	3.65	2.86	2.46	1.75	0.92	0.00
31	256	Okha	22.5	69.1	7	6	0.00	0.00	0.91	2.28	4.11	4.00	3.10	2.68	2.51	1.86	1.33	0.00
32	122	Fort Cochin	10.0	76.2	3	5	0.00	0.00	0.99	2.14	2.39	2.15	1.91	1.93	1.81	1.49	1.16	0.00
33	271	Patna Airport	25.6	85.1	60	5	0.00	0.00	0.94	2.92	4.45	4.40	3.26	2.77	2.26	1.67	0.98	0.00
34	278	Port Blair	11.7	92.7	79	5	0.00	0.00	0.93	2.21	2.34	2.38	2.31	2.15	1.73	1.51	1.13	0.00
35	281	Pune Airport	18.6	73.9	593	6	0.00	0.00	1.17	3.15	5.32	4.50	2.81	2.58	2.19	2.00	1.26	0.00
36	314	Shillong	25.6	91.9	1600	5	0.00	0.00	0.60	1.68	2.30	2.05	2.02	1.79	1.38	1.01	0.56	0.00
37	320	Silchar - Khumbhigram	24.9	93.0	97	5	0.00	0.00	0.81	1.97	2.64	2.56	2.64	2.37	1.92	1.39	0.86	0.00
38	325	Srinagar Airport	34.0	74.8	1666	5	0.00	0.00	0.36	1.23	2.40	3.56	3.48	2.86	1.88	0.98	0.38	0.00
39	340	Trivandrum Airport	8.5	77.0	8	5	0.00	0.00	0.90	1.90	2.50	2.28	2.29	2.49	2.15	1.50	1.03	0.00
40	342	Tuticorin	8.8	78.2	4	6	0.00	0.00	1.04	2.51	3.91	4.78	4.87	4.51	3.27	2.10	1.30	0.00
41	352	Veraval	20.9	70.4	8	6	0.00	0.00	1.02	2.46	4.01	4.29	2.88	2.55	2.50	2.11	1.40	0.00
42	353	Vishakhapatnam	17.7	83.2	3	5	0.00	0.00	1.09	2.84	4.16	3.65	3.02	3.00	2.27	1.85	1.31	0.00

Crop Coefficient, kc, for Mature Grapes (Doorenbos and Pruit, 1977)

Area Type	Description
1	Areas with light frosts, humid, light-moderate wind
2	Areas with light frosts, humid, strong wind
3	Areas with light frosts, dry, light-moderate wind
4	Areas with light frosts, dry, strong wind
5	Hot, humid areas, light-moderate wind
6	Hot, humid areas, strong wind
7	Hot, dry areas, light-moderate wind
8	Hot, dry areas, strong wind

Area	Crop Coefficient, kc											
Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.00	0.00	0.00	0.50	0.55	0.60	0.60	0.60	0.60	0.50	0.40	0.00
2	0.00	0.00	0.00	0.50	0.55	0.65	0.65	0.65	0.65	0.55	0.40	0.00
3	0.00	0.00	0.00	0.45	0.60	0.70	0.70	0.70	0.70	0.60	0.35	0.00
4	0.00	0.00	0.00	0.45	0.65	0.75	0.75	0.75	0.75	0.65	0.35	0.00
5	0.00	0.00	0.15	0.35	0.50	0.60	0.60	0.55	0.45	0.35	0.25	0.00
6	0.00	0.00	0.15	0.35	0.55	0.65	0.65	0.60	0.45	0.35	0.25	0.00
7	0.00	0.00	0.25	0.45	0.60	0.70	0.70	0.65	0.55	0.45	0.35	0.00
8	0.00	0.00	0.25	0.45	0.65	0.75	0.75	0.70	0.55	0.45	0.35	0.00

Assumptions: clean cultivated, infrequent Irrigation, soil surface dry most of the time, ground cover of 30-35% at mid-season
For areas with light frosts: inital leaves early August, harvest late August to early Spetember
For hot dry areas: inital leaves late February to early March, harvest late half of July

Reference Crop Evapotranspiration, Eto (mm/day)

St# Eto	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	3	Agra	27.2	78.1	169	2.87	4.34	6.02	7.73	8.64	8.67	6.21	5.00	5.55	4.98	3.51	2.55	2010
2	4	Ahmadabad	23.1	72.6	55	4.42	5.49	6.60	7.97	9.29	7.71	4.87	4.27	5.06	5.73	4.78	4.13	2138
3	5	Akola	20.7	77.0	282	4.97	5.97	6.72	8.18	9.56	8.09	4.70	4.40	4.91	5.65	5.03	4.17	2198
4	7	Allahabad	25.5	81.7	98	2.86	4.32	6.12	7.62	8.39	7.70	5.36	4.54	5.10	4.83	3.56	2.64	1918
5	8	Amini Divi	11.1	72.7	4	5.26	6.08	6.86	6.85	6.07	4.71	4.50	4.72	5.54	4.94	4.75	4.70	1975
6	9	Amritsar	31.6	74.9	234	1.90	3.02	4.55	6.86	8.63	8.67	6.69	5.82	5.31	4.42	2.82	1.88	1844
7	14	Bangalor	13.0	77.6	897	4.84	5.77	6.77	7.01	6.62	4.91	4.17	4.39	4.30	4.23	4.04	3.99	1854
8	21	Bhopal	23.3	77.4	503	4.04	5.59	6.87	8.30	10.56	8.86	4.59	3.80	4.80	5.68	4.55	3.59	2164
9	24	Bikaner	28.0	73.3	224	2.66	3.95	5.79	7.73	9.55	10.70	8.49	7.24	6.99	5.60	3.56	2.60	2280
10	26	Bombay	19.1	72.9	14	4.91	5.71	6.57	7.10	7.31	5.26	3.67	3.69	4.32	5.33	5.18	4.65	1936
11	26	Bombay	19.1	72.9	14	4.95	5.84	6.92	7.85	8.10	5.54	3.82	3.76	4.39	5.41	5.23	4.67	2020
12	27	Calcutta	22.7	88.5	6	3.36	4.53	6.20	7.10	7.16	4.78	4.31	4.15	4.04	4.21	3.76	3.12	1725
13	27	Calcutta	22.7	88.5	6	3.41	4.55	5.90	7.15	7.26	4.84	4.40	4.17	4.09	4.23	3.83	3.17	1733
14	34	Cuttack	20.5	85.9	24	3.76	4.91	6.14	6.96	7.66	5.42	4.08	4.17	4.28	4.46	4.01	3.47	1804
15	36	Dharwar	15.4	75.1	679	5.24	5.57	6.38	6.62	6.57	4.74	3.46	3.78	4.20	4.62	4.92	4.55	1843
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	2.22	2.88	4.19	4.21	4.40	4.08	4.19	4.45	3.77	3.61	2.83	2.20	1310
17	39	Gannavaram	16.5	80.8	24	4.87	6.13	6.81	7.47	8.40	6.80	5.32	5.31	5.01	5.02	4.85	4.38	2139
18	40	Gauhati	26.1	91.6	54	2.64	3.62	4.98	5.60	5.42	4.45	4.60	4.60	4.25	4.14	3.12	2.44	1518
19	41	Goa	15.5	73.8	55	5.36	6.14	6.74	7.28	7.25	4.53	3.78	4.25	4.54	5.18	5.65	5.04	1997
20	56	Hyderabad	17.5	78.5	545	4.93	6.37	7.25	8.20	9.32	7.66	5.40	5.22	5.03	5.42	4.81	4.47	2251
21	59	Indore	22.7	75.8	567	4.16	5.43	6.98	8.71	11.20	9.07	4.84	3.96	5.24	5.76	4.49	3.86	2241
22	61	Jagadalpur	19.1	82.0	553	3.96	5.36	6.48	7.16	7.33	5.38	3.72	3.63	3.98	4.55	4.16	3.63	1803
23	62	Jaipur	26.8	75.8	390	3.20	4.30	5.83	7.23	8.31	8.03	5.41	4.64	5.52	5.24	3.82	3.08	1965
24	69	Jodhpur	26.3	73.0	224	3.74	4.80	6.33	7.93	10.14	10.04	7.04	6.07	6.49	5.89	4.60	3.60	2334
25	76	Kodaikanal	10.2	77.5	2345	3.70	4.50	5.00	4.52	3.95	3.34	2.80	3.07	3.13	2.84	2.80	3.12	1299
26	79	Kota	25.2	75.5	257	3.62	5.08	6.38	8.74	10.44	9.80	6.23	4.90	5.69	5.75	4.46	3.45	2267
27	86	Madras	13.0	80.2	16	5.02	6.19	7.06	7.57	7.66	7.00	5.98	5.72	5.58	4.92	4.40	4.16	2166
28	89	Minicoy	8.3	73.0	2	5.33	5.86	6.17	6.20	5.69	4.70	4.69	5.30	5.23	5.12	5.01	4.62	1943
29	92	Nagpur	21.2	79.1	311	4.27	5.83	6.99	8.23	9.93	7.59	4.67	4.15	4.75	5.49	4.66	3.88	2141
30	97	New Dehli	28.6	77.2	216	2.73	4.40	5.89	7.86	8.79	8.57	6.08	5.20	5.46	4.99	3.68	2.64	2016
31	99	Okha	22.5	69.1	7	4.90	5.31	6.07	6.52	7.47	6.15	4.76	4.46	5.57	5.31	5.33	4.76	2026
32	100	Ollukara	10.5	76.3	22	5.43	6.08	6.61	6.11	4.78	3.58	3.18	3.50	4.03	4.27	4.65	4.60	1724
33	105	Patna	25.5	85.3	52	3.23	4.49	6.28	8.34	8.91	7.33	5.44	5.04	5.01	4.77	3.90	2.94	1998
34	107	Port Blair	11.7	92.7	79	4.96	5.77	6.23	6.31	4.68	3.96	3.86	3.91	3.85	4.31	4.53	4.59	1730
35	108	Pune	18.5	73.9	563	5.02	6.25	7.79	9.00	9.67	6.92	4.32	4.31	4.86	5.71	5.03	4.40	2228
36	123	Shillong	25.6	91.9	1598	2.03	2.84	3.99	4.79	4.61	3.41	3.37	3.25	3.08	2.90	2.25	1.89	1169
37	124	Silicuri	24.8	92.9	40	3.21	4.06	5.40	5.64	5.28	4.26	4.40	4.31	4.27	3.98	3.43	2.93	1557
38	127	Srinagar	34.1	74.8	1587	0.88	1.37	2.37	3.50	4.81	5.93	5.80	5.20	4.18	2.80	1.52	0.88	1197
39	134	Trivandrum	8.5	77.0	64	5.13	5.75	6.03	5.43	5.00	3.79	3.81	4.53	4.79	4.27	4.12	4.44	1735
40	135	Tuticorin	8.8	78.2	4	5.76	6.62	6.94	7.18	7.11	7.35	7.50	7.52	7.26	6.00	5.19	4.94	2414
41	142	Veraval	20.9	70.4	8	5.22	6.08	6.77	7.03	7.30	6.60	4.43	4.25	5.54	6.03	5.59	5.11	2126
42	144	Vishakhapatnam	17.7	83.2	3	5.36	6.94	7.27	8.11	8.32	6.09	5.03	5.45	5.04	5.29	5.26	4.78	2216

APPENDIX Y

GRAPES

Table Used to Identify
Stations Potentially Suited to Grape Cultivation

Average Relative Humidity (%) - Sorted by Annual Average Relative Humidity

Eto St#	Sun St#	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Grapes
34	107	Port Blair	11.7	92.7	79	78.1	78.4	78.0	79.0	85.8	86.9	88.2	88.6	89.8	88.0	84.6	80.7	83.8	
16	38	Dibrugarh (Mohanbari)	27.5	95.0	111	80.5	77.7	71.3	76.2	83.6	85.6	86.9	87.4	85.8	84.3	81.9	81.8	81.9	
32	100	Ollukara	10.5	76.3	22	74.3	74.8	76.2	78.5	83.0	87.8	89.2	88.3	86.7	85.3	81.0	77.2	81.9	
39	134	Trivandrum	8.5	77.0	64	72.9	71.5	74.5	79.3	82.6	86.1	87.7	85.9	85.0	85.8	83.2	77.8	81.0	
18	40	Gauhati	26.1	91.6	54	78.8	71.5	63.8	69.9	79.9	84.3	84.7	85.7	85.5	84.3	82.4	82.0	79.4	
28	89	Minicoy	8.3	73.0	2	76.2	76.8	77.5	74.6	76.6	80.2	80.7	80.3	79.7	80.8	79.7	79.8	78.6	
25	76	Kodaikanal	10.2	77.5	2345	72.3	65.5	63.9	75.1	78.8	80.7	86.0	85.9	85.4	87.8	84.1	76.4	78.5	
5	8	Amini Divi	11.1	72.7	4	72.0	72.5	72.5	75.4	77.3	81.9	83.2	84.1	80.8	79.8	77.4	75.1	77.7	
31	99	Okha	22.5	69.1	7	63.7	74.0	77.8	83.5	81.0	82.9	84.6	86.0	81.8	83.5	67.5	60.3	77.2	
12	27	Calcutta	22.7	88.5	6	69.8	66.3	64.9	68.0	73.3	81.1	84.8	85.4	85.6	80.3	72.6	71.3	75.3	
13	27	Calcutta	22.7	88.5	6	69.8	66.3	64.9	68.0	73.3	81.1	84.8	85.4	85.6	80.3	72.6	71.3	75.3	
37	124	Silicuri	24.8	92.9	40	68.5	65.3	60.0	68.3	76.5	84.8	85.0	85.0	83.3	80.5	73.8	71.8	75.2	
36	123	Shillong	25.6	91.9	1598	67.8	62.0	55.2	66.5	76.0	85.5	86.7	86.4	87.3	80.8	73.5	70.8	74.9	
42	144	Vishakhapatnam	17.7	83.2	3	73.0	71.3	72.1	74.1	72.7	72.2	79.2	79.4	81.8	78.7	71.9	69.7	74.7	
27	86	Madras	13.0	80.2	16	76.7	74.9	73.7	74.1	66.8	63.3	67.8	73.7	76.5	81.3	82.3	79.9	74.2	
19	41	Goa	15.5	73.8	55	63.8	66.3	67.9	68.9	70.9	80.8	86.8	84.6	84.5	77.5	64.4	67.9	73.7	
41	142	Veraval	20.9	70.4	8	52.9	61.5	71.1	75.7	81.6	83.0	87.4	87.6	82.9	72.5	60.5	54.6	72.6	
38	127	Srinagar	34.1	74.8	1587	81.1	80.3	74.0	72.3	66.8	60.8	67.3	69.4	70.3	70.3	76.1	81.1	72.5	
15	36	Dharwar	15.4	75.1	679	64.0	61.8	63.3	67.1	70.1	77.9	84.9	85.0	83.8	76.6	67.8	66.3	72.4	
17	39	Gannavaram	16.5	80.8	24	73.0	68.2	68.0	69.4	61.4	63.9	76.3	78.4	80.8	79.9	74.8	71.3	72.1	
7	14	Bangalor	13.0	77.6	897	65.5	63.0	50.8	53.5	64.4	78.4	80.8	80.4	82.5	80.5	81.6	75.9	71.4	
10	26	Bombay	19.1	72.9	14	56.8	57.2	63.7	69.1	70.4	78.3	86.0	85.7	83.0	73.3	63.5	61.8	70.7	
11	26	Bombay	19.1	72.9	14	56.8	57.2	63.7	69.1	70.4	78.3	86.0	85.7	83.0	73.3	63.5	61.8	70.7	
14	34	Cuttack	20.5	85.9	24	67.0	62.0	59.5	61.5	63.0	70.5	82.5	83.0	81.5	76.0	67.0	65.5	69.9	
40	135	Tuticorin	8.8	78.2	4	78.5	76.0	75.0	72.0	64.0	56.5	56.5	57.0	58.0	71.0	78.0	79.0	68.5	
22	61	Jagadalpur	19.1	82.0	553	63.3	55.0	46.5	51.3	52.3	71.2	85.3	86.7	83.8	77.0	70.5	67.5	67.5	
33	105	Patna	25.5	85.3	52	66.5	53.3	45.2	40.5	47.9	63.8	81.7	84.3	82.5	76.9	70.6	70.8	65.3	
6	9	Amritsar	31.6	74.9	234	74.0	66.9	60.9	47.8	37.4	44.8	72.0	78.9	74.5	65.8	66.2	71.6	63.4	
35	108	Pune	18.5	73.9	563	51.0	39.8	36.7	40.1	53.8	69.9	82.8	83.7	81.0	67.7	61.9	59.4	60.6	*
20	56	Hyderabad	17.5	78.5	545	58.9	45.2	40.4	41.6	38.5	60.5	75.4	77.5	77.9	72.0	66.3	61.6	59.7	*
4	7	Allahabad	25.5	81.7	98	67.3	54.6	38.5	28.2	28.9	46.0	76.6	83.5	78.1	68.7	63.2	68.0	58.5	*
29	92	Nagpur	21.2	79.1	311	56.1	40.3	34.3	30.5	28.6	57.2	77.9	83.9	80.3	66.6	59.7	61.3	56.4	*
30	97	New Dehli	28.6	77.2	216	66.3	53.1	46.2	33.5	31.9	42.2	69.3	79.3	71.9	59.3	57.3	65.9	56.3	*
1	3	Agra	27.2	78.1	169	59.5	48.5	40.0	36.0	34.5	43.0	70.0	79.5	71.0	56.0	53.5	62.5	54.5	*
2	4	Ahmadabad	23.1	72.6	55	41.3	35.6	30.5	31.8	41.0	60.8	79.1	80.5	76.3	56.3	48.6	47.9	52.5	*
8	21	Bhopal	23.3	77.4	503	50.2	37.0	28.5	25.9	26.7	51.7	80.2	85.2	77.8	54.6	49.4	50.6	51.5	*
3	5	Akola	20.7	77.0	282	43.4	27.8	27.2	25.2	29.6	56.0	77.4	79.8	75.2	56.0	48.0	50.4	49.7	*
21	59	Indore	22.7	75.8	567	45.5	30.1	28.7	22.7	26.8	54.7	78.4	83.8	72.6	44.6	40.5	45.6	47.8	*
23	62	Jaipur	26.8	75.8	390	50.5	39.5	30.4	24.3	24.3	41.8	70.1	78.1	71.9	47.9	44.9	48.9	47.7	*
9	24	Bikaner	28.0	73.3	224	50.8	43.5	39.0	33.0	30.3	43.5	60.5	65.5	60.0	41.8	45.0	52.5	47.1	*
26	79	Kota	25.2	75.5	257	47.2	36.2	29.0	23.2	23.0	43.8	69.2	77.6	70.6	47.0	45.0	52.2	47.0	*
24	69	Jodhpur	26.3	73.0	224	37.7	28.7	23.8	22.2	26.1	45.8	66.3	71.0	68.4	39.1	34.0	40.0	41.9	*

