EVAPOTRANSPIRATION MEASUREMENTS AND RESISTANCE PARAMETER ESTIMATION UNDER RANGE/PASTURE CONDITIONS IN OKLAHOMA

by

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Chapter 1

INTRODUCTION

Evaporation of water from the earth's surface plays an important role in the energy and water balances near the earth's surface. Water is evaporated from the earth's surface through evaporation from wet surfaces and through transpiration from plant tissues. These processes, evaporation and transpiration, are often combined and referred to as evapotranspiration (ET).

Evapotranspiration is a major component of the radiant energy balance at the earth's surface. Lemon et al. (1971), for example, reported that in the eastern United States in the summertime, up to 90% of net radiation was partitioned into evapotranspiration.

Evapotranspiration is a major component in the hydrologic balance at the earth's surface. Rosenberg et al. (1983) estimate that 70% of the water that falls on the continental United States returns to the atmosphere by direct evaporation or by transpiration. In the Great Plains of the United States, and other relatively dry regions of the world, 90% or more of the precipitation is returned to the atmosphere through evapotranspiration (Rosenberg et al., 1983).

Improved measurements and estimates of evapotranspiration are needed for many different applications, including improving the efficiency of water use in irrigated agriculture and estimating groundwater recharge and water resource availability.

Those studying global change and modeling earth-atmosphere processes are also interested in better quantification of ET over various space and time scales.

Much work has been done involving ET and irrigated agricultural crops, with less attention paid to non-irrigated, non-crop conditions. However, much larger land areas are under non-crop conditions. The Food and Agricultural Organization of the United Nations (FAO, 1994) estimates that about 26% of the earth's total land area is devoted to permanent pasture, while only 11% is arable crop land. In the United States, approximately 28% of the land area is devoted to permanent pasture and rangeland, while 22% is crop land (Oklahoma Department of Commerce, 1992). In Oklahoma, approximately 50% of the land area is under non-irrigated pasture and range conditions (David M. Engle, Oklahoma State University Department of Agronomy, personal communication; Oklahoma Department of Commerce, 1992). Quantifying ET under these conditions, therefore, is important in applications on watershed and regional scales.

Various methods have been used to measure ET, both directly and indirectly. The methods differ in equipment and labor requirements, measurement frequency, accuracy, and quantity actually measured. Eddy correlation and Bowen-ratio energy-balance methods, which provide direct measurements of water vapor flux, are used to make accurate, short-term measurements but are usually confined to research applications due to equipment and labor requirements. Neutron scattering and other methods for measuring soil water content can be used to indirectly estimate ET by attributing changes in water content over time to evapotranspiration. However, application of this approach has been limited due to the inaccuracies present in soil water accounting, and the requirements for labor and specialized equipment. Evaporation pans have been used in many parts of the world due to their simplicity, but the accuracy and usefulness of measurements have been questioned.

Lysimeters have been used for many years for measuring ET, especially in irrigation research applications, and many different lysimeter designs have emerged. Some designs have relied on hydraulic mechanisms and manual measurements of lysimeter weight. Others have relied on balance beams and counterweights, resulting in complex and expensive mechanisms often requiring considerable maintenance. Recent improvements in the performance and cost of electronic loadcells and datalogging equipment have allowed the design and installation of lysimeters which are simpler and less expensive to construct and maintain, and which can be operated remotely.

Measurement of evapotranspiration, due to equipment, operation, and maintenance requirements, has been limited almost entirely to research applications. The need for ET estimates, therefore, resulted in the development of estimation methods based on meteorological variables, which were more easily and routinely measured. Measurement of variables such as air temperature, solar radiation, relative humidity, and wind speed have been more common and widespread than measurement of actual evapotranspiration, and recent advances in sensor and data-recording technology have enabled the collection of more accurate, reliable, and affordable weather measurements. Estimation methods have ranged from strictly empirical, locally derived relationships between one or more weather parameters and ET, to theoretical descriptions of the evaporation process based on energy balance and mass transfer theory.

Empirical relationships have been developed which require little input data, allowing them to be used in areas where minimal weather data is available. The methods usually have to be calibrated for local conditions and for the specific vegetative cover of interest. Some methods require the estimation of a reference ET, the ET occurring from a particular vegetative cover under specific management and moisture conditions, and the measurement of weather parameters under these same conditions. An empirically derived crop coefficient specific to the vegetation of interest then has be applied to the reference ET to obtain an estimate of actual ET. Crop coefficients have been developed for a variety of crops, mostly those commercially grown under carefully managed and irrigated conditions, in various locations around the world.