Average Precipitation (mm) - Sorted by Total Annual Precipitation

St# Eto		Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Grapes
32		Fort Cochin	10.0	76.2	3	19.2	27.8	62.7	115.5	442.4	650.1	788.7	442.7	381.4	271.4	148.0	64.3	3414.2	
34		Port Blair	11.7	92.7	79	67.6	27.1	11.0	56.2	490.4	449.1	476.5	486.2	547.8	323.9	239.1	199.8	3374.7	
37		Silchar	24.8	92.8	29	13.7	50.6	138.4	238.9	419.8	659.7	537.0	457.3	364.5	248.6	22.6	9.0	3160.1	
11		Bombay/Santa Cruz	19.1	72.9	14	0.3	0.0	0.0	0.3	8.6	785.3	891.3	788.6	303.0	182.3	3.6	0.0	2963.3	
19		Goa/Panjim	15.5	73.8	57	0.3	0.3	0.0	9.6	87.7	778.7	980.2	409.2	281.7	122.7	55.0	56.0	2781.4	
16		Dibrugarh/Mohanbari	27.5	95.0	111	21.2	46.7	78.8	173.1	329.4	426.1	509.9	465.1	288.4	130.4	33.0	17.8	2519.9	
10		Bombay/Colaba,India	18.9	72.8	11	1.4	2.0	0.0	1.6	9.0	616.6	798.1	489.5	237.6	86.6	1.2	8.4	2252.0	
39		Trivandrum	8.5	77.0	64	27.0	36.1	34.1	115.1	272.5	349.9	289.0	148.2	192.5	282.7	148.4	65.3	1960.8	
36		Shillong	25.6	91.9	1500	5.0	11.3	39.0	61.0	203.6	314.0	282.3	201.0	435.0	213.0	14.0	3.0	1782.2	
28		Minicoy	8.3	73.0	2	35.1	26.2	4.8	70.3	256.6	262.5	230.5	231.7	181.6	191.0	130.7	118.4	1739.4	
25		Kodaikanal	10.2	77.5	2343	20.0	11.6	79.0	214.0	250.6	105.0	120.6	111.6	157.0	247.6	334.3	65.3	1716.6	
13		Calcutta/Dum Dum	22.7	88.5	6	16.0	10.6	22.6	33.3	83.0	179.6	315.0	334.3	447.6	160.6	4.0	0.3	1606.9	
18		Gauhti	26.1	91.6	54	12.4	16.7	59.5	117.7	259.4	285.4	305.1	294.2	160.9	63.2	15.5	2.2	1592.2	
12		Calcutta/Alipore	22.5	88.3	6	23.3	17.7	18.9	43.0	93.7	224.9	308.3	295.9	313.3	147.5	9.6	1.9	1498.0	
15		Belguam/Samra	15.9	74.6	747	0.2	3.2	15.2	53.2	152.8	149.0	556.6	260.1	129.4	110.3	42.6	14.1	1486.7	
22		Jogdalapur	19.1	82.0	553	9.9	14.6	20.0	62.4	69.7	226.7	313.5	356.6	249.0	107.8	8.8	21.3	1460.3	
5		Amini	11.1	72.7	4	3.0	0.0	1.6	27.3	293.6	311.6	261.0	187.6	150.0	87.0	114.3	6.6	1443.6	
14		Cuttack	20.5	85.9	27	23.3	26.4	14.8	45.5	56.6	176.9	376.1	290.0	236.5	141.1	18.6	1.0	1406.8	
27		Madras/Minambakkam	13.0	80.2	16	24.5	6.8	5.2	18.0	36.9	72.7	107.9	168.4	137.5	262.9	408.6	109.5	1358.9	
8		Sagar	23.9	78.8	551	20.0	5.6	12.0	2.7	10.7	86.3	343.0	486.0	226.6	63.2	8.7	16.9	1281.7	*
29		Nagpur/Sonegaon	21.1	79.1	310	17.0	6.1	18.9	12.4	21.2	178.5	334.1	268.1	225.3	45.6	7.4	31.4	1166.0	*
17		Masulipatam	16.2	81.1	3	4.2	10.1	12.3	20.3	15.6	134.0	260.2	172.5	223.2	138.0	91.3	13.7	1095.4	
21		Indore	22.7	75.8	567	15.7	1.8	6.1	3.0	6.0	117.8	295.7	264.0	257.4	35.2	21.0	18.0	1041.7	*
33		Patna	25.6	85.2	53	27.0	1.0	20.0	11.6	33.6	46.0	310.3	250.0	214.6	100.6	0.0	0.0	1014.7	
42		Vishakhapatnam	17.7	83.2	3	15.7	13.8	10.6	20.0	18.6	81.0	158.1	127.2	200.8	261.5	78.1	17.9	1003.3	
7		Bangalore	13.0	77.6	921	5.6	8.2	4.4	50.1	111.7	80.5	107.0	172.4	195.2	150.2	83.8	24.3	993.4	
41		Veraval	20.9	70.4	8	0.7	2.0	1.2	0.2	0.5	176.0	404.5	168.6	145.5	50.7	1.9	1.3	953.1	
4		Allahabad/Bamhrauli	25.5	81.7	98	16.7	6.7	11.1	7.9	8.7	62.8	290.7	330.5	162.9	37.7	8.5	6.2	950.4	*
40		Panam	9.3	79.3	11	43.1	21.1	23.8	60.5	51.2	3.9	14.1	9.4	19.8	201.3	278.4	181.4	908.0	
1		Agra	27.2	78.0	169	11.1	6.0	8.7	2.0	15.9	25.9	235.0	353.1	156.8	21.1	4.6	8.3	848.5	*
3		Akola	20.7	77.0	282	9.8	1.4	13.8	6.6	7.0	114.9	243.3	157.3	194.1	58.3	14.9	26.6	848.0	*
30		New Dehli-Safarjung	28.6	77.2	216	13.4	10.4	11.1	3.7	15.3	51.2	224.2	316.0	152.9	23.6	1.9	15.1	838.8	*
20		Begampet	17.5	78.5	545	0.6	4.3	13.6	30.2	26.0	87.9	216.0	143.3	198.9	76.8	15.0	14.5	827.1	*
2		Ahmadabad	23.1	72.6	55	2.6	0.1	2.1	2.5	3.0	89.2	304.4	150.8	242.7	17.4	6.8	1.7	823.3	*
35		Poona	18.5	73.9	559	0.1	0.0	5.5	20.7	66.7	97.2	263.2	98.3	105.4	55.5	23.8	11.6	748.0	*
38		Srinagar	34.1	74.8	1587	63.8	71.6	117.7	100.0	71.1	25.5	59.1	46.0	31.6	28.2	27.3	76.0	717.9	
23		Jaipur/Sanganer	26.8	75.8	390	1.0	1.3	3.3	5.0	36.3	62.0	151.0	316.3	112.6	12.6	13.3	3.0	717.7	*
26		Kota	25.2	75.9	257	7.0	0.2	4.6	1.3	10.5	52.8	262.7	220.8	115.6	6.4	3.0	1.1	686.0	*
6		Amritsar/Rajasansi	31.6	74.9	234	25.5	18.2	28.5	12.3	16.2	32.2	199.9	171.3	129.1	11.0	10.2	26.1	680.5	
31		Dwarka	22.4	69.1	11	0.8	0.4	1.8	0.2	0.0	75.2	304.4	89.2	63.5	9.9	7.5	5.1	558.0	
24		Jodhpur	26.3	73.0	224	0.7	2.7	14.7	1.2	8.2	28.4	117.9	97.8	78.5	3.2	3.6	1.0	357.9	*
9		Bikaner	28.0	73.3	224	5.4	6.9	10.1	0.6	15.5	23.3	78.8	74.9	72.1	4.2	4.4	6.9	303.1	*

Maximum Temperature (C) - Sorted by Annual Maximum

St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max	Grapes
1	3	Agra airport	10.0	76.2	3	22.5	26.5	32.2	38.0	41.5	42.4	35.6	32.8	33.1	33.2	29.1	24.5	42.4	*
3	5	Akola airport	11.7	92.7	79	30.1	33.6	37.0	40.9	42.3	38.1	32.9	30.8	31.9	33.8	31.7	29.3	42.3	*
26	79	Kota	24.8	92.8	29	24.2	28.9	33.9	38.7	42.1	40.7	34.6	32.0	32.8	34.3	29.3	25.6	42.1	*
9	24	Bikaner	19.1	72.9	14	23.3	27.4	32.3	37.6	41.5	41.7	38.2	36.7	36.3	36.0	30.2	24.2	41.7	*
2	4	Ahmadabad airport	15.5	73.8	57	28.0	31.6	35.1	38.8	40.9	37.1	31.7	30.8	31.6	34.6	32.2	28.9	40.9	*
4	7	Allahabad airport	27.5	95.0	111	22.5	26.6	32.6	38.2	40.9	39.3	32.7	31.2	31.7	32.7	27.8	23.2	40.9	*
29	92	Nagpur airport	18.9	72.8	11	27.2	31.3	34.6	38.4	40.5	35.4	29.5	28.7	29.7	31.0	29.1	26.6	40.5	*
24	69	Jodhpur	8.5	77.0	64	24.2	27.7	33.2	37.8	40.4	38.9	34.6	33.1	33.4	34.8	29.8	25.6	40.4	*
14	34	Cuttack	25.6	91.9	1500	28.6	32.2	35.8	38.5	39.5	35.9	31.9	32.1	32.5	32.4	30.9	28.9	39.5	
6	9	Amritsar airport	8.3	73.0	2	18.0	21.1	26.1	32.0	36.6	39.1	33.9	32.6	32.5	31.0	24.5	19.3	39.1	
8	21	Bhopal	10.2	77.5	2343	23.9	27.9	32.5	36.9	39.1	35.6	29.2	27.7	28.7	30.4	27.6	24.9	39.1	*
17	39	Gannavaram airport	22.7	88.5	6	28.7	32.1	33.8	35.4	39.1	35.6	31.6	31.3	31.1	30.5	29.5	28.6	39.1	
23	62	Jaipur airport	26.1	91.6	54	21.8	25.6	30.5	35.6	38.8	38.0	32.3	30.8	31.4	32.4	27.9	23.3	38.8	*
30	97	New Dehli - Safdarjung	22.5	88.3	6	19.7	23.9	28.9	35.1	38.7	38.5	33.7	31.6	32.0	31.3	26.4	20.9	38.7	*
21	59	Indore airpot	15.9	74.6	747	25.1	28.9	31.7	36.2	38.1	35.1	29.3	27.3	29.1	31.8	28.6	25.5	38.1	*
33	105	Patna	19.1	82.0	553	22.2	26.3	31.3	36.1	37.9	35.7	31.7	30.6	31.3	30.2	27.2	23.1	37.9	
15	36	Dhawar	11.1	72.7	4	30.1	33.2	36.2	37.4	36.1	31.2	28.1	28.8	30.0	31.3	30.3	29.3	37.4	
35	108	Pune	20.5	85.9	27	29.7	32.5	35.2	37.4	35.9	30.8	26.8	26.5	28.0	31.2	29.9	29.0	37.4	*
20	56	Hyderabad-Begumpet	13.0	80.2	16	27.6	30.6	33.6	35.6	37.0	32.6	28.5	28.0	28.4	29.2	27.7	26.9	37.0	*
22	61	Jagdalpur	23.9	78.8	551	27.4	30.3	33.7	35.5	36.5	31.4	26.8	26.9	28.0	28.7	27.4	26.4	36.5	
27	86	Madras- Hinambakkam	21.1	79.1	310	27.7	29.8	32.0	34.0	36.1	35.3	33.5	32.8	32.4	30.3	27.9	27.3	36.1	
42	144	Vishakhapatnam	16.2	81.1	3	28.0	30.4	32.6	34.1	35.4	33.9	31.3	31.2	31.1	30.2	29.2	27.8	35.4	
12	27	Calcutta alipore	22.7	75.8	567	25.1	28.8	32.8	35.2	34.7	32.4	30.5	30.6	30.2	30.0	28.0	25.3	35.2	
13	27	Calcutta-Dum Dum	25.6	85.2	53	25.1	28.8	32.8	35.2	34.7	32.4	30.5	30.6	30.2	30.0	28.0	25.3	35.2	
40	135	Tuticorin	17.7	83.2	3	27.7	28.4	30.2	31.9	34.4	34.9	34.5	34.7	34.3	31.7	29.2	28.0	34.9	
18	40	Gauhati airpot	13.0	77.6	921	34.0	25.0	29.1	30.5	29.6	29.5	30.4	30.3	30.3	28.9	26.3	23.3	34.0	
7	14	Bangalore airport	20.9	70.4	8	27.0	28.8	31.7	33.1	31.5	27.6	26.3	26.2	26.6	26.6	25.5	25.3	33.1	
32	100	Ollakura	25.5	81.7	98	31.6	32.0	32.5	32.9	31.8	30.0	29.1	29.1	29.5	30.1	31.1	31.3	32.9	
10	26	bombay colaba	9.3	79.3	11	29.6	30.7	31.3	31.9	32.4	30.5	28.3	27.9	28.8	31.6	32.1	30.5	32.4	
11	26	Bombay-Santacruz	27.2	78.0	169	29.6	30.7	31.3	31.9	32.4	30.5	28.3	27.9	28.8	31.6	32.1	30.5	32.4	
37	124	Silicuri	20.7	77.0	282	25.2	27.2	30.5	31.9	31.7	31.2	32.0	31.9	32.3	31.0	29.0	26.5	32.3	
34	107	Port Blair	28.6	77.2	216	29.4	30.4	31.3	32.0	29.5	28.4	28.0	27.7	27.5	28.5	29.3	28.9	32.0	
19	41	Gao-Panjim	17.5	78.5	545	30.6	31.0	30.8	31.8	31.8	29.1	27.4	27.9	28.3	30.7	31.5	30.8	31.8	
5	8	Amini Divi	23.1	72.6	55	29.6	30.3	30.9	31.6	31.4	29.0	28.2	28.6	28.7	29.5	29.7	29.5	31.6	
39	134	Trivandrum airport	18.5	73.9	559	30.1	30.5	31.4	31.4	30.0	28.2	27.8	27.9	28.5	28.7	29.0	29.6	31.4	
28	89	Minicoy	34.1	74.8	1587	29.5	29.7	30.2	30.7	30.5	29.2	28.5	28.7	28.8	29.1	29.4	29.3	30.7	
31	99	Okha	26.8	75.8	390	22.7	24.2	26.3	28.0	30.1	30.7	29.8	28.8	28.9	28.6	27.2	23.9	30.7	
41	142	Veraval	25.2	75.9	257	26.8	27.3	28.5	29.3	30.3	30.6	28.6	27.9	28.2	30.7	30.7	27.9	30.7	
16	38	Dibrugharh airport	31.6	74.9	234	21.7	22.5	26.3	27.2	27.4	29.3	29.9	29.8	29.5	27.8	25.1	22.4	29.9	
38	127	Srinagar	22.4	69.1	11	2.5	6.2	11.9	16.5	21.2	27.3	28.9	28.3	25.8	20.0	11.7	5.7	28.9	
36	123	Shillong	26.3	73.0	224	13.7	15.7	19.5	22.1	21.9	21.6	22.5	22.4	21.7	19.8	17.0	14.5	22.5	
25	76	Kodaikanal	28.0	73.3	224	15.7	16.6	18.1	18.5	18.8	17.2	16.0	16.4	16.5	15.6	14.9	15.1	18.8	

Minimum Temperature (C) - Sorted by Annual Minimum

St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Min	Grapes
5	8	Amini Divi	15.5	73.8	57	24.7	25.5	26.5	27.8	28.3	27.9	27.4	27.2	26.8	26.5	25.6	25.4	24.7	
28	89	Minicoy	25.5	81.7	98	24.0	24.3	25.7	26.6	27.5	27.0	26.7	26.5	26.2	25.6	24.9	24.5	24.0	
34	107	Port Blair	23.1	72.6	55	23.7	23.3	23.5	24.9	25.6	25.5	25.4	25.2	24.7	24.4	24.5	24.1	23.3	
39	134	Trivandrum airport	31.6	74.9	234	23.3	23.8	25.0	25.8	25.6	24.6	24.1	24.1	24.1	24.1	23.9	23.5	23.3	
32	100	Ollakura	28.6	77.2	216	22.3	23.2	24.9	25.3	25.3	24.2	23.6	23.7	23.6	23.9	23.5	22.7	22.3	
40	135	Tuticorin	22.4	69.1	11	21.9	22.7	24.5	25.9	26.5	25.9	25.8	25.9	25.4	24.4	23.4	22.0	21.9	
27	86	Madras- Hinambakkam	20.9	70.4	8	21.8	22.2	24.2	26.6	28.5	28.1	27.1	26.3	26.1	25.1	23.5	22.3	21.8	
19	41	Gao-Panjim	13.0	80.2	16	20.8	21.4	23.7	25.7	26.8	25.7	25.5	25.3	24.7	24.4	22.8	21.9	20.8	
31	99	Okha	20.7	77.0	282	20.1	21.3	23.3	25.1	27.2	28.5	28.1	27.1	26.4	25.9	24.9	21.5	20.1	
17	39	Gannavaram airport	11.1	72.7	4	19.8	20.7	23.5	26.1	28.4	28.3	26.7	26.5	26.1	24.7	22.4	19.6	19.6	
42	144	Vishakhapatnam	28.0	73.3	224	19.1	20.3	23.4	26.5	28.6	28.5	26.7	26.7	26.4	24.9	22.1	19.7	19.1	
10	26	bombay colaba	8.3	73.0	2	18.3	19.1	21.9	24.6	27.2	27.2	26.5	26.0	25.3	24.2	22.2	20.1	18.3	
11	26	Bombay-Santacruz	10.2	77.5	2343	18.3	19.1	21.9	24.6	27.2	27.2	26.5	26.0	25.3	24.2	22.2	20.1	18.3	
15	36	Dhawar	15.9	74.6	747	16.9	18.5	21.3	22.5	22.3	21.6	21.2	20.9	20.5	20.5	18.6	17.2	16.9	
41	142	Veraval	26.3	73.0	224	16.4	17.1	20.0	23.0	26.5	28.5	27.7	27.0	26.3	23.6	21.5	18.5	16.4	
14	34	Cuttack	22.5	88.3	6	15.7	18.5	22.2	25.0	27.0	26.7	25.7	25.8	25.6	23.7	19.3	15.8	15.7	
7	14	Bangalore airport	18.9	72.8	11	15.3	17.7	19.9	22.1	21.8	20.4	19.9	19.9	20.0	19.4	18.7	16.6	15.3	
20	56	Hyderabad-Begumpet	23.9	78.8	551	16.5	18.3	22.0	24.8	27.0	25.0	23.2	23.0	22.6	20.9	17.6	15.3	15.3	*
29	92	Nagpur airport	9.3	79.3	11	13.7	15.9	20.4	25.2	29.1	27.5	25.0	24.4	23.8	20.6	16.1	13.4	13.4	*
12	27	Calcutta alipore	22.7	88.5	6	13.3	16.3	21.0	25.0	27.0	27.2	26.6	26.7	26.4	24.3	18.3	13.9	13.3	
13	27	Calcutta-Dum Dum	26.1	91.6	54	13.3	16.3	21.0	25.0	27.0	27.2	26.6	26.7	26.4	24.3	18.3	13.9	13.3	
35	108	Pune	18.5	73.9	559	13.1	14.0	18.1	22.1	23.9	23.9	23.0	22.4	21.7	20.0	16.8	14.6	13.1	*
2	4	Ahmadabad airport	11.7	92.7	79	13.0	15.1	19.5	24.1	27.2	27.9	26.5	25.8	24.9	21.5	17.3	14.5	13.0	*
3	5	Akola airport	24.8	92.8	29	12.9	14.5	19.1	23.4	27.0	25.4	23.2	22.8	22.2	19.1	15.7	13.0	12.9	*
18	40	Gauhati airpot	20.5	85.9	27	17.0	13.3	16.8	21.6	23.7	25.8	26.8	26.7	25.9	22.8	17.4	12.9	12.9	
22	61	Jagdalpur	16.2	81.1	3	13.3	15.6	19.9	23.3	25.2	24.7	23.2	23.1	22.9	21.1	15.8	12.4	12.4	
8	21	Bhopal	8.5	77.0	64	12.2	14.1	19.0	23.4	26.5	26.7	24.4	23.6	22.5	19.9	16.5	13.2	12.2	*
37	124	Silicuri	26.8	75.8	390	11.7	13.9	17.1	20.4	22.2	23.7	24.2	24.2	23.9	21.7	16.6	13.0	11.7	
24	69	Jodhpur	25.6	85.2	53	11.4	13.9	19.1	24.0	27.1	29.2	28.0	26.8	25.1	21.4	16.3	12.9	11.4	*
21	59	Indore airpot	21.1	79.1	310	11.0	13.4	17.1	22.0	24.8	25.5	23.9	22.5	21.6	19.4	15.2	12.6	11.0	*
4	7	Allahabad airport	19.1	72.9	14	10.6	13.1	18.4	24.4	28.0	30.5	27.9	27.0	26.1	22.0	15.5	10.8	10.6	*
33	105	Patna	17.5	78.5	545	10.6	13.1	17.8	23.6	26.3	28.1	27.3	27.0	26.3	22.1	16.0	11.6	10.6	
26	79	Kota	13.0	77.6	921	10.1	13.5	18.8	24.2	28.6	29.2	26.3	25.4	24.3	20.7	15.4	11.4	10.1	*
23	62	Jaipur airport	22.7	75.8	567	9.5	13.0	17.7	23.3	26.4	29.1	27.4	25.7	24.2	20.1	14.8	10.5	9.5	*
25	76	Kodaikanal	17.7	83.2	3	9.5	9.8	11.1	12.6	14.0	13.5	12.7	12.8	12.6	12.1	11.1	10.1	9.5	
16	38	Dibrugharh airport	19.1	82.0	553	9.1	13.1	16.1	19.5	22.0	24.4	26.1	25.1	24.5	21.2	14.9	10.9	9.1	
30	97	New Dehli - Safdarjung	27.2	78.0	169	8.6	12.0	16.6	22.6	26.3	29.6	28.4	27.1	25.5	20.8	14.3	9.5	8.6	*
36	123	Shillong	34.1	74.8	1587	7.1	8.7	12.3	15.3	17.0	18.2	18.8	18.5	17.7	15.4	11.3	8.5	7.1	
1	3	Agra airport	10.0	76.2	3	6.9	10.8	15.8	21.7	26.0	29.5	29.0	22.7	24.4	19.3	12.6	8.1	6.9	*
6	9	Amritsar airport	27.5	95.0	111	5.9	8.7	13.2	18.5	22.4	26.8	27.2	26.8	24.4	18.2	10.9	6.1	5.9	
9	24	Bikaner	25.6	91.9	1500	4.4	8.7	14.6	20.8	25.3	28.9	27.8	26.8	24.8	18.6	10.7	5.5	4.4	*
38	127	Srinagar	25.2	75.9	257	-1.1	1.0	5.3	9.4	12.3	16.3	20.1	19.3	15.0	8.2	3.4	0.4	-1.1	

APPENDIX Z

GRAPES

Pump Sizing
for
Drip Irrigation Systems

PV, Diesel, Hand and Animal Powered Pumps

0.5, 1.0, 1.5, and 2.0 ha Farms

Pump Sizing for Grapes, Drip Irrigation					0.6 ha Plot								
									Crop	Water	Assumed	Nearest Pump Size	
Stn	Stn								Water	Pumping	Pumping	DC Surface Pump	
ETo	Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	24.9	15.1	16	21.6	530	162,668
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	22.9	13.9	16	23.6	530	162,668
3	5	Akola	20.7	77.0	282	5	May	6.93	23.9	14.5	16	15.2	424	143,104
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	20.8	12.6	16	21.1	530	162,668
8	21	Bhopal	23.3	77.4	503	5	May	7.17	26.4	16.1	16	27.2	530	162,668
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	36.7	22.4	16	32.4	530	162,668
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	22.7	13.8	16	15.0	424	143,104
21	59	Indore	22.7	75.8	567	6	May	7.35	30.8	18.7	16	28.1	530	162,668
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	27.4	16.7	16	22.1	530	162,668
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	35.1	21.3	16	26.0	530	162,668
26	79	Kota	25.2	75.5	257	7	Jun	6.72	31.1	18.9	16	25.1	530	162,668
29	92	Nagpur	21.2	79.1	311	5	May	6.75	24.8	15.1	16	25.2	530	162,668
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	24.2	14.7	16	14.7	530	162,668
35	108	Pune	18.5	73.9	563	6	May	6.92	26.3	16.0	16	26.0	530	162,668
AVERAGE								6.66	27.0	16.4	16	23.1	515	159,873

Pump Sizing for Grapes, Drip Irrigation					1.0 ha Plot								
									Crop	Water	Assumed	Nearest Pump Size	
Stn	Stn								Water	Pumping	Pumping	DC Surface Pump	
ETo	Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	49.7	30.3	16	34.1	742	213,993
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	45.7	27.8	16	29.9	636	188,331
3	5	Akola	20.7	77.0	282	5	May	6.93	47.8	29.1	16	32.9	636	188,331
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	41.6	25.3	16	27.0	636	188,331
8	21	Bhopal	23.3	77.4	503	5	May	7.17	52.8	32.1	16	34.3	636	188,331
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	73.5	44.7	16	48.9	742	213,993
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	45.3	27.6	16	32.5	636	188,331
21	59	Indore	22.7	75.8	567	6	May	7.35	61.6	37.5	16	42.7	742	213,993
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	54.8	33.3	16	34.7	742	213,993
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	70.2	42.7	16	46.3	848	188,331
26	79	Kota	25.2	75.5	257	7	Jun	6.72	62.2	37.8	16	38.7	742	213,993
29	92	Nagpur	21.2	79.1	311	5	May	6.75	49.6	30.2	16	31.9	636	188,331
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	48.4	29.5	16	31.6	742	213,993
35	108	Pune	18.5	73.9	563	6	May	6.92	52.5	31.9	16	32.9	636	188,331
AVERAGE								6.66	54.0	32.8	16	35.6	697	199,329

Pump Sizing for Grapes, Drip Irrigation					1.5 ha Plot								
									Crop	Water	Assumed	Nearest Pump Size	
Stn	Stn								Water	Pumping	Pumping	DC Surface Pump	
ETo	Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	74.6	45.4	16	49.4	1,060	282,008
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	68.6	41.7	16	42.9	848	239,656
3	5	Akola	20.7	77.0	282	5	May	6.93	71.7	43.6	16	46.5	848	239,656
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	62.4	37.9	16	39.4	848	239,656
8	21	Bhopal	23.3	77.4	503	5	May	7.17	79.2	48.2	16	59.7	1,060	282,008
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	110.2	67.1	16	72.0	1,060	282,008
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	68.0	41.4	16	46.0	848	239,656
21	59	Indore	22.7	75.8	567	6	May	7.35	92.4	56.2	16	61.2	1,060	282,008
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	82.2	50.0	16	50.2	1,060	282,008
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	105.3	64.0	16	65.7	1,272	331,539
26	79	Kota	25.2	75.5	257	7	Jun	6.72	93.3	56.7	16	63.9	1,272	331,539
29	92	Nagpur	21.2	79.1	311	5	May	6.75	74.5	45.3	16	45.3	848	239,656
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	72.6	44.2	16	46.0	1,060	282,008
35	108	Pune	18.5	73.9	563	6	May	6.92	78.8	47.9	16	57.5	1,060	282,008
AVERAGE								6.66	81.0	49.3	16	53.3	1,015	273,958

Pump Sizing for Grapes, Drip Irrigation					2.0 ha Plot								
									Crop	Water	Assumed	Nearest Pump Size	
Stn	Stn								Water	Pumping	Pumping	DC Surface Pump	
ETo	Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	99.5	60.5	16	63.3	1,484	381,070
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	91.4	55.6	16	60.7	1,272	331,539
3	5	Akola	20.7	77.0	282	5	May	6.93	95.6	58.1	16	66.0	1,272	331,539
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	83.2	50.6	16	55.6	1,272	331,539
8	21	Bhopal	23.3	77.4	503	5	May	7.17	105.6	64.2	16	68.3	1,272	331,539
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	147.0	89.4	16	93.0	1,484	381,070
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	90.7	55.2	16	57.0	1,060	282,008
21	59	Indore	22.7	75.8	567	6	May	7.35	123.2	74.9	16	78.0	1,484	381,070
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	109.6	66.7	16			
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	140.4	85.4	16			
26	79	Kota	25.2	75.5	257	7	Jun	6.72	124.4	75.7	16			
29	92	Nagpur	21.2	79.1	311	5	May	6.75	99.3	60.4	16	64.2	1,272	331,539
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	96.9	58.9	16	59.1	1,484	381,070
35	108	Pune	18.5	73.9	563	6	May	6.92	105.0	63.9	16	65.9	1,272	331,539
AVERAGE								6.66	108.0	65.7	16	66.5	1,330	345,047

Table 3.29 Pump Sizing: PV Pump with Drip Irrigation

Pump Sizing for Grapes, Surface Irrigation					0.5 ha Plot				Crop Water	Water Pumping	Assumed Pumping	Nearest Pump Size DC Surface Pump		
Stn ETo	Stn Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	24.9	41.4	2	58.6	424	131,182
2	4	Ahmedabad	23.1	72.6	55	5	Jun	6.39	22.9	38.1	2	44.8	318	104,662
3	5	Akola	20.7	77.0	282	5	May	6.93	23.9	39.8	2	40.2	212	78,062
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	20.8	34.6	2	36.7	318	104,622
8	21	Bhopal	23.3	77.4	503	5	May	7.17	26.4	44.0	2	57.0	318	104,622
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	36.7	61.2	2	64.8	318	104,622
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	22.7	37.8	2	52.2	318	104,622
21	59	Indore	22.7	75.8	567	6	May	7.35	30.8	51.3	2	59.9	318	104,622
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	27.4	45.7	2	59.6	424	131,182
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	35.1	58.5	2	68.4	424	131,182
26	79	Kota	25.2	75.5	257	7	Jun	6.72	31.1	51.8	2	66.4	424	131,182
29	92	Nagpur	21.2	79.1	311	5	May	6.75	24.8	41.4	2	50.5	318	104,622
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	24.2	40.4	2	54.4	424	131,182
35	108	Pune	18.5	73.9	563	6	May	6.92	26.3	43.8	2	53.1	318	104,622
AVERAGE								6.66	27.0	45.0	2	54.6	348	112,213

Pump Sizing for Grapes, Surface Irrigation					1.0 ha Plot				Crop Water	Water Pumping	Assumed Pumping	Nearest Pump Size DC Surface Pump		
Stn ETo	Stn Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	49.7	82.9	2	86.8	636	178,918
2	4	Ahmedabad	23.1	72.6	55	5	Jun	6.39	45.7	76.2	2	82.4	530	153,256
3	5	Akola	20.7	77.0	282	5	May	6.93	47.8	79.6	2	90.5	530	153,256
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	41.6	69.3	2	74.5	530	153,256
8	21	Bhopal	23.3	77.4	503	5	May	7.17	52.8	88.0	2	94.1	530	153,256
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	73.5	122.5	2	138.5	742	204,581
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	45.3	75.6	2	84.9	530	153,256
21	59	Indore	22.7	75.8	567	6	May	7.35	61.6	102.7	2	105.6	636	178,918
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	54.8	91.4	2	104.4	742	204,581
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	70.2	117.0	2	120.0	742	204,581
26	79	Kota	25.2	75.5	257	7	Jun	6.72	62.2	103.7	2	116.6	742	204,581
29	92	Nagpur	21.2	79.1	311	5	May	6.75	49.6	82.7	2	87.8	530	153,256
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	48.4	80.7	2	95.0	742	204,581
35	108	Pune	18.5	73.9	563	6	May	6.92	52.5	87.5	2	90.3	530	153,256
AVERAGE								6.66	54.0	90.0	2	98.0	621	175,252

Pump Sizing for Grapes, Surface Irrigation					1.5 ha Plot				Crop Water	Water Pumping	Assumed Pumping	Nearest Pump Size DC Surface Pump		
Stn ETo	Stn Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	74.6	124.3	2	132.2	1,060	272,596
2	4	Ahmedabad	23.1	72.6	55	5	Jun	6.39	68.6	114.3	2	123.4	848	230,244
3	5	Akola	20.7	77.0	282	5	May	6.93	71.7	119.5	2	120.6	742	204,581
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	62.4	103.9	2	112.7	848	230,244
8	21	Bhopal	23.3	77.4	503	5	May	7.17	79.2	132.0	2	139.5	848	230,244
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	110.2	183.7	2			
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	68.0	113.4	2	119.2	742	204,581
21	59	Indore	22.7	75.8	567	6	May	7.35	92.4	154.0	2	158.2	1,060	272,596
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	82.2	137.0	2			
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	105.3	175.4	2			
26	79	Kota	25.2	75.5	257	7	Jun	6.72	93.3	155.5	2			
29	92	Nagpur	21.2	79.1	311	5	May	6.75	74.5	124.1	2	130.8	848	230,244
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	72.6	121.1	2	124.6	1,060	272,596
35	108	Pune	18.5	73.9	563	6	May	6.92	78.8	131.3	2	134.3	848	230,244
AVERAGE								6.66	81.0	135.0	2	129.6	890	237,817

Pump Sizing for Grapes, Surface Irrigation					2.0 ha Plot				Crop Water	Water Pumping	Assumed Pumping	Nearest Pump Size DC Surface Pump		
Stn ETo	Stn Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Req'ment (m3/day)	Req'ment (m3/day)	Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	99.5	165.8	2			
2	4	Ahmedabad	23.1	72.6	55	5	Jun	6.39	91.4	152.4	2			
3	5	Akola	20.7	77.0	282	5	May	6.93	95.6	159.3	2			
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	83.2	138.6	2			
8	21	Bhopal	23.3	77.4	503	5	May	7.17	105.6	176.0	2			
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	147.0	245.0	2			
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	90.7	151.1	2			
21	59	Indore	22.7	75.8	567	6	May	7.35	123.2	205.4	2			
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	109.6	182.7	2			
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	140.4	233.9	2			
26	79	Kota	25.2	75.5	257	7	Jun	6.72	124.4	207.3	2			
29	92	Nagpur	21.2	79.1	311	5	May	6.75	99.3	165.5	2			
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	96.9	161.4	2			
35	108	Pune	18.5	73.9	563	6	May	6.92	105.0	175.0	2			
AVERAGE								6.66	108.0	180.0	2			

Table 3.30 Pump Sizing: PV Pump with Surface Irrigation

Pump Sizing for Grapes, Drip Irrigation					0.5 ha Plot							Nearest Pump Size		
									Crop	Water	Assumed	DC Surface Pump		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	24.9	15.1	16	21.6	530	162,668
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	22.9	13.9	16	23.6	530	162,668
3	5	Akola	20.7	77.0	282	5	May	6.93	23.9	14.5	16	15.2	424	143,104
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	20.8	12.6	16	21.1	530	162,668
8	21	Bhopal	23.3	77.4	503	5	May	7.17	26.4	16.1	16	27.2	530	162,668
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	36.7	22.4	16	32.4	530	162,668
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	22.7	13.8	16	15.0	424	143,104
21	59	Indore	22.7	75.8	567	6	May	7.35	30.8	18.7	16	28.1	530	162,668
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	27.4	16.7	16	22.1	530	162,668
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	35.1	21.3	16	26.0	530	162,668
26	79	Kota	25.2	75.5	257	7	Jun	6.72	31.1	18.9	16	25.1	530	162,668
29	92	Nagpur	21.2	79.1	311	5	May	6.75	24.8	15.1	16	25.2	530	162,668
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	24.2	14.7	16	14.7	530	162,668
35	108	Pune	18.5	73.9	563	6	May	6.92	26.3	16.0	16	26.0	530	162,668
AVERAGE								6.66	27.0	16.4	16	23.1	515	159,873

Pump Sizing for Grapes, Drip Irrigation					1.0 ha Plot							Nearest Pump Size		
									Crop	Water	Assumed	DC Surface Pump		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	49.7	30.3	16	34.1	742	213,993
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	45.7	27.8	16	29.9	636	188,331
3	5	Akola	20.7	77.0	282	5	May	6.93	47.8	29.1	16	32.9	636	188,331
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	41.6	25.3	16	27.0	636	188,331
8	21	Bhopal	23.3	77.4	503	5	May	7.17	52.8	32.1	16	34.3	636	188,331
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	73.5	44.7	16	48.9	742	213,993
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	45.3	27.6	16	32.5	636	188,331
21	59	Indore	22.7	75.8	567	6	May	7.35	61.6	37.5	16	42.7	742	213,993
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	54.8	33.3	16	34.7	742	213,993
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	70.2	42.7	16	46.3	848	188,331
26	79	Kota	25.2	75.5	257	7	Jun	6.72	62.2	37.8	16	38.7	742	213,993
29	92	Nagpur	21.2	79.1	311	5	May	6.75	49.6	30.2	16	31.9	636	188,331
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	48.4	29.5	16	31.6	742	213,993
35	108	Pune	18.5	73.9	563	6	May	6.92	52.5	31.9	16	32.9	636	188,331
AVERAGE								6.66	54.0	32.8	16	35.6	697	199,329

Pump Sizing for Grapes, Drip Irrigation					1.5 ha Plot							Nearest Pump Size		
									Crop	Water	Assumed	DC Surface Pump		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	74.6	45.4	16	49.4	1,060	282,008
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	68.6	41.7	16	42.9	848	239,656
3	5	Akola	20.7	77.0	282	5	May	6.93	71.7	43.6	16	46.5	848	239,656
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	62.4	37.9	16	39.4	848	239,656
8	21	Bhopal	23.3	77.4	503	5	May	7.17	79.2	48.2	16	59.7	1,060	282,008
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	110.2	67.1	16	72.0	1,060	282,008
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	68.0	41.4	16	46.0	848	239,656
21	59	Indore	22.7	75.8	567	6	May	7.35	92.4	56.2	16	61.2	1,060	282,008
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	82.2	50.0	16	50.2	1,060	282,008
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	105.3	64.0	16	65.7	1,272	331,539
26	79	Kota	25.2	75.5	257	7	Jun	6.72	93.3	56.7	16	63.9	1,272	331,539
29	92	Nagpur	21.2	79.1	311	5	May	6.75	74.5	45.3	16	45.3	848	239,656
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	72.6	44.2	16	46.0	1,060	282,008
35	108	Pune	18.5	73.9	563	6	May	6.92	78.8	47.9	16	57.5	1,060	282,008
AVERAGE								6.66	81.0	49.3	16	53.3	1,015	273,958

Pump Sizing for Grapes, Drip Irrigation					2.0 ha Plot							Nearest Pump Size		
									Crop	Water	Assumed	DC Surface Pump		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	99.5	60.5	16	63.3	1,484	381,070
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	91.4	55.6	16	60.7	1,272	331,539
3	5	Akola	20.7	77.0	282	5	May	6.93	95.6	58.1	16	66.0	1,272	331,539
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	83.2	50.6	16	55.6	1,272	331,539
8	21	Bhopal	23.3	77.4	503	5	May	7.17	105.6	64.2	16	68.3	1,272	331,539
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	147.0	89.4	16	93.0	1,484	381,070
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	90.7	55.2	16	57.0	1,060	282,008
21	59	Indore	22.7	75.8	567	6	May	7.35	123.2	74.9	16	78.0	1,484	381,070
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	109.6	66.7	16			
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	140.4	85.4	16			
26	79	Kota	25.2	75.5	257	7	Jun	6.72	124.4	75.7	16			
29	92	Nagpur	21.2	79.1	311	5	May	6.75	99.3	60.4	16	64.2	1,272	331,539
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	96.9	58.9	16	59.1	1,484	381,070
35	108	Pune	18.5	73.9	563	6	May	6.92	105.0	63.9	16	65.9	1,272	331,539
AVERAGE								6.66	108.0	65.7	16	66.5	1,330	345,047

Pump Sizing for Grapes, Surface Irrigation					0.5 ha Plot							Nearest Pump Size		
									Crop	Water	Assumed	DC Surface Pump		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	24.9	41.4	2	58.6	424	131,182
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	22.9	38.1	2	44.8	318	104,662
3	5	Akola	20.7	77.0	282	5	May	6.93	23.9	39.8	2	40.2	212	78,062
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	20.8	34.6	2	36.7	318	104,622
8	21	Bhopal	23.3	77.4	503	5	May	7.17	26.4	44.0	2	57.0	318	104,622
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	36.7	61.2	2	64.8	318	104,622
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	22.7	37.8	2	52.2	318	104,622
21	59	Indore	22.7	75.8	567	6	May	7.35	30.8	51.3	2	59.9	318	104,622
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	27.4	45.7	2	59.6	424	131,182
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	35.1	58.5	2	68.4	424	131,182
26	79	Kota	25.2	75.5	257	7	Jun	6.72	31.1	51.8	2	66.4	424	131,182
29	92	Nagpur	21.2	79.1	311	5	May	6.75	24.8	41.4	2	50.5	318	104,622
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	24.2	40.4	2	54.4	424	131,182
35	108	Pune	18.5	73.9	563	6	May	6.92	26.3	43.8	2	53.1	318	104,622
AVERAGE								6.66	27.0	45.0	2	54.8	348	112,213