The frequent absence of reference conditions or appropriate crop coefficients, however, prompted researchers to develop methods applicable under a wider variety of conditions. A description of the physical processes involved in the evaporation of water from the earth's surface was proposed by Penman (1948) and modified by Monteith (1973). The resulting Penman-Monteith equation has received a great deal of attention in modern evapotranspiration research. Based on the surface energy balance and mass and heat transfer theory, an equation was developed which described the evapotranspiration process from a vegetated surface in terms of meteorological variables and surface characterization parameters. While the Penman-Monteith method requires more input data, it is applicable under a wide variety of conditions and relies less on empirical relationships and crop-specific coefficients.

Advances in electronic instrumentation and more widespread availability of automated sensors and datalogging equipment have led to expanded deployment of automated weather stations. The availability of high-quality weather data has allowed more sophisticated methods, such as the Penman-Monteith equation, to be used to estimate ET. In Oklahoma, an extensive network of automated, remote weather stations has been installed. The Oklahoma Mesonetwork (Mesonet) consists of 111 weather stations located across the state which report a variety of meteorological measurements.

Given the importance of evapotranspiration in the energy and water balances, and in agricultural and hydrological applications, ET estimates are needed on local as well as regional scales. The Oklahoma Mesonet provides unique weather data capabilities and an opportunity to estimate ET at many locations over a large area.

OBJECTIVES

The overall objectives of this research effort were to quantify the evapotranspiration occurring under various range/pasture conditions which are representative of large areas in Oklahoma, and to examine the parameters which control and influence energy usage and water vapor transport under these conditions.

To meet these objectives, the following steps were taken:

1. installation of electronic weighing lysimeters in different regions of the state under soil and land-use conditions representative of larger areas;
2. automatic measurement of actual ET under range/pasture conditions using the lysimeters and the remote operating capability of the Oklahoma Mesonet;
3. estimation of resistance parameters necessary to characterize surface conditions for use in resistance-based ET estimation methods;
4. examination of the behavior of the resistance parameters in terms of the environmental factors which influence them for use at other, non-lysimeter sites.

Chapter 2

LITERATURE REVIEW

A large body of literature exists regarding the measurement and estimation of evapotranspiration. Much of the work has been done under agricultural conditions in efforts aimed at quantifying the water requirements of commercial crops in order to improve the efficiency of irrigations and maximize yields. Less work has been done for non-irrigated and non-agricultural crops, such as rangeland and pasture areas.

MEASUREMENT OF EVAPOTRANSPIRATION WITH LYSIMETERS

Lysimeters have been used extensively in evapotranspiration research for many years. Different designs have evolved and been applied under a variety of vegetative and climatic conditions.

Lysimeters used in evapotranspiration research consist basically of containers filled with soil in which plants are grown. The containers isolate the soil and plants from the surrounding field and allow the water balance in the container to be analyzed. The amount of water leaving the containers can be quantified and the water use of the soil-plant system, in the form of evapotranspiration, can be determined. Non-weighing lysimeters are used to determine water use by measuring changes in the volume of water inside the lysimeter, while weighing lysimeters measure changes in the weight of water present. Surface areas of lysimeters have varied from tens of centimeters in diameter to a square meter to more than six meters in diameter.

Advances in electronic instrumentation have allowed more accurate measurements to be made and for measurements to be more easily recorded and reported. Modern weighing lysimeters have been constructed which use mechanical and electronic weighing systems. Electronic datalogging equipment has enabled high resolution measurements to be made at increasingly shorter time intervals.

Lysimeters have been constructed which incorporate undisturbed blocks of soil and vegetation, such as those described by Armijo et al. (1972) and Howell et al. (1985). Others have consisted of disturbed and reconstructed soil profiles, such as that described by Pruitt and Angus (1960).

Plants grown in lysimeters have often been agricultural crops, such as wheat, cotton, corn, and vegetables, and have usually been grown under irrigated and highly managed conditions (see, for example, Ritchie and Burnett, 1968; Wright, 1982; Bland and Dugas, 1989). Evapotranspiration measurements have been used to define crop coefficient relationships for many different agricultural crops for use in ET estimation equations (Doorenbos and Pruitt, 1977; Wright, 1982; Burman et al., 1983; Cuenca, 1989; Jensen et al., 1990; Wright, 1991).

Other lysimeter studies have been undertaken to study the water use of a variety of vegetation types. Fritschen et al. (1973) constructed a lysimeter around a growing, 28-m tall fir tree. McFarland et al. (1983) reported a study involving citrus trees. A study undertaken by Abtew and Obeysekera (1995) measured ET from a stand of cattails. Studies such as those reported by Gee et al. (1991) and Murray et al. (1991) involved native vegetation. Work involving grassland areas has been reported by Armijo et al. (1972), Parton et al. (1981), Wight et al. (1986), and Wright and Harding (1991).