Pump Sizing for Grapes, Surface Irrigation					1.0 ha Plot							Nearest Pump Size		
									Crop	Water	Assumed	DC Surface Pump		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	49.7	82.9	2	86.8	636	178,918
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	45.7	76.2	2	82.4	530	153,256
3	5	Akola	20.7	77.0	282	5	May	6.93	47.8	79.6	2	90.5	530	153,256
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	41.6	69.3	2	74.5	530	153,256
8	21	Bhopal	23.3	77.4	503	5	May	7.17	52.8	88.0	2	94.1	530	153,256
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	73.5	122.5	2	138.5	742	204,581
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	45.3	75.6	2	84.9	530	153,256
21	59	Indore	22.7	75.8	567	6	May	7.35	61.6	102.7	2	106.6	636	178,918
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	54.8	91.4	2	104.4	742	204,581
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	70.2	117.0	2	120.0	742	204,581
26	79	Kota	25.2	75.5	257	7	Jun	6.72	62.2	103.7	2	116.6	742	204,581
29	92	Nagpur	21.2	79.1	311	5	May	6.75	49.6	82.7	2	87.8	530	153,256
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	48.4	80.7	2	95.0	742	204,581
35	108	Pune	18.5	73.9	563	6	May	6.92	52.5	87.5	2	90.3	530	153,256
AVERAGE								6.66	54.0	90.0	2	98.0	621	175,252

Pump Sizing for Grapes, Surface Irrigation					1.5 ha Plot							Nearest Pump Size		
									Crop	Water	Assumed	DC Surface Pump		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	74.6	124.3	2	132.2	1,060	272,596
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	68.6	114.3	2	123.4	848	230,244
3	5	Akola	20.7	77.0	282	5	May	6.93	71.7	119.5	2	120.6	742	204,581
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	62.4	103.9	2	112.7	848	230,244
8	21	Bhopal	23.3	77.4	503	5	May	7.17	79.2	132.0	2	139.5	848	230,244
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	110.2	183.7	2			
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	68.0	113.4	2	119.2	742	204,581
21	59	Indore	22.7	75.8	567	6	May	7.35	92.4	154.0	2	158.2	1,060	272,596
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	82.2	137.0	2			
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	105.3	175.4	2			
26	79	Kota	25.2	75.5	257	7	Jun	6.72	93.3	155.5	2			
29	92	Nagpur	21.2	79.1	311	5	May	6.75	74.5	124.1	2	130.8	848	230,244
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	72.6	121.1	2	124.6	1,060	272,596
35	108	Pune	18.5	73.9	563	6	May	6.92	78.8	131.3	2	134.3	848	230,244
AVERAGE								6.66	81.0	135.0	2	129.6	890	237,817

Pump Sizing for Grapes, Surface Irrigation					2.0 ha Plot							Nearest Pump Size		
									Crop	Water	Assumed	DC Surface Pump		
St# ETo	St# Sun	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Insolation (kWh/m2)	Water Req'ment (m3/day)	Pumping Req'ment (m3/day)	Pumping Head (m)	Output (m3/day)	Array (Wp)	Cost (Rs)
1	3	Agra	27.2	78.1	169	5	Jun	5.98	99.5	165.8	2			
2	4	Ahmadabad	23.1	72.6	55	5	Jun	6.39	91.4	152.4	2			
3	5	Akola	20.7	77.0	282	5	May	6.93	95.6	159.3	2			
4	7	Allahabad	25.5	81.7	98	5	Jun	5.87	83.2	138.6	2			
8	21	Bhopal	23.3	77.4	503	5	May	7.17	105.6	176.0	2			
9	24	Bikaner	28.0	73.3	224	7	Jun	7.74	147.0	245.0	2			
20	56	Hyderabad	17.5	78.5	545	5	May	6.86	90.7	151.1	2			
21	59	Indore	22.7	75.8	567	6	May	7.35	123.2	205.4	2			
23	62	Jaipur	26.8	75.8	390	7	Jun	6.08	109.6	182.7	2			
24	69	Jodhpur	26.3	73.0	224	7	Jun	6.90	140.4	233.9	2			
26	79	Kota	25.2	75.5	257	7	Jun	6.72	124.4	207.3	2			
29	92	Nagpur	21.2	79.1	311	5	May	6.75	99.3	165.5	2			
30	97	New Dehli	28.6	77.2	216	5	Jun	5.59	96.9	161.4	2			
35	108	Pune	18.5	73.9	563	6	May	6.92	105.0	175.0	2			
AVERAGE								6.66	108.0	180.0	2			

Diesel Pump Sizing for a 1.0 ha Grape Farm

Assumptions: Drip Irrigation		
Surface Water Source		
Drip Irrigation		
Water Savings =	48%	
EAdrip =	0.95	
EUdrip =	0.90	
Max Run Time per Day, Td =	8	hrs
Specific Weight of Water, Y =	9.789	kN/m3
Pump Efficiency, Ep =	0.5	
Minimum Diesel Engine Size =	3.7	kW
Unit Cost of a Diesel PUmpset =	2,682	Rs/kW
Fuel Consumption =	0.34	l/kWhr
Fuel Cost =	7	Rs/l

Assumptions: Surface Irrigation		
Surface Water Source		
Surface Irrigation		
Field Application Efficiency =	0.6	
Max Run Time per Day, Td =	8	hrs
Specific Weight of Water, Y =	9.789	kN/m3
Pump Efficiency, Ep =	0.5	
Minimum Diesel Engine Size =	3.7	kW
Unit Cost of a Diesel PUmpset =	2,682	Rs/kW
Fuel Consumption =	0.34	l/kWhr
Fuel Cost =	7	Rs/l

Diesel Pump Sizing for Grapes, Drip Irrigation					0.5 ha Plot									
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Crop Water Required (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Engine Size Req'd (kW)	Engine Size Used (kW)	Capital Cost of Pumpset (Rs)	Annual Pumping Req'ment (m3/yr)	Annual Run Time (hrs)	Annual Fuel Cost (Rs/yr)
1	Agra	27.2	78 1	169	5	Jun	24.9	15.1	16	0 16	3.7	10,000	1557.2	36 34	322 47
2	Ahmadabad	23.1	72 6	55	5	May	23.2	14.1	16	0.15	3.7	10,000	1727.2	40.31	357.69
3	Akola	20.7	77.0	282	5	May	23.9	14.5	16	0 16	3 7	10,000	1348 8	31.48	279 32
4	Allahabad	25 5	81.7	98	5	May	21.0	12 8	16	0 14	3 7	10,000	1345 4	31 40	278 63
8	Bhopal	23.3	77.4	503	5	May	26.4	16.1	16	0 17	3 7	10,000	1483.0	34 61	307.12
9	Bikaner	28 0	73 3	224	7	Jun	36.7	22 4	16	0.24	3 7	10,000	3222.1	75.19	667.27
20	Hyderabad	17.5	78 5	545	5	May	22.7	13 8	16	0 15	3 7	10,000	1273 7	29.72	263.77
21	Indore	22.7	75 8	567	6	May	30.8	18.7	16	0.20	3 7	10,000	1611.0	37.60	333 63
23	Jaipur	26 8	75 8	390	7	Jun	27.4	16.7	16	0 18	3 7	10,000	2048 3	47.80	424 18
24	Jodhpur	26.3	73 0	224	7	Jun	35 1	21.3	16	0.23	3 7	10,000	3029 0	70 69	627.28
26	Kota	25 2	75 5	257	7	May	31.3	19 0	16	0 21	3 7	10,000	2236 0	52 18	463 05
29	Nagpur	21.2	79 1	311	5	May	24 8	15.1	16	0.16	3 7	10,000	1187.7	27.72	245 96
30	New Dehli	28 6	77.2	216	5	Jun	24 2	14.7	16	0.16	3 7	10,000	1604 1	37.44	332 20
35	Pune	18 5	73 9	563	6	May	26 3	16 0	16	0 17	3 7	10,000	1514 1	35 34	313 56
AVERAGE							27.1	16 5	16	0 18	3 7	10,000	1,799 1	41 99	372 58

Diesel Pump Sizing for Grapes, Drip Irrigation					1.0 ha Plot									
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Crop Water Required (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Engine Size Req'd (kW)	Engine Size Used (kW)	Capital Cost of Pumpset (Rs)	Annual Pumping Req'ment (m3/yr)	Annual Run Time (hrs)	Annual Fuel Cost (Rs/yr)
1	Agra	27.2	78 1	169	5	Jun	49 7	30.3	16	0.33	3 7	10,000	3114.3	72 68	644 95
2	Ahmadabad	23 1	72 6	55	5	May	46 4	28.2	16	0 31	3 7	10,000	3454 4	80 62	715 38
3	Akola	20 7	77.0	282	5	May	47.8	29.1	16	0.32	3 7	10,000	2697.5	62 95	558 63
4	Allahabad	25 5	81 7	98	5	May	42.0	25.5	16	0.28	3.7	10,000	2690 9	62 80	557 25
8	Bhopal	23 3	77 4	503	5	May	52 8	32 1	16	0.35	3.7	10,000	2966.1	69.22	614 25
9	Bikaner	28 0	73.3	224	7	Jun	73.5	44.7	16	0.49	3.7	10,000	6444.2	150 39	1,334 53
20	Hyderabad	17.5	78 5	545	5	May	45 3	27.6	16	0 30	3.7	10,000	2547.3	59 45	527.53
21	Indore	22.7	75 8	567	6	May	61.6	37.5	16	0 41	3.7	10,000	3222.0	75 19	667.25
23	Jaipur	26 8	75 8	390	7	Jun	54 8	33 3	16	0 36	3 7	10,000	4096 6	95 60	848 36
24	Jodhpur	26.3	73 0	224	7	Jun	70 2	42.7	16	0 46	3 7	10,000	6058 0	141.38	1,254 57
26	Kota	25.2	75 5	257	7	May	62 6	38.1	16	0.41	3.7	10,000	4471 9	104 36	926 10
29	Nagpur	21.2	79 1	311	5	May	49.6	30.2	16	0.33	3.7	10,000	2375 4	55 43	491.92
30	New Dehli	28 6	77.2	216	5	Jun	48 4	29.5	16	0.32	3.7	10,000	3208 3	74 87	664 41
35	Pune	18 5	73 9	563	6	May	52 5	31 9	16	0 35	3 7	10,000	3028 2	70 67	627.12
AVERAGE							54 1	32 9	16	0 36	3 7	10,000	3,598 2	83 97	745 16

Diesel Pump Sizing for Grapes, Drip Irrigation					1.5 ha Plot									
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Engine Size Req'd (kW)	Engine Size Used (kW)	Capital Cost of Pumpset (Rs)	Annual Pumping Req'ment (m3/yr)	Annual Run Time (hrs)	Annual Fuel Cost (Rs/yr)
1	Agra	27.2	78 1	169	5	Jun	74 6	45 4	16	0 49	3 7	10,000	4671.5	109 02	967 42
2	Ahmadabad	23 1	72 6	55	5	Jun	69 7	42.4	16	0 46	3.7	10,000	5181 6	120 92	1,073 07
3	Akola	20 7	77 0	282	5	May	71.7	43 6	16	0 47	3.7	10,000	4046 3	94 43	837.95
4	Allahabad	25 5	81.7	98	5	Jun	63 0	38 3	16	0 42	3.7	10,000	4036 3	94.20	835 88
8	Bhopal	23 3	77.4	503	5	May	79 2	48 2	16	0 52	3 7	10,000	4449.1	103 83	921 37
9	Bikaner	28 0	73 3	224	7	Jun	110 2	67.1	16	0 73	3.7	10,000	9666 2	225 58	2,001 80
20	Hyderabad	17.5	78 5	545	5	May	68.0	41.4	16	0 45	3 7	10,000	3821 0	89 17	791.30
21	Indore	22.7	75 8	567	6	May	92 4	56 2	16	0 61	3 7	10,000	4833 0	112 79	1,000 88
23	Jaipur	26 8	75 8	390	7	Jun	82.2	50 0	16	0 54	3.7	10,000	6144 8	143 40	1,272 55
24	Jodhpur	26.3	73 0	224	7	Jun	105.3	64 0	16	0 70	3 7	10,000	9087.1	212.07	1,881 85
26	Kota	25 2	75 5	257	7	Jun	94 0	57.1	16	0 62	3 7	10,000	6707 9	156 55	1,389 15
29	Nagpur	21.2	79 1	311	5	May	74 5	45 3	16	0 49	3 7	10,000	3563.1	83 15	737 88
30	New Dehli	28 6	77.2	216	5	Jun	72 6	44 2	16	0 48	3 7	10,000	4812.4	112.31	996 61
35	Pune	18 5	73 9	563	6	May	78 8	47 9	16	0 52	3 7	10,000	4542 3	106 01	940 68
AVERAGE							81.2	49 4	16	0 54	3 7	10,000	5,397 3	125 96	1,117 74

Diesel Pump Sizing for Grapes, Drip Irrigation					2.0 ha Plot									
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Engine Size Req'd (kW)	Engine Size Used (kW)	Capital Cost of Pumpset (Rs)	Annual Pumping Req'ment (m3/yr)	Annual Run Time (hrs)	Annual Fuel Cost (Rs/yr)
1	Agra	27 2	78.1	169	5	Jun	99.5	60.5	16	0.66	3.7	10,000	6228 6	145.36	1,289 89
2	Ahmadabad	23 1	72 6	55	5	Jun	92.9	56 5	16	0 61	3 7	10,000	6908 8	161.23	1,430 76
3	Akola	20.7	77.0	282	5	May	95.6	58.1	16	0 63	3 7	10,000	5395 0	125 91	1,117.26
4	Allahabad	25 5	81.7	98	5	Jun	83.9	51.1	16	0 56	3.7	10,000	5381.7	125 59	1,114 51
8	Bhopal	23.3	77.4	503	5	May	105.6	64 2	16	0.70	3.7	10,000	5932.1	138 44	1,228 50
9	Bikaner	28.0	73 3	224	7	Jun	147.0	89.4	16	0.97	3.7	10,000	12888 3	300 78	2,669 06
20	Hyderabad	17.5	78 5	545	5	May	90.7	55.2	16	0 60	3.7	10,000	5094 7	118 90	1,055 06
21	Indore	22 7	75 8	567	6	May	123 2	74.9	16	0.82	3.7	10,000	6444 0	150 39	1,334 50
23	Jaipur	26 8	75 8	390	7	Jun	109.6	66.7	16	0.73	3.7	10,000	8193.1	191.21	1,696 73
24	Jodhpur	26.3	73 0	224	7	Jun	140.4	85.4	16	0.93	3.7	10,000	12116 1	282 76	2,509 14
26	Kota	25.2	75 5	257	7	Jun	125.3	76.2	16	0 83	3.7	10,000	8943 9	208 73	1,852 21
29	Nagpur	21.2	79.1	311	5	May	99 3	60.4	16	0 66	3 7	10,000	4750 7	110 87	983 84
30	New Dehli	28 6	77.2	216	5	Jun	96 9	58.9	16	0 64	3.7	10,000	6416 6	149 75	1,328 81
35	Pune	18 5	73 9	563	6	May	105.0	63 9	16	0 69	3.7	10,000	6056 4	141 34	1,254 23
AVERAGE							108 2	65 8	16	0 72	3 7	10,000	7,196 4	167 95	1,490 32

Diesel Pump Sizing for Grapes, Surface Irrigation					0.5 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Engine Size	Engine Size	Capital Cost of	Annual Pumping	Annual Run	Annual Fuel
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	Used (kW)	Pumpset (Rs)	Req'ment (m3/yr)	Time (hrs)	Cost (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	24.9	41.4	2	0.06	3.7	10,000	4267.2	12.45	110.46
2	Ahmadabad	23.1	72.6	55	5	May	23.2	38.7	2	0.05	3.7	10,000	4733.2	13.81	122.53
3	Akola	20.7	77.0	282	5	May	23.9	39.8	2	0.05	3.7	10,000	3696.1	10.78	95.68
4	Allahabad	25.5	81.7	98	5	May	21.0	35.0	2	0.05	3.7	10,000	3687.0	10.76	95.44
8	Bhopal	23.3	77.4	503	5	May	26.4	44.0	2	0.06	3.7	10,000	4064.1	11.86	105.20
9	Bikaner	28.0	73.3	224	7	Jun	36.7	61.2	2	0.08	3.7	10,000	8829.7	25.76	228.57
20	Hyderabad	17.5	78.5	545	5	May	22.7	37.8	2	0.05	3.7	10,000	3490.3	10.18	90.35
21	Indore	22.7	75.8	567	6	May	30.8	51.3	2	0.07	3.7	10,000	4414.8	12.88	114.28
23	Jaipur	26.8	75.8	390	7	Jun	27.4	45.7	2	0.06	3.7	10,000	5613.1	16.37	145.30
24	Jodhpur	26.3	73.0	224	7	Jun	35.1	58.5	2	0.08	3.7	10,000	8300.7	24.21	214.88
26	Kota	25.2	75.5	257	7	May	31.3	52.2	2	0.07	3.7	10,000	6127.4	17.87	158.62
29	Nagpur	21.2	79.1	311	5	May	24.8	41.4	2	0.06	3.7	10,000	3254.7	9.49	84.25
30	New Dehli	28.6	77.2	216	5	Jun	24.2	40.4	2	0.05	3.7	10,000	4396.0	12.82	113.80
35	Pune	18.5	73.9	563	6	May	26.3	43.8	2	0.06	3.7	10,000	4149.2	12.10	107.41
AVERAGE							27.1	45.1	2	0.06	3.7	10,000	4,930.2	14.38	127.63

Diesel Pump Sizing for Grapes, Surface Irrigation					1.0 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Engine Size	Engine Size	Capital Cost of	Annual Pumping	Annual Run	Annual Fuel
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	Used (kW)	Pumpset (Rs)	Req'ment (m3/yr)	Time (hrs)	Cost (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	49.7	82.9	2	0.11	3.7	10,000	8534.4	24.90	220.93
2	Ahmadabad	23.1	72.6	55	5	May	46.4	77.4	2	0.11	3.7	10,000	9466.4	27.62	245.05
3	Akola	20.7	77.0	282	5	May	47.8	79.6	2	0.11	3.7	10,000	7392.2	21.56	191.36
4	Allahabad	25.5	81.7	98	5	May	42.0	70.0	2	0.10	3.7	10,000	7374.0	21.51	190.89
8	Bhopal	23.3	77.4	503	5	May	52.8	88.0	2	0.12	3.7	10,000	8128.2	23.71	210.41
9	Bikaner	28.0	73.3	224	7	Jun	73.5	122.5	2	0.17	3.7	10,000	17559.5	51.52	457.14
20	Hyderabad	17.5	78.5	545	5	May	45.3	75.6	2	0.10	3.7	10,000	6980.7	20.36	180.70
21	Indore	22.7	75.8	567	6	May	61.6	102.7	2	0.14	3.7	10,000	8829.5	25.76	228.57
23	Jaipur	26.8	75.8	390	7	Jun	54.8	91.4	2	0.12	3.7	10,000	11226.1	32.75	290.61
24	Jodhpur	26.3	73.0	224	7	Jun	70.2	117.0	2	0.16	3.7	10,000	16601.3	48.43	429.75
26	Kota	25.2	75.5	257	7	May	62.6	104.4	2	0.14	3.7	10,000	12254.8	35.75	317.23
29	Nagpur	21.2	79.1	311	5	May	49.6	82.7	2	0.11	3.7	10,000	6509.4	18.99	168.51
30	New Dehli	28.6	77.2	216	5	Jun	48.4	80.7	2	0.11	3.7	10,000	8791.9	25.65	227.59
35	Pune	18.5	73.9	563	6	May	52.5	87.5	2	0.12	3.7	10,000	8298.5	24.21	214.82
AVERAGE							54.1	90.2	2	0.12	3.7	10,000	9,860.5	28.76	255.25

Diesel Pump Sizing for Grapes, Surface Irrigation					1.5 ha Plot			Water Pumping	Assumed Pumping	Engine Size	Engine Size	Capital Cost of	Annual Pumping	Annual Run	Annual Fuel
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	Used (kW)	Pumpset (Rs)	Req'ment (m3/yr)	Time (hrs)	Cost (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	74.6	124.3	2	0.17	3.7	10,000	12801.6	37.34	331.39
2	Ahmadabad	23.1	72.6	55	5	Jun	69.7	116.1	2	0.16	3.7	10,000	14199.6	41.42	367.58
3	Akola	20.7	77.0	282	5	May	71.7	119.5	2	0.16	3.7	10,000	11088.3	32.35	287.04
4	Allahabad	25.5	81.7	98	5	Jun	63.0	104.9	2	0.14	3.7	10,000	11061.0	32.27	286.33
8	Bhopal	23.3	77.4	503	5	May	79.2	132.0	2	0.18	3.7	10,000	12192.3	35.57	315.61
9	Bikaner	28.0	73.3	224	7	Jun	110.2	183.7	2	0.25	3.7	10,000	26489.2	77.27	685.71
20	Hyderabad	17.5	78.5	545	5	May	68.0	113.4	2	0.15	3.7	10,000	10471.0	30.55	271.06
21	Indore	22.7	75.8	567	6	May	92.4	154.0	2	0.21	3.7	10,000	13244.3	38.64	342.85
23	Jaipur	26.8	75.8	390	7	Jun	82.2	137.0	2	0.19	3.7	10,000	16839.2	49.12	435.91
24	Jodhpur	26.3	73.0	224	7	Jun	105.3	175.4	2	0.24	3.7	10,000	24902.0	72.64	644.63
26	Kota	25.2	75.5	257	7	Jun	94.0	156.6	2	0.21	3.7	10,000	18382.3	53.62	475.85
29	Nagpur	21.2	79.1	311	5	May	74.5	124.1	2	0.17	3.7	10,000	9764.2	28.48	252.76
30	New Dehli	28.6	77.2	216	5	Jun	72.6	121.1	2	0.16	3.7	10,000	13187.9	38.47	341.39
35	Pune	18.5	73.9	563	6	May	78.8	131.3	2	0.18	3.7	10,000	12447.7	36.31	322.23
AVERAGE							81.2	135.3	2	0.18	3.7	10,000	14,790.7	43.15	382.88

Diesel Pump Sizing for Grapes, Surface Irrigation					2.0 ha Plot			Water Pumping	Assumed Pumping	Engine Size	Engine Size	Capital Cost of	Annual Pumping	Annual Run	Annual Fuel
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	Used (kW)	Pumpset (Rs)	Req'ment (m3/yr)	Time (hrs)	Cost (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	99.5	165.8	2	0.23	3.7	10,000	17068.8	49.79	441.85
2	Ahmadabad	23.1	72.6	55	5	Jun	92.9	154.8	2	0.21	3.7	10,000	18932.8	55.23	490.10
3	Akola	20.7	77.0	282	5	May	95.6	159.3	2	0.22	3.7	10,000	14784.4	43.13	382.72
4	Allahabad	25.5	81.7	98	5	Jun	83.9	139.9	2	0.19	3.7	10,000	14747.9	43.02	381.77
8	Bhopal	23.3	77.4	503	5	May	105.6	176.0	2	0.24	3.7	10,000	16256.4	47.42	420.82
9	Bikaner	28.0	73.3	224	7	Jun	147.0	245.0	2	0.33	3.7	10,000	35318.9	103.03	914.28
20	Hyderabad	17.5	78.5	545	5	May	90.7	151.1	2	0.21	3.7	10,000	13961.3	40.73	361.41
21	Indore	22.7	75.8	567	6	May	123.2	205.4	2	0.28	3.7	10,000	17659.1	51.51	457.13
23	Jaipur	26.8	75.8	390	7	Jun	109.6	182.7	2	0.25	3.7	10,000	22452.3	65.50	581.21
24	Jodhpur	26.3	73.0	224	7	Jun	140.4	233.9	2	0.32	3.7	10,000	33202.7	96.86	859.50
26	Kota	25.2	75.5	257	7	Jun	125.3	208.8	2	0.28	3.7	10,000	24509.7	71.50	634.47
29	Nagpur	21.2	79.1	311	5	May	99.3	165.5	2	0.22	3.7	10,000	13018.9	37.98	337.01
30	New Dehli	28.6	77.2	216	5	Jun	96.9	161.4	2	0.22	3.7	10,000	17583.8	51.29	455.18
35	Pune	18.5	73.9	563	6	May	105.0	175.0	2	0.24	3.7	10,000	16596.9	48.42	429.64
AVERAGE							108.2	180.3	2	0.25	3.7	10,000	19,721.0	57.53	510.51

Hand Pump Sizing for a 1.0 ha Grape Farm

Assumptions: Drip Irrigation		
Surface Water Source		
Drip Irrigation		
Water Savings =	0.48	
EAdrip =	0.95	
EUdrip =	0.9	
Max Run Time per Day, Td =	8	hrs
Specific Weight of Water, Y =	9.789	kN/m3
Hydraulic Power/Pump, Php =	0.036	kW
Cost/Pump, Cd =	3,630	Rs/Pump
Average Labour Costs =	23.3	Rs/day

Assumptions: Surface Irrigation	
Surface Water Source	
Surface Irrigation	
EAsurface =	0.6

Hand Pump Sizing for Grapes, Drip Irrigation					0.5 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Hydraulic Power		Capital Cost of	Annual Pumping	Annual Run	Annual Operating
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No of Pumps Req'd	Pumps (Rs)	Req'ment (m3/yr)	Time (days)	Costs (Rs/yr)
1	Agra	27.2	78 1	169	5	Jun	24.9	15 1	16	0 08	3	10,890	1,437.4	72.38	5,059
2	Ahmadabad	23.1	72.6	55	5	May	23.2	14 1	16	0 08	3	10,890	1,594 3	80 28	5,612
3	Akola	20.7	77.0	282	5	May	23.9	14.5	16	0.08	3	10,890	1,245 0	62 69	4,382
4	Allahabad	25.5	81.7	98	5	May	21.0	12 8	16	0.07	2	7,260	1,241.9	93 81	4,371
8	Bhopal	23.3	77.4	503	5	May	26 4	16 1	16	0.09	3	10,890	1,369 0	68 93	4,818
9	Bikaner	28 0	73 3	224	7	Jun	36.7	22.4	16	0 12	4	14,520	2,974.2	112.33	10,469
20	Hyderabad	17.5	78.5	545	5	May	22.7	13 8	16	0 07	3	10,890	1,175.7	59.20	4,138
21	Indore	22.7	75.8	567	6	May	30.8	18.7	16	0 10	3	10,890	1,487.1	74 88	5,234
23	Jaipur	26.8	75 8	390	7	Jun	27.4	16 7	16	0.09	3	10,890	1,890 7	95 21	6,655
24	Jodhpur	26 3	73.0	224	7	Jun	35.1	21.3	16	0 12	4	14,520	2,796 0	105 59	9,841
26	Kota	25.2	75.5	257	7	May	31.3	19.0	16	0 10	3	10,890	2,064 0	103.93	7,265
29	Nagpur	21.2	79.1	311	5	May	24.8	15.1	16	0 08	3	10,890	1,096 3	55 21	3,859
30	New Dehli	28.6	77.2	216	5	Jun	24.2	14.7	16	0 08	3	10,890	1,480.7	74 56	5,212
35	Pune	18 5	73 9	563	6	May	26.3	16 0	16	0 09	3	10,890	1,397 6	70 38	4,919
AVERAGE							27.1	16 5	16	0 09	3 1	11,149	1,660 7	80 67	5 845

Hand Pump Sizing for Grapes, Drip Irrigation					1.0 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Hydraulic Power		Capital Cost of	Annual Pumping	Annual Run	Annual Operating
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No of Pumps Req'd	Pumps (Rs)	Req'ment (m3/yr)	Time (days)	Costs (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	49.7	30.3	16	0 16	5	18,150	2874.7	86 85	10,119
2	Ahmadabad	23.1	72 6	55	5	May	46.4	28.2	16	0 15	5	18,150	3188 7	96.34	11,224
3	Akola	20.7	77.0	282	5	May	47.8	29.1	16	0 16	5	18,150	2490 0	75 23	8,764
4	Allahabad	25 5	81.7	98	5	May	42.0	25.5	16	0.14	4	14,520	2483 9	93 81	8,743
8	Bhopal	23.3	77.4	503	5	May	52.8	32.1	16	0 17	5	18,150	2737.9	82.72	9,637
9	Bikaner	28 0	73.3	224	7	Jun	73.5	44 7	16	0.24	7	25,410	5948 4	128 37	20,937
20	Hyderabad	17.5	78 5	545	5	May	45 3	27.6	16	0.15	5	18,150	2351 4	71 04	8,276
21	Indore	22.7	75.8	567	6	May	61.6	37.5	16	0.20	6	21,780	2974 2	74 88	10,468
23	Jaipur	26.8	75.8	390	7	Jun	54 8	33 3	16	0.18	6	21,780	3781 4	95 21	13,310
24	Jodhpur	26 3	73 0	224	7	Jun	70 2	42.7	16	0.23	7	25,410	5592 0	120 68	19,683
26	Kota	25.2	75 5	257	7	May	62.6	38 1	16	0 21	6	21,780	4127.9	103 93	14,530
29	Nagpur	21.2	79 1	311	5	May	49 6	30.2	16	0 16	5	18,150	2192.7	66 25	7,718
30	New Dehli	28.6	77.2	216	5	Jun	48 4	29 5	16	0 16	5	18,150	2961.5	89 48	10,424
35	Pune	18 5	73 9	563	6	May	52.5	31.9	16	0 17	5	18,150	2795 3	84 45	9 839
AVERAGE							54.1	32.9	16	0 18	5 4	19,706	3,321 4	90 66	11 691

Hand Pump Sizing for Grapes, Drip Irrigation					1.5 ha Plot			Water Pumping	Assumed Pumping	Hydraulic Power		Capital Cost of	Annual Pumping	Annual Run	Annual Operating
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No of Pumps Req'd	Pumps (Rs)	Req'ment (m3/yr)	Time (days)	Costs (Rs/yr)
1	Agra	27.2	78 1	169	5	Jun	74 6	45.4	16	0.25	7	25,410	4312.1	93 06	15,178
2	Ahmadabad	23 1	72 6	55	5	Jun	69.7	42.4	16	0.23	7	25,410	4783 0	103 22	16,835
3	Akola	20.7	77.0	282	5	May	71.7	43.6	16	0.24	7	25,410	3735 0	80 60	13,146
4	Allahabad	25 5	81.7	98	5	Jun	63 0	38.3	16	0.21	6	21,780	3725 8	93 81	13,114
8	Bhopal	23 3	77.4	503	5	May	79.2	48.2	16	0 26	8	29,040	4106 9	77 55	14,455
9	Bikaner	28 0	73 3	224	7	Jun	110.2	67.1	16	0.36	11	39,930	8922.7	122 54	31,406
20	Hyderabad	17.5	78.5	545	5	May	68 0	41.4	16	0.22	7	25,410	3527.1	76.12	12,415
21	Indore	22.7	75.8	567	6	May	92.4	56.2	16	0 31	9	32,670	4461.2	74 88	15,703
23	Jaipur	26 8	75.8	390	7	Jun	82.2	50 0	16	0.27	8	29,040	5672.2	107.11	19,965
24	Jodhpur	26 3	73 0	224	7	Jun	105 3	64 0	16	0.35	10	36,300	8388 0	126 71	29.524
26	Kota	25 2	75 5	257	7	Jun	94 0	57.1	16	0.31	9	32,670	6191 9	103 93	21,794
29	Nagpur	21.2	79 1	311	5	May	74 5	45.3	16	0.25	7	25,410	3289 0	70 98	11,577
30	New Dehli	28 6	77.2	216	5	Jun	72.6	44 2	16	0.24	7	25,410	4442 2	95 87	15,636
35	Pune	18 5	73 9	563	6	May	78 8	47 9	16	0 26	8	29,040	4192 9	79 18	14 758
AVERAGE							81.2	49 4	16	0 27	7.9	28,781	4 982 1	93 25	17.536

Hand Pump Sizing for Grapes, Drip Irrigation					2.0 ha Plot			Water Pumping	Assumed Pumping	Hydraulic Power		Capital Cost of	Annual Pumping	Annual Run	Annual Operating
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No of Pumps Req'd	Pumps (Rs)	Req'ment (m3/yr)	Time (days)	Costs (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	99 5	60.5	16	0.33	10	36,300	5749 5	86 85	20,237
2	Ahmadabad	23.1	72.6	55	5	Jun	92.9	56.5	16	0.31	9	32,670	6377.4	107.04	22,447
3	Akola	20.7	77.0	282	5	May	95 6	58 1	16	0.32	9	32,670	4980 0	83 59	17,529
4	Allahabad	25 5	81.7	98	5	Jun	83.9	51.1	16	0 28	8	29,040	4967.7	93 81	17,485
8	Bhopal	23 3	77.4	503	5	May	105 6	64.2	16	0.35	10	36,300	5475 8	82.72	19,274
9	Bikaner	28 0	73 3	224	7	Jun	147.0	89 4	16	0.49	14	50,820	11896 9	128 37	41,875
20	Hyderabad	17.5	78.5	545	5	May	90.7	55.2	16	0.30	9	32,670	4702.8	78 94	16,553
21	Indore	22.7	75.8	567	6	May	123.2	74 9	16	0.41	12	43,560	5948 3	74 88	20,937
23	Jaipur	26 8	75 8	390	7	Jun	109 6	66 7	16	0.36	11	39,930	7562.9	103 86	26,620
24	Jodhpur	26 3	73.0	224	7	Jun	140.4	85 4	16	0.46	13	47,190	11184.1	129 96	39,366
26	Kota	25.2	75.5	257	7	Jun	125.3	76.2	16	0.41	12	43,560	8255.9	103 93	29,059
29	Nagpur	21.2	79.1	311	5	May	99.3	60 4	16	0.33	10	36,300	4385.3	66 25	15,435
30	New Dehli	28 6	77.2	216	5	Jun	96 9	58 9	16	0.32	9	32,670	5923 0	99 42	20,848
35	Pune	18 5	73.9	563	6	May	105 0	63 9	16	0.35	10	36,300	5590 5	84 45	19,678
AVERAGE							108 2	65 8	16	0 36	10 4	37,856	6.642 9	94 58	23.382

Hand Pump Sizing for Grapes, Surface Irrigation					0.5 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Hydraulic Power		Capital Cost of	Annual Pumping	Annual Run	Annual Operating
Stn# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Pumps (Rs)	Req'ment (m3/yr)	Time (days)	Costs (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	24.9	41.4	2	0.03	1	3,630	1,437.4	27.14	632
2	Ahmadabad	23.1	72.6	55	5	May	23.2	38.7	2	0.03	1	3,630	1,594.3	30.11	701
3	Akola	20.7	77.0	282	5	May	23.9	39.8	2	0.03	1	3,630	1,245.0	23.51	548
4	Allahabad	25.5	81.7	98	5	May	21.0	35.0	2	0.02	1	3,630	1,241.9	23.45	546
8	Bhopal	23.3	77.4	503	5	May	26.4	44.0	2	0.03	1	3,630	1,369.0	25.85	602
9	Bikaner	28.0	73.3	224	7	Jun	36.7	61.2	2	0.04	2	7,260	2,974.2	28.08	1,309
20	Hyderabad	17.5	78.5	545	5	May	22.7	37.8	2	0.03	1	3,630	1,175.7	22.20	517
21	Indore	22.7	75.8	567	6	May	30.8	51.3	2	0.03	1	3,630	1,487.1	28.08	654
23	Jaipur	26.8	75.8	390	7	Jun	27.4	45.7	2	0.03	1	3,630	1,890.7	35.70	832
24	Jodhpur	26.3	73.0	224	7	Jun	35.1	58.5	2	0.04	2	7,260	2,796.0	26.40	1,230
26	Kota	25.2	75.5	257	7	May	31.3	52.2	2	0.04	1	3,630	2,064.0	38.97	908
29	Nagpur	21.2	79.1	311	5	May	24.8	41.4	2	0.03	1	3,630	1,096.3	20.70	482
30	New Dehli	28.6	77.2	216	5	Jun	24.2	40.4	2	0.03	1	3,630	1,480.7	27.96	651
35	Pune	18.5	73.9	563	6	May	26.3	43.8	2	0.03	1	3,630	1,397.6	26.39	615
AVERAGE							27.1	45.1	2	0.03	1.1	4,149	1,660.7	27.47	731

Hand Pump Sizing for Grapes, Surface Irrigation					1.0 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Hydraulic Power		Capital Cost of	Annual Pumping	Annual Run	Annual Operating
Stn# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Pumps (Rs)	Req'ment (m3/yr)	Time (days)	Costs (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	49.7	82.9	2	0.06	2	7,260	2874.7	27.14	1,265
2	Ahmadabad	23.1	72.6	55	5	May	46.4	77.4	2	0.05	2	7,260	3188.7	30.11	1,403
3	Akola	20.7	77.0	282	5	May	47.8	79.6	2	0.05	2	7,260	2490.0	23.51	1,096
4	Allahabad	25.5	81.7	98	5	May	42.0	70.0	2	0.05	2	7,260	2483.9	23.45	1,093
8	Bhopal	23.3	77.4	503	5	May	52.8	88.0	2	0.06	2	7,260	2737.9	25.85	1,205
9	Bikaner	28.0	73.3	224	7	Jun	73.5	122.5	2	0.08	3	10,890	5948.4	37.44	2,617
20	Hyderabad	17.5	78.5	545	5	May	45.3	75.6	2	0.05	2	7,260	2351.4	22.20	1,035
21	Indore	22.7	75.8	567	6	May	61.6	102.7	2	0.07	2	7,260	2974.2	28.08	1,309
23	Jaipur	26.8	75.8	390	7	Jun	54.8	91.4	2	0.06	2	7,260	3781.4	35.70	1,664
24	Jodhpur	26.3	73.0	224	7	Jun	70.2	117.0	2	0.08	3	10,890	5592.0	35.20	2,460
26	Kota	25.2	75.5	257	7	May	62.6	104.4	2	0.07	2	7,260	4127.9	38.97	1,816
29	Nagpur	21.2	79.1	311	5	May	49.6	82.7	2	0.06	2	7,260	2192.7	20.70	965
30	New Dehli	28.6	77.2	216	5	Jun	48.4	80.7	2	0.05	2	7,260	2961.5	27.96	1,303
35	Pune	18.5	73.9	563	6	May	52.5	87.5	2	0.06	2	7,260	2795.3	26.39	1,230
AVERAGE							54.1	90.2	2	0.06	2.1	7,779	3,321.4	28.77	1,461

Hand Pump Sizing for Grapes, Surface Irrigation					1.5 ha Plot			Water Pumping	Assumed Pumping	Hydraulic Power		Capital Cost of	Annual Pumping	Annual Run	Annual Operating
Stn# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Pumps (Rs)	Req'ment (m3/yr)	Time (days)	Costs (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	74.6	124.3	2	0.08	3	10,890	4312.1	27.14	1,897
2	Ahmadabad	23.1	72.6	55	5	Jun	69.7	116.1	2	0.08	3	10,890	4783.0	30.11	2,104
3	Akola	20.7	77.0	282	5	May	71.7	119.5	2	0.08	3	10,890	3735.0	23.51	1,643
4	Allahabad	25.5	81.7	98	5	Jun	63.0	104.9	2	0.07	2	7,260	3725.8	35.18	1,639
8	Bhopal	23.3	77.4	503	5	May	79.2	132.0	2	0.09	3	10,890	4106.9	25.85	1,807
9	Bikaner	28.0	73.3	224	7	Jun	110.2	183.7	2	0.12	4	14,520	8922.7	42.12	3,926
20	Hyderabad	17.5	78.5	545	5	May	68.0	113.4	2	0.08	3	10,890	3527.1	22.20	1,552
21	Indore	22.7	75.8	567	6	May	92.4	154.0	2	0.10	3	10,890	4461.2	28.08	1,963
23	Jaipur	26.8	75.8	390	7	Jun	82.2	137.0	2	0.09	3	10,890	5672.2	35.70	2,496
24	Jodhpur	26.3	73.0	224	7	Jun	105.3	175.4	2	0.12	4	14,520	8388.0	39.60	3,691
26	Kota	25.2	75.5	257	7	Jun	94.0	156.6	2	0.11	3	10,890	6191.9	38.97	2,724
29	Nagpur	21.2	79.1	311	5	May	74.5	124.1	2	0.08	3	10,890	3289.0	20.70	1,447
30	New Dehli	28.6	77.2	216	5	Jun	72.6	121.1	2	0.08	3	10,890	4442.2	27.96	1,954
35	Pune	18.5	73.9	563	6	May	78.8	131.3	2	0.09	3	10,890	4192.9	26.39	1,845
AVERAGE							81.2	135.3	2	0.09	3.1	11,149	4,982.1	30.25	2,192