Comprehensive discussions on lysimetry and recent work involving evapotranspiration research and lysimeters can be found in Aboukhaled et al. (1982), ASAE (1985), and Allen et al. (1991).

ESTIMATION OF EVAPOTRANSPIRATION

Many methods have been used in the past to estimate evapotranspiration under various surface cover, water availability, and meteorological conditions. Early methods consisted of a simple correlation between one or more weather parameters and plant growth. Over time, as experience with ET estimation was gained and more accurate and reliable meteorological data became available, existing methods were refined and improved methods were developed. Estimation methods based on the physical processes involved in evaporation more realistically modeled evaporative conditions and relied less on empirical, locally calibrated methods.

In determining and interpreting evapotranspiration estimates, an understanding of the assumptions involved in making the estimate is necessary. The various estimation methods currently in use are based on assumptions relating to vegetative and water-availability conditions, and the resulting ET estimates fall into three main categories based on those assumptions: potential ET, reference ET, and actual ET.

Potential ET is the evapotranspiration that would occur from an extended vegetated surface with wet plant and soil surfaces which exert little or no resistance to the flow of water and which are always well supplied with water (Rosenberg et al., 1983; Jensen et al., 1990). Under these conditions of unlimited water availability, the limiting factor in evapotranspiration is the amount of energy available at the surface. Conditions under which potential ET occurs are rare in the field, approached briefly perhaps following a regionwide rainfall (Shuttleworth, 1993). Potential ET is useful as a conceptual measure of the evaporative energy or demand of the atmosphere.

Reference ET is the evapotranspiration occurring from a specific vegetated surface under specific management and available-water conditions. The reference surface consists of a stand of alfalfa or dense grass, completely shading the soil surface, clipped to a height of 0.08-0.15 m, and always well-supplied with water (Jensen et al., 1990).

Actual ET is the evapotranspiration occurring from the surface of interest under the actual vegetative and environmental conditions occurring at the time. No assumptions are made about surface or available-water conditions, and conditions can vary from densely vegetated and well-watered to sparsely vegetated and water-stressed.

Empirical Methods

A variety of empirical methods have been proposed relating various weather parameters and water use of different plants. Equations were often developed in a given region under the climatic conditions of the region. Data requirements included various combinations of weather parameters such as air temperature, solar radiation, humidity, vapor pressure, percent daytime hours, cloudiness, and wind speed. While many methods have been proposed, several methods have been widely adopted, refined, and applied under varying weather and crop conditions.

The method proposed by Blaney and Criddle (1962) has been widely used in the western part of the United States and estimates evaporative demand based on monthly average air temperature and the percentage of the annual daylight hours occurring in the month. A variety of modifications have been proposed in an attempt to improve estimates and to allow the method to be used in other areas and for shorter time periods (Doorenbos and Pruitt, 1977; Jensen et al., 1990). A method proposed by Jensen and Haise (1963) uses air temperature and solar radiation to estimate evapotranspiration. Hargreaves developed a method based on air temperature and solar radiation, which was later modified so that the radiation term, which was often not measured, could be estimated from calculated extraterrestrial radiation (Hargreaves and Samani, 1985). Christiansen (1968) developed a method based on pan evaporation and measurements of air temperature, wind speed, and humidity.

Penman (1948) first developed a method based on the surface energy balance and mass transfer principles. While being theoretically based, the method includes empirical terms which have to be locally calibrated. Priestley and Taylor (1972) proposed a simplified version of the Penman formula. The resulting equation estimates ET in terms of radiation and air temperature.

The ET estimates obtained from most of these and other empirical methods were considered reference ET estimates which had to be adjusted for the particular vegetative conditions present. To obtain an estimate of the actual ET of the particular crop, an empirical crop coefficient had to be applied to the reference ET estimate. Coefficients were developed for the different ET estimation methods for a variety of vegetation types, mostly agricultural crops, in areas around the world (see, for example, Doorenbos and Pruitt, 1977). The crop coefficients reflect varying growth stages of the plant and their effects on the water requirements of the crops. Crop coefficients developed for one ET estimation method should not, in general, be used with other methods, however.

Physically Based Methods

Physically based methods of estimating evapotranspiration were developed based on the surface energy balance and mass and heat transfer theory. The surface energy balance is an accounting of the radiative energy usage at the earth's surface, and partitions the energy into incoming and outgoing energy, and that converted to other forms. Incoming energy is composed primarily of short-wave radiation emitted from the sun and long-wave radiation emitted from the atmosphere, while outgoing energy includes short-wave radiation which is reflected away from the surface and long-wave radiation emitted by the surface (Rosenberg et al., 1983). Some energy is converted and is used in heating of the atmosphere, heating of the soil, evaporation of water, and photosynthesis.