Hand Pump Sizing for Grapes, Surface Irrigation					2.0 ha Plot			Water Pumping	Assumed Pumping	Hydraulic Power		Capital Cost of	Annual Pumping	Annual Run	Annual Operating
Stn# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Pumps (Rs)	Req'ment (m3/yr)	Time (days)	Costs (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	99.5	165.8	2	0.11	4	14,520	5749.5	27.14	2,530
2	Ahmadabad	23.1	72.6	55	5	Jun	92.9	154.8	2	0.11	3	10,890	6377.4	40.14	2,806
3	Akola	20.7	77.0	282	5	May	95.6	159.3	2	0.11	3	10,890	4980.0	31.35	2,191
4	Allahabad	25.5	81.7	98	5	Jun	83.9	139.9	2	0.10	3	10,890	4967.7	31.27	2,186
8	Bhopal	23.3	77.4	503	5	May	105.6	176.0	2	0.12	4	14,520	5475.8	25.85	2,409
9	Bikaner	28.0	73.3	224	7	Jun	147.0	245.0	2	0.17	5	18,150	11896.9	44.93	5,234
20	Hyderabad	17.5	78.5	545	5	May	90.7	151.1	2	0.10	3	10,890	4702.8	29.60	2,069
21	Indore	22.7	75.8	567	6	May	123.2	205.4	2	0.14	4	14,520	5948.3	28.08	2,617
23	Jaipur	26.8	75.8	390	7	Jun	109.6	182.7	2	0.12	4	14,520	7562.9	35.70	3,327
24	Jodhpur	26.3	73.0	224	7	Jun	140.4	233.9	2	0.16	5	18,150	11184.1	42.24	4,921
26	Kota	25.2	75.5	257	7	Jun	125.3	208.8	2	0.14	4	14,520	8255.9	38.97	3,632
29	Nagpur	21.2	79.1	311	5	May	99.3	165.5	2	0.11	4	14,520	4385.3	20.70	1,929
30	New Dehli	28.6	77.2	216	5	Jun	96.9	161.4	2	0.11	4	14,520	5923.0	27.96	2,606
35	Pune	18.5	73.9	563	6	May	105.0	175.0	2	0.12	4	14,520	5590.5	26.39	2,460
AVERAGE							108.2	180.3	2	0.12	3.9	14,001	6,642.9	32.17	2,923

Animal Pump Sizing for a 1.0 ha Grape Farm

Assumptions: Drip Irrigation		
Surface Water Source		
Drip Irrigation		
Water Savings	0.48	
EAdrip	0.95	
EUdrip	0.9	
Max Run Time per Day, Td =	8	hrs
Specific Weight of Water, Y =	9.789	kN/m3
Hydraulic Power/Pump, Php =	0.210	kW
Cost/Pump, Cd =	16,875	Rs/Pump
Cost/Animal, A =	5,000	Rs/beast
No. of Animals per Pump, n =	4	
Cost of Fodder, F =	8,300	Rs/yr

Assumptions: Surface Irrigation	
Surface Water Source	
Surface Irrigation	
EAsurface	0.6

Animal Pump Sizing, Grapes, Drip Irrigation					0.5 ha Plot		Crop Water Required (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Hydraulic Power Req'd (kW)	No. of Pumps Req'd	Capital Cost of Pumps (Rs)	*Capital Cost of Animals (Rs)	*Annual Cost of Fodder (Rs/yr)
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month								
1	Agra	27.2	78.1	169	5	Jun	24.9	15.1	16	0.08	1	16,875	0	0
2	Ahmadabad	23.1	72.6	55	5	May	23.2	14.1	16	0.08	1	16,875	0	0
3	Akola	20.7	77.0	282	5	May	23.9	14.5	16	0.08	1	16,875	0	0
4	Allahabad	25.5	81.7	98	5	May	21.0	12.8	16	0.07	1	16,875	0	0
8	Bhopal	23.3	77.4	503	5	May	26.4	16.1	16	0.09	1	16,875	0	0
9	Bikaner	28.0	73.3	224	7	Jun	36.7	22.4	16	0.12	1	16,875	0	0
20	Hyderabad	17.5	78.5	545	5	May	22.7	13.8	16	0.07	1	16,875	0	0
21	Indore	22.7	75.8	567	6	May	30.8	18.7	16	0.10	1	16,875	0	0
23	Jaipur	26.8	75.8	390	7	Jun	27.4	16.7	16	0.09	1	16,875	0	0
24	Jodhpur	26.3	73.0	224	7	Jun	35.1	21.3	16	0.12	1	16,875	0	0
26	Kota	25.2	75.5	257	7	May	31.3	19.0	16	0.10	1	16,875	0	0
29	Nagpur	21.2	79.1	311	5	May	24.8	15.1	16	0.08	1	16,875	0	0
30	New Dehli	28.6	77.2	216	5	Jun	24.2	14.7	16	0.08	1	16,875	0	0
35	Pune	18.5	73.9	563	6	May	26.3	16.0	16	0.09	1	16,875	0	0
AVERAGE							27.1	16.5	16	0.09	1.0	16,875	0	0

Animal Pump Sizing, Grapes, Drip Irrigation					1.0 ha Plot		Crop Water Required (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Hydraulic Power Req'd (kW)	No. of Pumps Req'd	Capital Cost of Pumps (Rs)	*Capital Cost of Animals (Rs)	*Annual Cost of Fodder (Rs/yr)
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month								
1	Agra	27.2	78.1	169	5	Jun	49.7	30.3	16	0.16	1	16,875	0	0
2	Ahmadabad	23.1	72.6	55	5	May	46.4	28.2	16	0.15	1	16,875	0	0
3	Akola	20.7	77.0	282	5	May	47.8	29.1	16	0.16	1	16,875	0	0
4	Allahabad	25.5	81.7	98	5	May	42.0	25.5	16	0.14	1	16,875	0	0
8	Bhopal	23.3	77.4	503	5	May	52.8	32.1	16	0.17	1	16,875	0	0
9	Bikaner	28.0	73.3	224	7	Jun	73.5	44.7	16	0.24	2	33,750	20,000	33,200
20	Hyderabad	17.5	78.5	545	5	May	45.3	27.6	16	0.15	1	16,875	0	0
21	Indore	22.7	75.8	567	6	May	61.6	37.5	16	0.20	1	16,875	0	0
23	Jaipur	26.8	75.8	390	7	Jun	54.8	33.3	16	0.18	1	16,875	0	0
24	Jodhpur	26.3	73.0	224	7	Jun	70.2	42.7	16	0.23	2	33,750	20,000	33,200
26	Kota	25.2	75.5	257	7	May	62.6	38.1	16	0.21	1	16,875	0	0
29	Nagpur	21.2	79.1	311	5	May	49.6	30.2	16	0.16	1	16,875	0	0
30	New Dehli	28.6	77.2	216	5	Jun	48.4	29.5	16	0.16	1	16,875	0	0
35	Pune	18.5	73.9	563	6	May	52.5	31.9	16	0.17	1	16,875	0	0
AVERAGE							54.1	32.9	16	0.18	1.1	19,286	2,857	4,743

Animal Pump Sizing, Grapes, Drip Irrigation					1.5 ha Plot			Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Hydraulic Power Req'd (kW)	No. of Pumps Req'd	Capital Cost of Pumps (Rs)	*Capital Cost of Animals (Rs)	*Annual Cost of Fodder (Rs/yr)
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)							
1	Agra	27.2	78.1	169	5	Jun	74.6	45.4	16	0.25	2	33,750	20,000	33,200
2	Ahmadabad	23.1	72.6	55	5	Jun	69.7	42.4	16	0.23	2	33,750	20,000	33,200
3	Akola	20.7	77.0	282	5	May	71.7	43.6	16	0.24	2	33,750	20,000	33,200
4	Allahabad	25.5	81.7	98	5	Jun	63.0	38.3	16	0.21	1	16,875	0	0
8	Bhopal	23.3	77.4	503	5	May	79.2	48.2	16	0.26	2	33,750	20,000	33,200
9	Bikaner	28.0	73.3	224	7	Jun	110.2	67.1	16	0.36	2	33,750	20,000	33,200
20	Hyderabad	17.5	78.5	545	5	May	68.0	41.4	16	0.22	2	33,750	20,000	33,200
21	Indore	22.7	75.8	567	6	May	92.4	56.2	16	0.31	2	33,750	20,000	33,200
23	Jaipur	26.8	75.8	390	7	Jun	82.2	50.0	16	0.27	2	33,750	20,000	33,200
24	Jodhpur	26.3	73.0	224	7	Jun	105.3	64.0	16	0.35	2	33,750	20,000	33,200
26	Kota	25.2	75.5	257	7	Jun	94.0	57.1	16	0.31	2	33,750	20,000	33,200
29	Nagpur	21.2	79.1	311	5	May	74.5	45.3	16	0.25	2	33,750	20,000	33,200
30	New Dehli	28.6	77.2	216	5	Jun	72.6	44.2	16	0.24	2	33,750	20,000	33,200
35	Pune	18.5	73.9	563	6	May	78.8	47.9	16	0.26	2	33,750	20,000	33,200
AVERAGE							81.2	49.4	16	0.27	1.9	32,545	18,571	30,829

Animal Pump Sizing, Grapes, Drip Irrigation					2.0 ha Plot			Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Hydraulic Power Req'd (kW)	No. of Pumps Req'd	Capital Cost of Pumps (Rs)	*Capital Cost of Animals (Rs)	*Annual Cost of Fodder (Rs/yr)
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)							
1	Agra	27.2	78.1	169	5	Jun	99.5	60.5	16	0.33	2	33,750	20,000	33,200
2	Ahmadabad	23.1	72.6	55	5	Jun	92.9	56.5	16	0.31	2	33,750	20,000	33,200
3	Akola	20.7	77.0	282	5	May	95.6	58.1	16	0.32	2	33,750	20,000	33,200
4	Allahabad	25.5	81.7	98	5	Jun	83.9	51.1	16	0.28	2	33,750	20,000	33,200
8	Bhopal	23.3	77.4	503	5	May	105.6	64.2	16	0.35	2	33,750	20,000	33,200
9	Bikaner	28.0	73.3	224	7	Jun	147.0	89.4	16	0.49	3	50,625	40,000	66,400
20	Hyderabad	17.5	78.5	545	5	May	90.7	55.2	16	0.30	2	33,750	20,000	33,200
21	Indore	22.7	75.8	567	6	May	123.2	74.9	16	0.41	2	33,750	20,000	33,200
23	Jaipur	26.8	75.8	390	7	Jun	109.6	66.7	16	0.36	2	33,750	20,000	33,200
24	Jodhpur	26.3	73.0	224	7	Jun	140.4	85.4	16	0.46	3	50,625	40,000	66,400
26	Kota	25.2	75.5	257	7	Jun	125.3	76.2	16	0.41	2	33,750	20,000	33,200
29	Nagpur	21.2	79.1	311	5	May	99.3	60.4	16	0.33	2	33,750	20,000	33,200
30	New Dehli	28.6	77.2	216	5	Jun	96.9	58.9	16	0.32	2	33,750	20,000	33,200
35	Pune	18.5	73.9	563	6	May	105.0	63.9	16	0.35	2	33,750	20,000	33,200
AVERAGE							108.2	65.8	16	0.36	2.1	36,161	22,857	37,943

*Assumes Farmer Already Owns and Feeds 4 Animals

Animal Pump Sizing, Grapes, Drip Irrigation					0.5 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Hydraulic Power		Capital	*Capital	*Annual
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Cost of Pumps (Rs)	Cost of Animals (Rs)	Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	24.9	15.1	16	0.08	1	16,875	20,000	33,200
2	Ahmadabad	23.1	72.6	55	5	May	23.2	14.1	16	0.08	1	16,875	20,000	33,200
3	Akola	20.7	77.0	282	5	May	23.9	14.5	16	0.08	1	16,875	20,000	33,200
4	Allahabad	25.5	81.7	98	5	May	21.0	12.8	16	0.07	1	16,875	20,000	33,200
8	Bhopal	23.3	77.4	503	5	May	26.4	16.1	16	0.09	1	16,875	20,000	33,200
9	Bikaner	28.0	73.3	224	7	Jun	36.7	22.4	16	0.12	1	16,875	20,000	33,200
20	Hyderabad	17.5	78.5	545	5	May	22.7	13.8	16	0.07	1	16,875	20,000	33,200
21	Indore	22.7	75.8	567	6	May	30.8	18.7	16	0.10	1	16,875	20,000	33,200
23	Jaipur	26.8	75.8	390	7	Jun	27.4	16.7	16	0.09	1	16,875	20,000	33,200
24	Jodhpur	26.3	73.0	224	7	Jun	35.1	21.3	16	0.12	1	16,875	20,000	33,200
26	Kota	25.2	75.5	257	7	May	31.3	19.0	16	0.10	1	16,875	20,000	33,200
29	Nagpur	21.2	79.1	311	5	May	24.8	15.1	16	0.08	1	16,875	20,000	33,200
30	New Dehli	28.6	77.2	216	5	Jun	24.2	14.7	16	0.08	1	16,875	20,000	33,200
35	Pune	18.5	73.9	563	6	May	26.3	16.0	16	0.09	1	16,875	20,000	33,200
AVERAGE							27.1	16.5	16	0.09	1.0	16,875	20,000	33,200

Animal Pump Sizing, Grapes, Drip Irrigation					1.0 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Hydraulic Power		Capital	*Capital	*Annual
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Cost of Pumps (Rs)	Cost of Animals (Rs)	Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	49.7	30.3	16	0.16	1	16,875	20,000	33,200
2	Ahmadabad	23.1	72.6	55	5	May	46.4	28.2	16	0.15	1	16,875	20,000	33,200
3	Akola	20.7	77.0	282	5	May	47.8	29.1	16	0.16	1	16,875	20,000	33,200
4	Allahabad	25.5	81.7	98	5	May	42.0	25.5	16	0.14	1	16,875	20,000	33,200
8	Bhopal	23.3	77.4	503	5	May	52.8	32.1	16	0.17	1	16,875	20,000	33,200
9	Bikaner	28.0	73.3	224	7	Jun	73.5	44.7	16	0.24	2	33,750	40,000	66,400
20	Hyderabad	17.5	78.5	545	5	May	45.3	27.6	16	0.15	1	16,875	20,000	33,200
21	Indore	22.7	75.8	567	6	May	61.6	37.5	16	0.20	1	16,875	20,000	33,200
23	Jaipur	26.8	75.8	390	7	Jun	54.8	33.3	16	0.18	1	16,875	20,000	33,200
24	Jodhpur	26.3	73.0	224	7	Jun	70.2	42.7	16	0.23	2	33,750	40,000	66,400
26	Kota	25.2	75.5	257	7	May	62.6	38.1	16	0.21	1	16,875	20,000	33,200
29	Nagpur	21.2	79.1	311	5	May	49.6	30.2	16	0.16	1	16,875	20,000	33,200
30	New Dehli	28.6	77.2	216	5	Jun	48.4	29.5	16	0.16	1	16,875	20,000	33,200
35	Pune	18.5	73.9	563	6	May	52.5	31.9	16	0.17	1	16,875	20,000	33,200
AVERAGE							54.1	32.9	16	0.18	1.1	19,286	22,857	37,943

Animal Pump Sizing, Grapes, Drip Irrigation					1.5 ha Plot			Water Pumping	Assumed Pumping	Hydraulic Power		Capital	*Capital	*Annual
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Cost of Pumps (Rs)	Cost of Animals (Rs)	Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	74.6	45.4	16	0.25	2	33,750	40,000	66,400
2	Ahmadabad	23.1	72.6	55	5	Jun	69.7	42.4	16	0.23	2	33,750	40,000	66,400
3	Akola	20.7	77.0	282	5	May	71.7	43.6	16	0.24	2	33,750	40,000	66,400
4	Allahabad	25.5	81.7	98	5	Jun	63.0	38.3	16	0.21	1	16,875	20,000	33,200
8	Bhopal	23.3	77.4	503	5	May	79.2	48.2	16	0.26	2	33,750	40,000	66,400
9	Bikaner	28.0	73.3	224	7	Jun	110.2	67.1	16	0.36	2	33,750	40,000	66,400
20	Hyderabad	17.5	78.5	545	5	May	68.0	41.4	16	0.22	2	33,750	40,000	66,400
21	Indore	22.7	75.8	567	6	May	92.4	56.2	16	0.31	2	33,750	40,000	66,400
23	Jaipur	26.8	75.8	390	7	Jun	82.2	50.0	16	0.27	2	33,750	40,000	66,400
24	Jodhpur	26.3	73.0	224	7	Jun	105.3	64.0	16	0.35	2	33,750	40,000	66,400
26	Kota	25.2	75.5	257	7	Jun	94.0	57.1	16	0.31	2	33,750	40,000	66,400
29	Nagpur	21.2	79.1	311	5	May	74.5	45.3	16	0.25	2	33,750	40,000	66,400
30	New Dehli	28.6	77.2	216	5	Jun	72.6	44.2	16	0.24	2	33,750	40,000	66,400
35	Pune	18.5	73.9	563	6	May	78.8	47.9	16	0.26	2	33,750	40,000	66,400
AVERAGE							81.2	49.4	16	0.27	1.9	32,545	38,571	64,029

Animal Pump Sizing, Grapes, Drip Irrigation					2.0 ha Plot			Water Pumping	Assumed Pumping	Hydraulic Power		Capital	*Capital	*Annual
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Cost of Pumps (Rs)	Cost of Animals (Rs)	Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	99.5	60.5	16	0.33	2	33,750	40,000	66,400
2	Ahmadabad	23.1	72.6	55	5	Jun	92.9	56.5	16	0.31	2	33,750	40,000	66,400
3	Akola	20.7	77.0	282	5	May	95.6	58.1	16	0.32	2	33,750	40,000	66,400
4	Allahabad	25.5	81.7	98	5	Jun	83.9	51.1	16	0.28	2	33,750	40,000	66,400
8	Bhopal	23.3	77.4	503	5	May	105.6	64.2	16	0.35	2	33,750	40,000	66,400
9	Bikaner	28.0	73.3	224	7	Jun	147.0	89.4	16	0.49	3	50,625	60,000	99,600
20	Hyderabad	17.5	78.5	545	5	May	90.7	55.2	16	0.30	2	33,750	40,000	66,400
21	Indore	22.7	75.8	567	6	May	123.2	74.9	16	0.41	2	33,750	40,000	66,400
23	Jaipur	26.8	75.8	390	7	Jun	109.6	66.7	16	0.36	2	33,750	40,000	66,400
24	Jodhpur	26.3	73.0	224	7	Jun	140.4	85.4	16	0.46	3	50,625	60,000	99,600
26	Kota	25.2	75.5	257	7	Jun	125.3	76.2	16	0.41	2	33,750	40,000	66,400
29	Nagpur	21.2	79.1	311	5	May	99.3	60.4	16	0.33	2	33,750	40,000	66,400
30	New Dehli	28.6	77.2	216	5	Jun	96.9	58.9	16	0.32	2	33,750	40,000	66,400
35	Pune	18.5	73.9	563	6	May	105.0	63.9	16	0.35	2	33,750	40,000	66,400
AVERAGE							108.2	65.8	16	0.36	2.1	36,161	42,857	71,143

*Includes the Cost of Purchasing and Feeding Animals

Animal Pump Sizing, Grapes, Surface Irrigation					0.5 ha Plot									
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Crop Water Required (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Hydraulic Power Req'd (kW)	No. of Pumps Req'd	Capital Cost of Pumps (Rs)	*Capital Cost of Animals (Rs)	*Annual Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	24.9	41.4	2	0.03	1	16,875	0	0
2	Ahmadabad	23.1	72.6	55	5	May	23.2	38.7	2	0.03	1	16,875	0	0
3	Akola	20.7	77.0	282	5	May	23.9	39.8	2	0.03	1	16,875	0	0
4	Allahabad	25.5	81.7	98	5	May	21.0	35.0	2	0.02	1	16,875	0	0
8	Bhopal	23.3	77.4	503	5	May	26.4	44.0	2	0.03	1	16,875	0	0
9	Bikaner	28.0	73.3	224	7	Jun	36.7	61.2	2	0.04	1	16,875	0	0
20	Hyderabad	17.5	78.5	545	5	May	22.7	37.8	2	0.03	1	16,875	0	0
21	Indore	22.7	75.8	567	6	May	30.8	51.3	2	0.03	1	16,875	0	0
23	Jaipur	26.8	75.8	390	7	Jun	27.4	45.7	2	0.03	1	16,875	0	0
24	Jodhpur	26.3	73.0	224	7	Jun	35.1	58.5	2	0.04	1	16,875	0	0
26	Kota	25.2	75.5	257	7	May	31.3	52.2	2	0.04	1	16,875	0	0
29	Nagpur	21.2	79.1	311	5	May	24.8	41.4	2	0.03	1	16,875	0	0
30	New Dehli	28.6	77.2	216	5	Jun	24.2	40.4	2	0.03	1	16,875	0	0
35	Pune	18.5	73.9	563	6	May	26.3	43.8	2	0.03	1	16,875	0	0
AVERAGE							27.1	45.1	2	0.03	1.0	16,875	0	0