Radiant energy incident on the earth's surface is distributed across the surface and into the atmosphere due to the roughness of the surface and the turbulent nature of the atmosphere (Oke, 1987). Surface features, ranging in size from soil particles to plants and trees to mountains, disturb the flow of air across the surface and create turbulence in the atmosphere. Turbulent air transfers mass and heat back and forth between the surface and the atmospheric boundary layer above the surface, affecting the microclimate to which the plants and soil surface are exposed (Rosenberg et al., 1983). Turbulent air removes water from plant and soil surfaces, modifies the humidity and temperature conditions near the surface, and, under conditions of sensible heat advection, can increase the amount of energy available for evaporation.

Penman-Monteith Method

The work of H.L. Penman (1948) is cited extensively in the literature as the starting point in the physical description and theoretical analysis of the evaporation process. Penman was interested in describing the physics of evaporation and the development of a formula which would allow the rate of evaporation to be estimated from any surface based on climatological variables (Monteith, 1985). The resulting formula dealt with the conservation of energy and mass at the interface of a wet surface and the atmosphere, and, while still containing empirical relations to describe certain physical processes, served as the basis for many theoretical and experimental studies of evaporation.

Monteith, building on the theory and formula developed by Penman, introduced terms to allow for evaporation from non-saturated surfaces (Monteith, 1985). The terms introduced were described as resistances which control the rate of evaporation and which are functions of plant and atmospheric conditions. The resulting Penman-Monteith formula describes the physics of the evaporative process from most surfaces based on climatological variables and plant characteristics.

Much of the data required to estimate ET using the Penman-Monteith equation is now becoming relatively easily, inexpensively, and routinely available. Required weather variables include net radiation, air temperature, relative humidity, and wind speed measured at one height above the plant canopy. Other information relating to plant conditions, including leaf-area index, canopy height, and canopy aerodynamic properties, is typically less available. This information, which often must be estimated, is necessary in determining the resistances and, in turn, the evapotranspiration.

Shuttleworth-Wallace Method

Shuttleworth and Wallace (1985) developed a method to estimate evapotranspiration from a sparsely vegetated surface using energy balance and mass and heat transfer equations in a manner similar to the development of the Penman-Monteith equation. They did not assume that the surface was covered by dense vegetation and, therefore, allowed evaporation from exposed soil surfaces to contribute to the total evapotranspiration from the surface.

The Shuttleworth-Wallace model uses surface and aerodynamic resistance terms similar to those in the Penman-Monteith equation. Crop canopy and above-canopy aerodynamic resistance terms are similar to those in the Penman-Monteith equation, but since the model allows for sparse canopy conditions to exist, new resistance terms are included to describe soil surface and in-canopy effects on evaporation. A soil surface resistance term describes the control which the soil surface exerts on evaporation. Two aerodynamic terms are added to account for in-canopy air flow and the transfer of water vapor from plant and soil surfaces to the above-canopy air flow.

Assumptions made in the derivation of the Penman and Penman-Monteith formulas limited their application estimating actual evapotranspiration under all conditions. Penman assumed that the vegetation was dense, forming a closed canopy that shaded the soil surface, and was well-watered. The Penman-Monteith formula allowed for water-stressed conditions, but still assumed a densely vegetated surface. In both cases, evaporation from the soil surface was assumed to be negligible.

In the early stages of plant growth and under row-crop and sparse-vegetation conditions, however, extensive areas of bare soil may exist and can play significant roles in surface energy balance and evapotranspiration calculations. Shuttleworth and Wallace (1985) reinterpreted the work of Penman and Monteith and developed a formula describing evaporation under sparse-canopy conditions. Combining the surface energy balance and mass and heat transfer theory, evaporative pathways from both the plant canopy and from the soil surface were included. Resistance terms similar to those in the Penman-Monteith formula were used to describe the control of evaporation exerted by the plant, the atmosphere, and the soil surface.

The Shuttleworth-Wallace model explicitly recognizes that evaporation from the soil surface can be significant, and provides a means of quantifying evaporation from plant as well as soil surfaces. In the development of the model, no assumptions were made regarding actual vegetative conditions. In this way, the model can be used under all conditions, ranging from bare soil with no vegetation to a closed canopy completely shading the soil surface. The resulting model, under closed canopy conditions, simplifies to the Penman-Monteith formula.

Data requirements for using the Shuttleworth-Wallace model are similar to those for the Penman-Monteith equation. The same meteorological variables, including net radiation, air temperature, relative humidity, and wind speed, and plant characteristics, such as leaf-area index, height, and aerodynamic properties, are required. The inclusion of evaporation from the soil surface requires additional information relating to the soil and soil moisture in order for the soil resistance parameter to be estimated.

To date, only a few applications of the Shuttleworth-Wallace model have been reported. The conditions under which the model has been applied include a subarctic wetland, a shortgrass steppe, a semiarid rangeland, and an irrigated agricultural crop. The diversity of conditions encountered in these studies resulted in a variety of assumptions and unique solutions relating to resistance and other model parameter estimation.

Lafleur and Rouse (1990) tested the Shuttleworth-Wallace model using field data collected using the Bowen-ratio energy-balance approach in a subarctic wetland. Vegetation consisted of a sparse cover of sedge grass hummocks, and the soil surface was wet at all times. Wet soil surface conditions allowed the soil surface resistance to be assumed small and negligible.

Massman (1992) applied the Shuttleworth-Wallace model in an effort to separate the plant and soil components of ET from a vegetated region consisting primarily of shortgrasses. Eddy correlation and meteorological measurements were used to determine latent and sensible heat fluxes and, in turn, to estimate resistance values. A model of soil surface resistance was developed for use in partitioning ET into soil and plant components.

Stannard (1993) used eddy correlation measurements to develop models of evapotranspiration from a sparsely vegetated, semiarid rangeland. Model parameters were estimated for the Penman-Monteith, Shuttleworth-Wallace, and a modified Priestley-Taylor model, and ET estimates from the three models were compared. The Penman-Monteith model did not perform adequately due to the sparse vegetation conditions which violated principal assumptions inherent in this method. The modified Priestley-Taylor model, containing a relationship to account for soil evaporation and the small leaf-area index of the vegetation, performed well despite the original intended use in estimating ET under well-watered, potential evaporation conditions. An empirical model developed to estimate canopy resistance and a soil surface resistance model based on cumulative soil evaporation were used to obtain ET estimates with the Shuttleworth-Wallace model.

Farahani and Bausch (1994) used Bowen-ratio energy-balance measurements to evaluate the performance of the Penman-Monteith and Shuttleworth-Wallace models applied to an irrigated corn crop. A relationship involving leaf-area index and solar radiation was used to estimate canopy resistance, and an empirical relationship based on soil moisture was developed to estimate soil surface resistance. A constant value for the soil surface resistance was also tested and found to provide ET estimates similar to those obtained using the empirical soil surface resistance relationship. The authors encouraged other researchers to verify these results in the hope that the difficulty in determining the soil surface resistance could be alleviated.

Resistance Parameters

The resistance parameters introduced by Monteith (1973) and used in the Penman-Monteith equation consist of a canopy resistance and an aerodynamic resistance. The canopy resistance is a measure of the control of evaporation exerted by the plant through stomatal regulation. The aerodynamic resistance accounts for the ability of the turbulent atmosphere to transfer momentum, heat, and water vapor away from the plant canopy.

Resistance terms used in the Shuttleworth-Wallace ET model are affected by sparse vegetation conditions. Assumptions made in estimating parameters under dense-canopy conditions for use in the Penman-Monteith model may not be appropriate for conditions of incomplete cover. For some parameters, established methods for estimating the different parameters have been used or adapted, but for others, entirely new relationships must be developed.

Aerodynamic Resistances

Aerodynamic resistance has been related to the roughness of the surface and the speed of the air flowing over the surface (Thom, 1975). Wind speeds measured at different heights above a smooth surface were found to vary logarithmically with height, and the logarithmic wind profile has come to be widely accepted (Thom, 1975; Brutsaert, 1982; Oke, 1987; Allen et al., 1989; Jensen et al., 1990). The wind-speed profile above a densely vegetated surface was found to be logarithmic also, but displaced above the surface by a distance related to the density of the vegetation (Brutsaert, 1982). This distance, often referred to as the zero-plane displacement height, represents the mean level at which momentum of the flowing air is absorbed by the plant community (Rosenberg et al., 1983).

Another term introduced to describe the wind profile above a vegetated surface is the roughness length, which is a function of the nature, size, and geometry of the surface roughness elements (Brutsaert, 1982). The roughness length is used to describe the effective roughness of the canopy above the zero-plane displacement height which interacts with the flowing air and contributes to the turbulence of the air. Roughness length has often been estimated as a function of plant height, with various functions reported (Brutsaert, 1982; Oke, 1987; Allen et al., 1989; Jensen et al., 1990). It has been reasoned that the roughness lengths of flexible elements, such as plants, however, would also be affected by the density of the elements and by wind speed (Szeicz et al., 1969; Elston and Monteith, 1975; Rosenberg et al., 1983; Oke, 1987).