Animal Pump Sizing, Grapes, Surface Irrigation					1.0 ha Plot									
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Crop Water Required (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Hydraulic Power Req'd (kW)	No. of Pumps Req'd	Capital Cost of Pumps (Rs)	*Capital Cost of Animals (Rs)	*Annual Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	49.7	82.9	2	0.06	1	16,875	0	0
2	Ahmadabad	23.1	72.6	55	5	May	46.4	77.4	2	0.05	1	16,875	0	0
3	Akola	20.7	77.0	282	5	May	47.8	79.6	2	0.05	1	16,875	0	0
4	Allahabad	25.5	81.7	98	5	May	42.0	70.0	2	0.05	1	16,875	0	0
8	Bhopal	23.3	77.4	503	5	May	52.8	88.0	2	0.06	1	16,875	0	0
9	Bikaner	28.0	73.3	224	7	Jun	73.5	122.5	2	0.08	1	16,875	0	0
20	Hyderabad	17.5	78.5	545	5	May	45.3	75.6	2	0.05	1	16,875	0	0
21	Indore	22.7	75.8	567	6	May	61.6	102.7	2	0.07	1	16,875	0	0
23	Jaipur	26.8	75.8	390	7	Jun	54.8	91.4	2	0.06	1	16,875	0	0
24	Jodhpur	26.3	73.0	224	7	Jun	70.2	117.0	2	0.08	1	16,875	0	0
26	Kota	25.2	75.5	257	7	May	62.6	104.4	2	0.07	1	16,875	0	0
29	Nagpur	21.2	79.1	311	5	May	49.6	82.7	2	0.06	1	16,875	0	0
30	New Dehli	28.6	77.2	216	5	Jun	48.4	80.7	2	0.05	1	16,875	0	0
35	Pune	18.5	73.9	563	6	May	52.5	87.5	2	0.06	1	16,875	0	0
AVERAGE							54.1	90.2	2	0.06	1.0	16,875	0	0

Animal Pump Sizing, Grapes, Surface Irrigation					1.5 ha Plot									
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Hydraulic Power Req'd (kW)	No. of Pumps Req'd	Capital Cost of Pumps (Rs)	*Capital Cost of Animals (Rs)	*Annual Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	74.6	124.3	2	0.08	1	16,875	0	0
2	Ahmadabad	23.1	72.6	55	5	Jun	69.7	116.1	2	0.08	1	16,875	0	0
3	Akola	20.7	77.0	282	5	May	71.7	119.5	2	0.08	1	16,875	0	0
4	Allahabad	25.5	81.7	98	5	Jun	63.0	104.9	2	0.07	1	16,875	0	0
8	Bhopal	23.3	77.4	503	5	May	79.2	132.0	2	0.09	1	16,875	0	0
9	Bikaner	28.0	73.3	224	7	Jun	110.2	183.7	2	0.12	1	16,875	0	0
20	Hyderabad	17.5	78.5	545	5	May	68.0	113.4	2	0.08	1	16,875	0	0
21	Indore	22.7	75.8	567	6	May	92.4	154.0	2	0.10	1	16,875	0	0
23	Jaipur	26.8	75.8	390	7	Jun	82.2	137.0	2	0.09	1	16,875	0	0
24	Jodhpur	26.3	73.0	224	7	Jun	105.3	175.4	2	0.12	1	16,875	0	0
26	Kota	25.2	75.5	257	7	Jun	94.0	156.6	2	0.11	1	16,875	0	0
29	Nagpur	21.2	79.1	311	5	May	74.5	124.1	2	0.08	1	16,875	0	0
30	New Dehli	28.6	77.2	216	5	Jun	72.6	121.1	2	0.08	1	16,875	0	0
35	Pune	18.5	73.9	563	6	May	78.8	131.3	2	0.09	1	16,875	0	0
AVERAGE							81.2	135.3	2	0.09	1.0	16,875	0	0

Animal Pump Sizing, Grapes, Surface Irrigation					2.0 ha Plot									
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Water Pumping Req'ment (m3/day)	Assumed Pumping Head (m)	Hydraulic Power Req'd (kW)	No. of Pumps Req'd	Capital Cost of Pumps (Rs)	*Capital Cost of Animals (Rs)	*Annual Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	99.5	165.8	2	0.11	1	16,875	0	0
2	Ahmadabad	23.1	72.6	55	5	Jun	92.9	154.8	2	0.11	1	16,875	0	0
3	Akola	20.7	77.0	282	5	May	95.6	159.3	2	0.11	1	16,875	0	0
4	Allahabad	25.5	81.7	98	5	Jun	83.9	139.9	2	0.10	1	16,875	0	0
8	Bhopal	23.3	77.4	503	5	May	105.6	176.0	2	0.12	1	16,875	0	0
9	Bikaner	28.0	73.3	224	7	Jun	147.0	245.0	2	0.17	1	16,875	0	0
20	Hyderabad	17.5	78.5	545	5	May	90.7	151.1	2	0.10	1	16,875	0	0
21	Indore	22.7	75.8	567	6	May	123.2	205.4	2	0.14	1	16,875	0	0
23	Jaipur	26.8	75.8	390	7	Jun	109.6	182.7	2	0.12	1	16,875	0	0
24	Jodhpur	26.3	73.0	224	7	Jun	140.4	233.9	2	0.16	1	16,875	0	0
26	Kota	25.2	75.5	257	7	Jun	125.3	208.8	2	0.14	1	16,875	0	0
29	Nagpur	21.2	79.1	311	5	May	99.3	165.5	2	0.11	1	16,875	0	0
30	New Dehli	28.6	77.2	216	5	Jun	96.9	161.4	2	0.11	1	16,875	0	0
35	Pune	18.5	73.9	563	6	May	105.0	175.0	2	0.12	1	16,875	0	0
AVERAGE							108.2	180.3	2	0.12	1.0	16,875	0	0

*Assumes Farmer Already Owns and Feeds 4 Animals

Animal Pump Sizing, Grapes, Surface Irrigation					0.5 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Hydraulic Power		Capital	*Capital	*Annual
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Cost of Pumps (Rs)	Cost of Animals (Rs)	Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	24.9	41.4	2	0.03	1	16,875	20,000	33,200
2	Ahmadabad	23.1	72.6	55	5	May	23.2	38.7	2	0.03	1	16,875	20,000	33,200
3	Akola	20.7	77.0	282	5	May	23.9	39.8	2	0.03	1	16,875	20,000	33,200
4	Allahabad	25.5	81.7	98	5	May	21.0	35.0	2	0.02	1	16,875	20,000	33,200
8	Bhopal	23.3	77.4	503	5	May	26.4	44.0	2	0.03	1	16,875	20,000	33,200
9	Bikaner	28.0	73.3	224	7	Jun	36.7	61.2	2	0.04	1	16,875	20,000	33,200
20	Hyderabad	17.5	78.5	545	5	May	22.7	37.8	2	0.03	1	16,875	20,000	33,200
21	Indore	22.7	75.8	567	6	May	30.8	51.3	2	0.03	1	16,875	20,000	33,200
23	Jaipur	26.8	75.8	390	7	Jun	27.4	45.7	2	0.03	1	16,875	20,000	33,200
24	Jodhpur	26.3	73.0	224	7	Jun	35.1	58.5	2	0.04	1	16,875	20,000	33,200
26	Kota	25.2	75.5	257	7	May	31.3	52.2	2	0.04	1	16,875	20,000	33,200
29	Nagpur	21.2	79.1	311	5	May	24.8	41.4	2	0.03	1	16,875	20,000	33,200
30	New Dehli	28.6	77.2	216	5	Jun	24.2	40.4	2	0.03	1	16,875	20,000	33,200
35	Pune	18.5	73.9	563	6	May	26.3	43.8	2	0.03	1	16,875	20,000	33,200
AVERAGE							27.1	45.1	2	0.03	1.0	16,875	20,000	33,200

Animal Pump Sizing, Grapes, Surface Irrigation					1.0 ha Plot		Crop Water	Water Pumping	Assumed Pumping	Hydraulic Power		Capital	*Capital	*Annual
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Required (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Cost of Pumps (Rs)	Cost of Animals (Rs)	Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	49.7	82.9	2	0.06	1	16,875	20,000	33,200
2	Ahmadabad	23.1	72.6	55	5	May	46.4	77.4	2	0.05	1	16,875	20,000	33,200
3	Akola	20.7	77.0	282	5	May	47.8	79.6	2	0.05	1	16,875	20,000	33,200
4	Allahabad	25.5	81.7	98	5	May	42.0	70.0	2	0.05	1	16,875	20,000	33,200
8	Bhopal	23.3	77.4	503	5	May	52.8	88.0	2	0.06	1	16,875	20,000	33,200
9	Bikaner	28.0	73.3	224	7	Jun	73.5	122.5	2	0.08	1	16,875	20,000	33,200
20	Hyderabad	17.5	78.5	545	5	May	45.3	75.6	2	0.05	1	16,875	20,000	33,200
21	Indore	22.7	75.8	567	6	May	61.6	102.7	2	0.07	1	16,875	20,000	33,200
23	Jaipur	26.8	75.8	390	7	Jun	54.8	91.4	2	0.06	1	16,875	20,000	33,200
24	Jodhpur	26.3	73.0	224	7	Jun	70.2	117.0	2	0.08	1	16,875	20,000	33,200
26	Kota	25.2	75.5	257	7	May	62.6	104.4	2	0.07	1	16,875	20,000	33,200
29	Nagpur	21.2	79.1	311	5	May	49.6	82.7	2	0.06	1	16,875	20,000	33,200
30	New Dehli	28.6	77.2	216	5	Jun	48.4	80.7	2	0.05	1	16,875	20,000	33,200
35	Pune	18.5	73.9	563	6	May	52.5	87.5	2	0.06	1	16,875	20,000	33,200
AVERAGE							54.1	90.2	2	0.06	1.0	16,875	20,000	33,200

Animal Pump Sizing, Grapes, Surface Irrigation					1.5 ha Plot			Water Pumping	Assumed Pumping	Hydraulic Power		Capital	*Capital	*Annual
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Cost of Pumps (Rs)	Cost of Animals (Rs)	Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	74.6	124.3	2	0.08	1	16,875	20,000	33,200
2	Ahmadabad	23.1	72.6	55	5	Jun	69.7	116.1	2	0.08	1	16,875	20,000	33,200
3	Akola	20.7	77.0	282	5	May	71.7	119.5	2	0.08	1	16,875	20,000	33,200
4	Allahabad	25.5	81.7	98	5	Jun	63.0	104.9	2	0.07	1	16,875	20,000	33,200
8	Bhopal	23.3	77.4	503	5	May	79.2	132.0	2	0.09	1	16,875	20,000	33,200
9	Bikaner	28.0	73.3	224	7	Jun	110.2	183.7	2	0.12	1	16,875	20,000	33,200
20	Hyderabad	17.5	78.5	545	5	May	68.0	113.4	2	0.08	1	16,875	20,000	33,200
21	Indore	22.7	75.8	567	6	May	92.4	154.0	2	0.10	1	16,875	20,000	33,200
23	Jaipur	26.8	75.8	390	7	Jun	82.2	137.0	2	0.09	1	16,875	20,000	33,200
24	Jodhpur	26.3	73.0	224	7	Jun	105.3	175.4	2	0.12	1	16,875	20,000	33,200
26	Kota	25.2	75.5	257	7	Jun	94.0	156.6	2	0.11	1	16,875	20,000	33,200
29	Nagpur	21.2	79.1	311	5	May	74.5	124.1	2	0.08	1	16,875	20,000	33,200
30	New Dehli	28.6	77.2	216	5	Jun	72.6	121.1	2	0.08	1	16,875	20,000	33,200
35	Pune	18.5	73.9	563	6	May	78.8	131.3	2	0.09	1	16,875	20,000	33,200
AVERAGE							81.2	135.3	2	0.09	1.0	16,875	20,000	33,200

Animal Pump Sizing, Grapes, Surface Irrigation					2.0 ha Plot			Water Pumping	Assumed Pumping	Hydraulic Power		Capital	*Capital	*Annual
St# ETo	Station Name	Lat(N)	Long(E)	Elev(m)	Area Type	Critical Month	Water (m3/day)	Req'ment (m3/day)	Head (m)	Req'd (kW)	No. of Pumps Req'd	Cost of Pumps (Rs)	Cost of Animals (Rs)	Cost of Fodder (Rs/yr)
1	Agra	27.2	78.1	169	5	Jun	99.5	165.8	2	0.11	1	16,875	20,000	33,200
2	Ahmadabad	23.1	72.6	55	5	Jun	92.9	154.8	2	0.11	1	16,875	20,000	33,200
3	Akola	20.7	77.0	282	5	May	95.6	159.3	2	0.11	1	16,875	20,000	33,200
4	Allahabad	25.5	81.7	98	5	Jun	83.9	139.9	2	0.10	1	16,875	20,000	33,200
8	Bhopal	23.3	77.4	503	5	May	105.6	176.0	2	0.12	1	16,875	20,000	33,200
9	Bikaner	28.0	73.3	224	7	Jun	147.0	245.0	2	0.17	1	16,875	20,000	33,200
20	Hyderabad	17.5	78.5	545	5	May	90.7	151.1	2	0.10	1	16,875	20,000	33,200
21	Indore	22.7	75.8	567	6	May	123.2	205.4	2	0.14	1	16,875	20,000	33,200
23	Jaipur	26.8	75.8	390	7	Jun	109.6	182.7	2	0.12	1	16,875	20,000	33,200
24	Jodhpur	26.3	73.0	224	7	Jun	140.4	233.9	2	0.16	1	16,875	20,000	33,200
26	Kota	25.2	75.5	257	7	Jun	125.3	208.8	2	0.14	1	16,875	20,000	33,200
29	Nagpur	21.2	79.1	311	5	May	99.3	165.5	2	0.11	1	16,875	20,000	33,200
30	New Dehli	28.6	77.2	216	5	Jun	96.9	161.4	2	0.11	1	16,875	20,000	33,200
35	Pune	18.5	73.9	563	6	May	105.0	175.0	2	0.12	1	16,875	20,000	33,200
AVERAGE							108.2	180.3	2	0.12	1.0	16,875	20,000	33,200

*Includes the Cost of Purchasing and Feeding Animals

APPENDIX AA

GRAPES

Life Cycle Cost Comparison for PV, Diesel, Hand and Animal Powered Pumps

0.5, 1.0, 1.5, and 2.0 ha Farms

Life Cycle Cost Comparison for Remote Pumping Systems: Grapes Under Drip Irrigation

	0.5 ha Plot					1.0 ha Plot				
	PV	Diesel	Animal 1	Animal 2	Hand	PV	Diesel	Animal 1	Animal 2	Hand
PW (Rs)	197,286	35,241	29,900	496,735	131,608	240,308	40,256	100,789	567,625	250,230
Year 0	167,867	10,050	16,875	36,875	11,149	209,295	10,050	22,143	42,143	19,706
1	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
2	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
3	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
4	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
5	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
6	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
7	480	1,373	130	33,330	19,003	598	1,745	4,886	38,086	34,896
8	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
9	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
10	34,834	11,423	17,005	50,205	7,854	34,953	11,795	24,172	57,372	15,190
11	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
12	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
13	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
14	480	1,373	130	33,330	19,003	598	1,745	4,886	38,086	34,896
15	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
16	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
17	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
18	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
19	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190
20	480	1,373	130	33,330	7,854	598	1,745	4,886	38,086	15,190

	1.5 ha Plot					2.0 ha Plot				
	PV	Diesel	Animal 2	Animal 1	Hand	PV	Diesel	Animal 2	Animal 1	Hand
PW (Rs)	321,682	45,270	491,110	957,946	371,787	399,196	50,285	597,525	1,064,360	351,479
Year 0	287,656	10,050	51,116	71,116	28,781	362,299	10,050	59,018	79,018	37,856
1	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
2	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
3	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
4	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
5	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
6	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
7	822	2,118	31,075	64,275	51,437	1,035	2,490	38,215	71,415	67,978
8	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
9	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
10	35,176	12,168	63,620	96,820	22,656	35,390	12,540	74,376	107,576	18,431
11	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
12	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
13	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
14	822	2,118	31,075	64,275	51,437	1,035	2,490	38,215	71,415	67,978
15	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
16	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
17	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
18	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
19	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431
20	822	2,118	31,075	64,275	22,656	1,035	2,490	38,215	71,415	18,431

APPENDIX AB

Economic and Financial Cost-Benefit Analysis

PV Drip Irrigation for a 1.0 ha Grape Farm

a) GRAPES (Anib-e-Shahi) Overall Economics

Economics	Present Worth (1994 Rs)	Discount Rate = 4% Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pump System Cost	222,294	199,329																				
Pump System Installation (5%)	9,966	9,966										34,355										
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines	15,000	15,000																				
Yield (t/ha) Anab-e-Shahi Grapes			26.74	27.52	28.33	29.17	30.02	30.91	31.82	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561.3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60.8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24.8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75.6 Rs/t)	31,665		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	434,764	246,805	6,952	7,678	8,409	9,144	9,885	10,631	11,383	12,140	12,702	67,307	13,263	13,263	13,263	13,263	13,263	13,263	13,263	13,263	13,263	13,263
INCOME (5000 Rs/t of produce)	2,094,249		133,676	137,609	141,658	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLOW (Rs)	1,659,485	-246,805	126,724	129,931	133,250	136,682	140,232	143,903	147,699	151,622	151,061	96,456	150,500	150,500	150,500	150,500	150,500	150,500	150,500	150,500	150,500	150,500

b) GRAPES (Anib-e-Shahi) Incremental Economics of PV Drip Irrigation over PV Surface Irrigation

Economics	Present Worth (1994 Rs)	Discount Rate = 4% Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pump System Cost	222,294	199,329																				
Pump System Installation (5%)	9,966	9,966										34,355										
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Subtract PV Surface Irrig. Pump Cost*	-191,925	-175,252										-24,942										
Subtract PV Surface Pump Instal. (5%)	-8,763	-8,763																				
Subtract PV Surface Maintenance (0.3%)	-7,076		-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Inc. Yield (t/ha) Anab-e-Shahi Grapes			5.02	5.17	5.32	5.47	5.64	5.80	5.97	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15
Inc. Fertilizer Cost (47.1 Rs/t of produce)	3,703		236	243	250	258	265	273	281	290	290	290	290	290	290	290	290	290	290	290	290	290
Inc. Harvesting Cost (60.8 Rs/t of produce)	4,780		305	314	323	333	343	353	363	374	374	374	374	374	374	374	374	374	374	374	374	374
Inc. Labour Cost (24.8 Rs/t of produce)	1,950		124	128	132	136	140	144	148	152	152	152	152	152	152	152	152	152	152	152	152	152
Inc. Packaging/Transport Cost (75.6 Rs/t)	5,944		379	391	402	414	426	439	451	465	465	465	465	465	465	465	465	465	465	465	465	465
ADDITIONAL COST (Rs)	85,125	45,595	1,319	1,350	1,382	1,415	1,449	1,483	1,519	1,556	1,556	30,656	1,556	1,556	1,556	1,556	1,556	1,556	1,556	1,556	1,556	1,556
ADDITIONAL INCOME (5000 Rs/t yield)	393,091		25,091	25,829	26,589	27,372	28,177	29,006	29,860	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738
NET ADDITIONAL CASH INFLOW (Rs)	307,965	-45,595	23,772	24,479	25,207	25,957	26,728	27,523	28,341	29,182	29,182	81	29,182	29,182	29,182	29,182	29,182	29,182	29,182	29,182	29,182	29,182

*PV pump sized for drip irrigation replaces PV pump sized for surface irrigation. PV pumping system sized for surface irrigation costs Rs 175,252. Pump replacement cost is Rs 24,942.

c) GRAPES (Anib-e-Shahi) Incremental Economics of PV Drip Irrigation over Surface Irrigation with a Diesel Pump