In the Penman-Monteith model, a single parameter is used to describe the aerodynamic resistance of the canopy. Since the canopy is assumed to be dense and completely covering the soil surface, air flow within the canopy is assumed to be very small and negligible in its contribution to evaporation. Under sparse vegetation conditions, however, plant elements may be spaced far apart and there may be significant areas of exposed soil surfaces. Depending on the structure of the vegetation, in-canopy air flow may be considerable and may contribute to the removal of water vapor from plant surfaces. Bare soil surfaces between plants and under plant canopies may be exposed directly to turbulent air flow and allow water from the soil surface to be transported much quicker into the mean, above-canopy air flow. For sparse-canopy conditions, therefore, three aerodynamic resistances must be estimated: the aerodynamic resistance of the mean, above-canopy flow; the aerodynamic resistance of the in-canopy flow from the plant canopy; and the aerodynamic resistance of the in-canopy flow from the soil surface.

Aerodynamic Resistance of Mean Flow

In work reported involving evapotranspiration under sparse vegetation conditions, the logarithmic wind profile assumed above a dense canopy is often assumed to exist above the sparse canopy (Shuttleworth and Wallace, 1985; Lafleur and Rouse, 1990; Massman, 1992; Stannard, 1993). Based on the specific vegetative conditions which he examined, Stannard (1993) assumed that the logarithmic wind profile extended down to the level of the soil surface. Shuttleworth and Wallace (1985) used a logarithmic wind profile but added a linear relation based on leaf-area index to adjust the resistance for effects of canopy density.

The estimation of the zero-plane displacement height has been the topic of much research and debate, both for sparse as well as dense canopies. The displacement height, the level in the canopy below which the influence of the turbulent air flow is assumed negligible, has often been assumed to be a function strictly of the height of the canopy (Brutsaert, 1982; Oke, 1987; Allen et al., 1989; Jensen et al., 1990). This function has varied, however, depending on the vegetation type and density (Verma and Barfield, 1979; Hatfield, 1989; Kustas et al., 1989).

Sparse vegetation has been reported to have the effect of reducing displacement height. For very sparsely placed roughness elements, Brutsaert (1982) placed the zero-plane level at the base of the elements, and for very densely placed elements at the top of the elements, so that in most situations, the level would be somewhere in between. Based on the extremely sparse canopy conditions encountered, Stannard (1993) assumed that the wind profile extended to very near the soil surface and that the displacement height should be 0.

Aerodynamic Resistance of the Canopy to In-Canopy Flow

In the Penman-Monteith equation, vegetation is assumed to be dense, forming a closed canopy completely shading the ground surface. It is assumed that the movement of air above the canopy does not penetrate into the canopy, and that ET occurs from the upper levels of the canopy which are exposed to the boundary layer above the plant canopy.

For sparse canopies, air can penetrate into the canopy and come into contact with vegetative elements at all levels in the canopy. The aerodynamic resistance of the canopy to in-canopy flow in the Shuttleworth-Wallace model takes this interaction of wind and vegetation into account and is used to describe the transfer of water vapor from the outer surface of the plant leaves away from the plant and into the mean air flow.

For estimating the in-canopy aerodynamic resistance, several models have been proposed based on wind speed and canopy structure. In most cases, some measure of turbulence is determined and then adjusted for the surface area of exposed leaves by dividing by the leaf-area index of the canopy. A model proposed by Jones (1983) relates the resistance to the average width of plant leaves and wind speed. The model was simplified to an empirical constant divided by the leaf-area index of the canopy (Shuttleworth, 1991). Shuttleworth and Gurney (1990) proposed a model based on leaf width, wind speed at the top of the canopy, and an extinction coefficient for turbulent transfer in the canopy. Stannard (1993) developed a model based on leaf width and turbulence parameters. Shuttleworth and Wallace (1985) noted that measurements of in-canopy resistance displayed significant scatter and that a constant value could be used. Ham and Heilman (1991) and Massman (1992) also reported significant variability and little correlation with wind speed, and suggested that a constant value could be used.

Aerodynamic Resistance of the Soil Surface to In-Canopy Flow

Similar to the aerodynamic resistance of the canopy to in-canopy flow, an aerodynamic resistance of the soil surface has been included to describe the interaction of the soil surface and the flow of air in contact with exposed soil surfaces. Shuttleworth and Wallace (1985) suggested a model derived from the logarithmic wind profile and a linear interpolation based on leaf-area index but pointed out that this model had not been tested. Stannard (1993) assumed that the above-canopy air flow extended into the canopy and down to the soil surface, and developed a model based on the logarithmic wind profile. Farahani and Bausch (1994) developed a model based on the logarithmic wind profile. Massman (1992) assumed a constant value equal to that for the aerodynamic resistance of the canopy to in-canopy flow.

Canopy Resistance

Canopy resistance, a measure of the regulation of evapotranspiration exerted by the plant canopy, has been related to canopy structure and to environmental factors which influence stomatal behavior. Measurements of stomatal resistance have been made for individual plant leaves, but these measurements have been difficult to obtain and apply for predictive purposes. Methods of estimating resistances have been developed and have ranged from simple, constant values assumed to apply over all time periods to complex functions which vary the resistance throughout the day and throughout the year.

In much of the work relating to stomatal resistance reported in the literature, relations have been developed which describe the conductance, rather than the resistance, of the stomates. Conductance, which is the inverse of resistance, has been found to be related to and more easily described in terms of the atmospheric parameters influencing stomatal behavior (Jones, 1983). A wide variety of models of stomatal conductance have been developed based on atmospheric and soil parameters which differ depending on the intended use of the model. Models have been developed for use in studying leaf function, in assessing crop and forest production, and in climate prediction and remote sensing.

Since almost all water transpired by plants passes through stomatal openings on leaf surfaces, stomata have a central role in regulating water vapor exchange from plants (Jones, 1983). Factors affecting stomatal response have been studied and include environmental variables such as incident radiation, carbon dioxide concentration, leaf water status, leaf-to-air vapor pressure difference, and temperature (Rutter, 1975; Jarvis and Mansfield, 1981; Jones, 1983; Rosenberg et al., 1983; Oke, 1987). Due to the difficulty in measuring these parameters, however, models have often been based on more easily and commonly measured atmospheric and soil parameters related to those listed above. Atmospheric parameters have included solar radiation, atmospheric vapor-pressure deficit, humidity, and air temperature. Soil parameters have included soil water potential and soil water content.

A common approach used in modeling stomatal conductance is that proposed by Stewart (1988). A model was developed consisting of a maximum conductance multiplied by a series of stress functions or response curves which reduce the conductance depending on the level of stress. Response curves account for changes in solar radiation, specific-humidity deficit, temperature, and soil moisture deficit, and their effects on the stomatal behavior of the plant leaves. Others, such as Avissar et al. (1985), Shuttleworth (1991), and Massman and Kaufman (1991) have proposed similar models containing a maximum and/or minimum conductance and a series of multiplicative response curves. Response curves used to modify stomatal conductance vary for the different weather parameters, with typical shapes shown in Figure 2.1 (Jarvis and Mansfield, 1981; Grace, 1983; Oke, 1987; Stewart, 1988; Shuttleworth, 1991). Different researchers have proposed unique empirical functions to model each stress and provide response curves similar to those shown in Figure 2.1.

Avissar et al. (1985) took a slightly different approach by modeling stomatal conductance using a threshold concept. In place of response curves for each