Economics	Present Worth (1994 Rs)	Discount Rate = 4% Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pump System Cost	222,294	199,329																				
Pump System Installation (5%)	9,966	9,966										34,355										
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Subtract Diesel System Cost*	-16,685	-10,000										-10,000										
Subtract Diesel System Installation (.5%)	-83	-50										-50										
Subtract Annual Fuel Costs	-3,435		-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255
Subtract Annual Maintenance Costs (10%)	-13,459		-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Inc. Yield (t/ha) Anab-e-Shahi Grapes			5.02	5.17	5.32	5.47	5.64	5.80	5.97	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15
Inc. Fertilizer Cost (47.1 Rs/t of produce)	3,703		236	243	250	258	265	273	281	290	290	290	290	290	290	290	290	290	290	290	290	290
Inc. Harvesting Cost (60.8 Rs/t of produce)	4,780		305	314	323	333	343	353	363	374	374	374	374	374	374	374	374	374	374	374	374	374
Inc. Labour Cost (24.8 Rs/t of produce)	1,950		124	128	132	136	140	144	148	152	152	152	152	152	152	152	152	152	152	152	152	152
Inc. Packaging/Transport Cost (75.6 Rs/t)	5,944		379	391	402	414	426	439	451	465	465	465	465	465	465	465	465	465	465	465	465	465
ADDITIONAL COST (Rs)	259,226	219,559	590	621	653	685	719	754	790	826	826	44,820	826	826	826	826	826	826	826	826	826	826
ADDITIONAL INCOME (5000 Rs/t yield)	393,091		25,091	25,829	26,589	27,372	28,177	29,006	29,860	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738
NET ADDITIONAL CASH INFLOW (Rs)	133,864	-219,559	24,501	25,208	25,937	26,686	27,458	28,252	29,070	29,912	29,912	-14,082	29,912	29,912	29,912	29,912	29,912	29,912	29,912	29,912	29,912	29,912

*PV pump sized for drip irrigation replaces diesel pump sized for surface irrigation.

a) GRAPES (Anib-e-Shahi) Overall Finances Considering Subsidies and Soft Loans for Pumping System and Drip Irrigation Equipment

Financial	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost*	112,724		10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	9,530	9,530	9,530	9,530	9,530					
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Drip System Cost**	23,403				3,426	3,426	3,426	3,426	3,426						3,426	3,426	3,426	3,426	3,426			
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines***	18,468		4,161	4,161	4,161	4,161	4,161															
Yield (t/ha) Anab-e-Shahi Grapes			26.74	27.52	28.33	29.17	30.02	30.91	31.82	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561.3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60.8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24.8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75.6 Rs/t)	31,865		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	319,215	12,587	21,562	22,308	26,464	27,200	27,941	24,526	25,278	22,809	23,171	23,732	22,793	22,793	26,219	26,219	26,219	16,689	16,689	13,263	13,263	13,263
INCOME (5000 Rs/t of produce)	2,094,249		133,676	137,809	141,656	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLOW (Rs)	1,775,034	-12,587	112,094	115,301	115,194	118,626	122,176	130,008	133,804	141,153	140,592	140,031	140,969	140,969	137,544	137,544	137,544	147,074	147,074	150,500	150,500	150,500

*Assumes pump cost is Rs 199,329 with subsidy of Rs 118,490. Remaining portion of cost (Rs 80,839) paid off over 10 years at 5% interest as per MNES program. Pump is replaced in year 10 with a loan at 12% interest paid off over 5 years.
**Assumes drip system cost is Rs 19,689 with subsidy of 50%. Remaining portion of cost is Rs 9,844 paid off over 5 years at 12% interest after a 2 year moratorium. Entire drip system is replaced in year 10 under the same loan conditions.
***Assumes the full cost of the support pillars are covered by a loan at 12% interest, paid over 5 years after a 2 year moratorium

b) GRAPES (Anab-e-Shahi) Incremental Financial Benefit of PV Drip Irrigation over PV Surface Irrigation considering Subsidies and Soft Loans

Financial	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	112,724		10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	9,530	9,530	9,530	9,530	9,530					
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Subtract PV Surface Pump Cost (Rs)* =	-93,322		-9,024	-9,024	-9,024	-9,024	-9,024	-9,024	-9,024	-9,024	-9,024	-9,024	-6,919	-6,919	-6,919	-6,919	-6,919					
Subtract PV Surface Instal. Costs (5%)	-8,763	-8,763																				
Subtract Maintenance Costs (0.3%)	-7,078		-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526
Drip System Cost	23,403				3,426	3,426	3,426	3,426	3,426						3,426	3,426	3,426	3,426	3,426			
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Inc. Yield (t/ha) Anab-e-Shahi Grapes			5.02	5.17	5.32	5.47	5.64	5.80	5.97	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15
Cost of Fertilizer (47.1 Rs/t of produce)	3,703		236	243	250	258	265	273	281	290	290	290	290	290	290	290	290	290	290	290	290	290
Cost of Harvesting (60.8 Rs/t of produce)	4,780		305	314	323	333	343	353	363	374	374	374	374	374	374	374	374	374	374	374	374	374
Cost of Labour (24.8 Rs/t of produce)	1,950		124	128	132	136	140	144	148	152	152	152	152	152	152	152	152	152	152	152	152	152
Cost of Packaging &Transport (75.6 Rs/t)	5,944		379	391	402	414	426	439	451	465	465	465	465	465	465	465	465	465	465	465	465	465
ADDITIONAL COST (Rs)	64,711	1,829	2,764	2,795	6,253	6,285	6,319	6,354	6,390	3,001	3,001	3,001	4,167	4,167	7,593	7,593	7,593	4,982	4,982	1,556	1,556	1,556
ADDITIONAL INCOME (5000 Rs/t yield)	393,091		25,091	25,829	26,589	27,372	28,177	29,006	29,860	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738
NET ADDITIONAL CASH INFLOW (Rs)	328,379	-1,829	22,327	23,034	20,337	21,086	21,858	22,652	23,470	27,738	27,738	27,738	26,571	26,571	23,145	23,145	23,145	25,757	25,757	29,182	29,182	29,182

*PV pump sized for drip irrigation replaces PV pump sized for surface irrigation. Financing for PV surface irrigation pumping system is assumed to be the same as that for the drip irrigation pumping system.

c) GRAPES (Anab-e-Shahi) Incremental Financial Benefit of PV Drip Irrigation over Surface Irrigation with a Diesel Pump considering Subsidies and Soft Loans

Financial	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	112,724		10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	9,530	9,530	9,530	9,530	9,530					
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Subtract Diesel System Cost*	-20,542		-2,774	-2,774	-2,774	-2,774	-2,774						-2,774	-2,774	-2,774	-2,774	-2,774					
Subtract Diesel Installation Cost	-83	-50										-50										
Subtract Annual Fuel Costs	-3,435		-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255
Subtract Annual Maintenance Costs (10%)	-13,459		-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000
Drip System Cost	23,403				3,426	3,426	3,426	3,426	3,426						3,426	3,426	3,426	3,426	3,426			
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Inc. Yield (t/ha) Anab-e-Shahi Grapes			5.02	5.17	5.32	5.47	5.64	5.80	5.97	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15
Cost of Fertilizer (47.1 Rs/t of produce)	3,703		236	243	250	258	265	273	281	290	290	290	290	290	290	290	290	290	290	290	290	290
Cost of Harvesting (60.8 Rs/t of produce)	4,780		305	314	323	333	343	353	363	374	374	374	374	374	374	374	374	374	374	374	374	374
Cost of Labour (24.8 Rs/t of produce)	1,950		124	128	132	136	140	144	148	152	152	152	152	152	152	152	152	152	152	152	152	152
Cost of Packaging &Transport (75.6 Rs/t)	5,944		379	391	402	414	426	439	451	465	465	465	465	465	465	465	465	465	465	465	465	465
ADDITIONAL COST (Rs)	136,352	10,541	8,285	8,316	11,773	11,806	11,840	14,649	14,684	11,295	11,295	11,245	7,583	7,583	11,008	11,008	11,008	4,252	4,252	826	826	826
ADDITIONAL INCOME (5000 Rs/t yield)	393,091		25,091	25,829	26,589	27,372	28,177	29,006	29,860	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738	30,738
NET ADDITIONAL CASH INFLOW (Rs)	256,738	-10,541	16,806	17,514	14,816	15,566	16,337	14,358	15,175	19,443	19,443	19,493	23,156	23,156	19,730	19,730	19,730	26,486	26,486	29,912	29,912	29,912

*PV pump sized for drip irrigation replaces diesel pump sized for surface irrigation. Financing for diesel pump is assumed to be 12% paid off over 5 years. Diesel pump would have been replaced in year 10 under the same loan conditions.

a) GRAPES (Thompson Seedless) Overall Finances Considering Subsidies and Soft Loans for Pumping System and Drip Irrigation Equipment

Financial	Present Worth (1994 Rs)	Discount Rate = 4% Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pump System Cost*	112,724		10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	9,530	9,530	9,530	9,530	9,530					
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Drip System Cost**	33,874				4,958	4,958	4,958	4,958	4,958						4,958	4,958	4,958	4,958	4,958			
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	3,835		285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285
Cost of Support Pillars for Vines***	18,468		4,161	4,161	4,161	4,161	4,161															
Yield (t/ha) Thompson Seedless Grapes			18.17	21.14	24.60	28.63	32.50	32.50	32.50	32.50	32.50	32.50	32.50	32.50	32.50	32.50	32.50	32.50	32.50	32.50	32.50	32.50
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	19,716	740	856	996	1,159	1,349	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531
Cost of Interculture (561.3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60.8 Rs/t of produce)	24,495		1,105	1,285	1,496	1,741	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976
Cost of Labour (24.8 Rs/t of produce)	10,291	300	451	524	610	710	806	806	806	806	806	806	806	806	806	806	806	806	806	806	806	806
Cost of Packaging &Transport (75.6 Rs/t)	30,458		1,374	1,598	1,860	2,165	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457
TOTAL COST (Rs)	327,526	12,587	19,877	21,061	27,305	28,709	30,060	26,480	27,042	22,845	23,206	23,767	22,829	22,829	27,787	27,787	27,787	18,257	18,257	13,298	13,298	13,298
INCOME (4500 Rs/t of produce)	1,812,962		81,750	95,143	110,717	128,841	146,250	146,250	146,250	146,250	146,250	146,250	146,250	146,250	146,250	146,250	146,250	146,250	146,250	146,250	146,250	146,250
NET CASH INFLOW (Rs)	1,485,434	-12,587	61,882	74,082	83,413	100,132	116,190	119,770	119,208	123,605	123,044	122,483	123,421	123,421	118,463	118,463	118,463	127,993	127,993	132,952	132,952	132,952

*Assumes pump cost is Rs 199,329 with subsidy of Rs 118,490. Remaining portion of cost (Rs 80,839) paid off over 10 years at 5% interest as per MNES program. Pump is replaced in year 10 with a loan at 12% interest paid off over 5 years.
**Assumes drip system cost is Rs 19,689 with subsidy of 50%. Remaining portion of cost is Rs 9,844 paid off over 5 years at 12% interest after a 2 year moratorium. Entire drip system is replaced in year 10 under the same loan conditions.
***Assumes the full cost of the support pillars are covered by a loan at 12% interest, paid over 5 years after a 2 year moratorium

b) GRAPES (Thompson Seedless) Incremental Financial Benefit of PV Drip Irrigation over PV Surface Irrigation considering Subsidies and Soft Loans

Financial	Present Worth (1994 Rs)	Discount Rate = 4% Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pump System Cost	112,724		10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	9,530	9,530	9,530	9,530	9,530					
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Subtract PV Surface Irrig. Pump Cost*	-93,322		-8,024	-8,024	-8,024	-8,024	-8,024	-8,024	-8,024	-8,024	-8,024	-8,024	-8,919	-8,919	-8,919	-8,919	-8,919					
Subtract PV Surface Pump Install. (5%)	-8,783	-8,783																				
Subtract PV Surface Maintenance (0.3%)	-7,076		-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526	-526
Drip System Cost	33,874				4,958	4,958	4,958	4,958	4,958						4,958	4,958	4,958	4,958	4,958			
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	3,835		285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285
Inc. Yield (t/ha) Thompson Seedless			3.41	3.97	4.62	5.37	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10
Inc. Fertilizer Cost (47.1 Rs/t of produce)	3,562		161	187	218	253	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287
Inc. Harvesting Cost (60.8 Rs/t of produce)	4,598		207	241	281	327	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371
Inc. Labour Cost (24.8 Rs/t of produce)	1,875		85	98	115	133	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151
Inc. Packaging/Transport Cost (75.6 Rs/t)	5,717		258	300	349	406	461	461	461	461	461	461	461	461	461	461	461	461	461	461	461	461
ADDITIONAL COST (Rs)	75,740	1,829	2,516	2,633	7,727	7,885	8,037	8,037	8,037	3,079	3,079	3,079	4,245	4,245	9,204	9,204	9,204	6,592	6,592	1,634	1,634	1,634
ADDITIONAL INCOME (4500 Rs/t yield)	340,293		15,346	17,858	20,782	24,184	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451
NET ADDITIONAL CASH INFLOW (Rs)	264,553	-1,829	12,830	15,226	13,055	16,298	19,414	19,414	19,414	24,372	24,372	24,372	23,206	23,206	18,248	18,248	18,248	20,859	20,859	25,817	25,817	25,817

*PV pump sized for drip irrigation replaces a PV pump sized for surface irrigation. Cost of PV pump for surface irrigation is Rs 175,252 with subsidy of Rs 106,250 (170 Rs/Wp).

c) GRAPES (Thompson Seedless) Incremental Financial Benefit of PV Drip Irrigation over Surface Irrigation with a Diesel Pump considering Subsidies and Soft Loans

Financial	Present Worth (1994 Rs)	Discount Rate = 4% Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pump System Cost	112,724		10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	10,469	9,530	9,530	9,530	9,530	9,530					
Pump System Installation (5%)	9,966	9,966																				
Maintenance for Pump System (0.3%)	8,048		598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598	598
Subtract Diesel System Cost*	-20,542		-2,774	-2,774	-2,774	-2,774	-2,774						-2,774	-2,774	-2,774	-2,774	-2,774					
Subtract Diesel Installation Cost	-83	-50										-50										
Subtract Annual Fuel Costs	-3,435		-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255	-255
Subtract Annual Maintenance Costs (10%)	-13,459		-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000
Drip System Cost	33,874				4,958	4,958	4,958	4,958	4,958						4,958	4,958	4,958	4,958	4,958			
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	3,835		285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285
Inc. Yield (t/ha) Thompson Seedless			3.41	3.97	4.62	5.37	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10
Inc. Fertilizer Cost (47.1 Rs/t of produce)	3,562		161	187	218	253	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287
Inc. Harvesting Cost (60.8 Rs/t of produce)	4,598		207	241	281	327	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371
Inc. Labour Cost (24.8 Rs/t of produce)	1,875		85	98	115	133	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151
Inc. Packaging/Transport Cost (75.6 Rs/t)	5,717		258	300	349	406	461	461	461	461	461	461	461	461	461	461	461	461	461	461	461	461
ADDITIONAL COST (Rs)	147,381	10,541	8,036	8,153	13,248	13,406	13,558	16,332	16,332	11,374	11,374	11,324	7,861	7,861	12,619	12,619	12,619	5,863	5,863	904	904	904
ADDITIONAL INCOME (4500 Rs/t yield)	340,293		15,346	17,858	20,782	24,184	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451	27,451
NET ADDITIONAL CASH INFLOW (Rs)	192,912	-10,541	7,310	9,705	7,534	10,778	13,893	11,119	11,119	16,078	16,078	16,128	19,790	19,790	14,832	14,832	14,832	21,588	21,588	26,547	26,547	26,547

*PV pump sized for drip irrigation replaces a diesel pump sized for surface irrigation. Cost of diesel pump is Rs 10,000 paid off over 5 years at 12% interest. Diesel pump would have been replaced in year 10.

a) GRAPES (Anib-e-Shahi) Overall Economics for a PV Drip Irrigation System using a Ground Water Source (Depth to Water Table = 5 m)

Economics	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	278,140	253,175										34,355										
Pump System Installation (5%)	12,659	12,659																				
Maintenance for Pump System (0.3%)	10,222		760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760	760
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines	15,000	15,000																				
Yield (t/ha) Anab-e-Shahi Grapes			26.74	27.52	28.33	29.17	30.02	30.91	31.82	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561.3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60.8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24.8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75.6 Rs/t)	31,665		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	493,477	303,144	7,113	7,839	8,570	9,306	10,047	10,793	11,545	12,302	12,863	67,468	13,425	13,425	13,425	13,425	13,425	13,425	13,425	13,425	13,425	13,425
INCOME (5000 Rs/t of produce)	2,094,249		133,676	137,609	141,658	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLOW (Rs)	1,600,772	-303,144	126,563	129,770	133,088	136,521	140,071	143,742	147,537	151,461	150,899	96,294	150,338	150,338	150,338	150,338	150,338	150,338	150,338	150,338	150,338	150,338

b) GRAPES (Anib-e-Shahi) Overall Economics for a PV Drip Irrigation System using a Ground Water Source (Depth to Water Table = 10 m)

Economics	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	408,856	348,246										90,671										
Pump System Installation (5%)	17,412	17,412																				
Maintenance for Pump System (0.3%)	14,061		1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines	15,000	15,000																				
Yield (t/ha) Anab-e-Shahi Grapes			26.74	27.52	28.33	29.17	30.02	30.91	31.82	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561.3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60.8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24.8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75.6 Rs/t)	31,665		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	634,785	402,968	7,399	8,125	8,855	9,591	10,332	11,078	11,830	12,587	13,148	124,009	13,710	13,710	13,710	13,710	13,710	13,710	13,710	13,710	13,710	13,710
INCOME (5000 Rs/t of produce)	2,094,249		133,676	137,609	141,658	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLOW (Rs)	1,459,464	-402,968	126,277	129,485	132,803	136,235	139,785	143,456	147,252	151,176	150,614	39,753	150,053	150,053	150,053	150,053	150,053	150,053	150,053	150,053	150,053	150,053

c) GRAPES (Anib-e-Shahi) Overall Economics for a PV Drip Irrigation System using a Ground Water Source (Depth to Water Table = 15 m)

Economics	Present Worth (1994 Rs)	Discount Rate = Year End 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		4%																				
Pump System Cost	487,229	426,619										90,671										
Pump System Installation (5%)	21,331	21,331																				
Maintenance for Pump System (0.3%)	17,225		1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280
Drip System Cost	32,850	19,689										19,689										
Drip System Design Cost	625	625																				
Maintenance for Drip System (1%)	2,650		197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197	197
Cost of Support Pillars for Vines	15,000	15,000																				
Yield (t/ha) Anab-e-Shahi Grapes			26.74	27.52	28.33	29.17	30.02	30.91	31.82	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75	32.75
Cost of Seedlings and Planting	706	706																				
Cost of Fertilizer (47.1 Rs/t of produce)	20,468	740	1,259	1,296	1,334	1,374	1,414	1,456	1,499	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543
Cost of Interculture (561.3 Rs/yr)	53,919	250	561	1,123	1,684	2,245	2,807	3,368	3,929	4,490	5,052	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Cost of Harvesting (60.8 Rs/t of produce)	25,466		1,625	1,673	1,723	1,773	1,825	1,879	1,934	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991	1,991
Cost of Labour (24.8 Rs/t of produce)	10,687	300	663	683	703	723	745	766	789	812	812	812	812	812	812	812	812	812	812	812	812	812
Cost of Packaging &Transport (75.6 Rs/t)	31,665		2,021	2,081	2,142	2,205	2,270	2,337	2,405	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476	2,476
TOTAL COST (Rs)	720,241	485,260	7,634	8,360	9,090	9,826	10,567	11,313	12,065	12,822	13,384	124,305	13,945	13,945	13,945	13,945	13,945	13,945	13,945	13,945	13,945	13,945
INCOME (5000 Rs/t of produce)	2,094,249		133,676	137,609	141,658	145,827	150,118	154,535	159,082	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763	163,763
NET CASH INFLOW (Rs)	1,374,008	-485,260	126,042	129,250	132,568	136,000	139,550	143,221	147,017	150,940	150,379	39,458	149,818	149,818	149,818	149,818	149,818	149,818	149,818	149,818	149,818	149,818