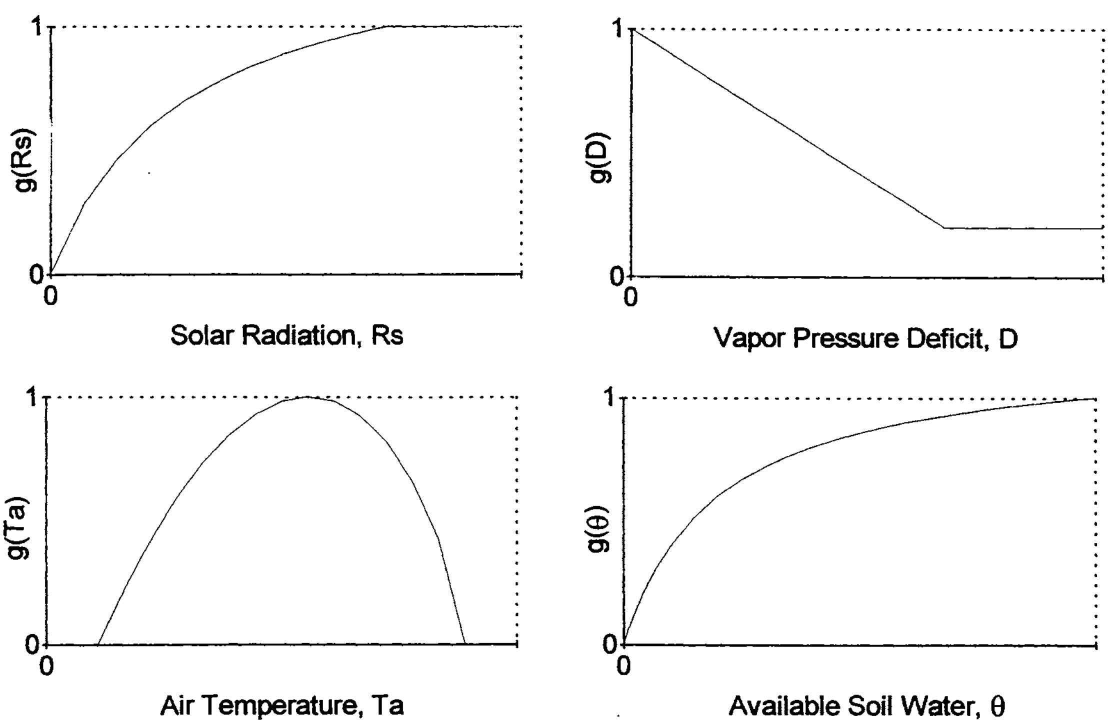

Figure 2.1. Shapes of Stomatal Conductance Response Curves.

weather parameter, threshold functions were used. For each parameter, there was assumed to be no change in stomatal conductance until a critical value was reached. Beyond this threshold value, stomatal conductance dropped off rapidly to some minimum value. Stomatal conductance was determined by a series of multiplicative threshold functions which varied conductance between minimum and maximum values.

In formulating models for stomatal conductance, not all stress functions have been included. Some researchers have chosen to omit certain parameters which were not considered to be significant, were not measured, or could not be estimated. In other cases, empirical models were developed which included parameters other than those listed above.

The model proposed by Stewart (1988) has been often cited in recent work involving ET estimation using the Penman-Monteith and Shuttleworth-Wallace methods. Adams et al. (1991) used the Stewart model to estimate canopy conductance and evapotranspiration from a grass-covered forest clearcut. Stannard (1993) developed a model which included vapor pressure deficit and radiation, but found that the inclusion of air temperature and soil moisture deficit functions did not improve the accuracy of the model.

Lafleur and Rouse (1990) developed a model to account for diurnal changes in canopy resistance. Resistance was assumed to follow a regular daily course and was based on time of day, solar radiation, vapor pressure deficit, and leaf-area index. Massman (1992) examined several models of canopy conductance based on photosynthetically active radiation, leaf-to-air vapor pressure deficit, and relative humidity. Shuttleworth and Gurney (1990) proposed a model based on solar radiation and an extinction coefficient representing the decrease in radiation available to the plant as it passed through the plant canopy. This model was later used by Farahani and Bausch (1994).

In order to estimate ET using the Shuttleworth-Wallace method, the resistance of the plant canopy, rather than the resistance of individual leaf stomates is needed. Canopy resistance takes the stomatal resistances of individual leaves into account to determine the overall resistance of the entire plant canopy by adjusting the stomatal resistance for the amount of exposed leaf area in the canopy. This involves dividing the stomatal resistance by the effective leaf area of the canopy. The effective leaf area is that amount of leaf surface area per unit soil surface area which is actively transpiring and contributing to the total evaporation of the canopy. Effective leaf area has been the topic of some debate, with values usually assumed to be one-half, one, or two, depending on the amount of leaf area assumed to be actively transpiring (Shuttleworth and Wallace, 1985; Jensen, et al., 1990; Stannard, 1993; Farahani and Bausch, 1994). Differences arise depending on assumptions about the actual transpiration from the leaves and from the three-dimensional canopy: from one side versus two sides of the leaf; only from the upper levels of the canopy in direct sunlight; from the entire canopy weighted by the leaf area of the canopy at different levels in the canopy; etc.

In almost all work reported relating to the estimation of canopy resistance, one characteristic of the vegetation, dormancy, has not been considered explicitly. Evapotranspiration research has often involved annual crops and has been limited to the growing season of these crops. Evapotranspiration measurements have often been made with Bowen-ratio or eddy-correlation equipment, and maintenance and environmental conditions have limited the duration of ET measurements. Evaporation occurring during periods when the vegetation has been dormant appears to have received little attention, and methods of estimating parameters for use in ET estimation models during periods of inactive vegetation have not been adequately addressed. In one study of evaporation from a grassland water catchment area, Wright and Harding (1993) reported that ET estimates calculated using the Penman equation were significantly higher than measured values. The difference was attributed to the reduction in actual ET from the vegetation during dormant periods, when the ET model failed to account for inactive vegetation and overestimated ET. Models were tested to account for changes in vegetative cover and for periods of dormancy, and also for evaporation of intercepted rainfall on vegetation which could still occur during dormant periods.

A range of values of canopy resistance has been reported for different grass and native vegetation covers under various environmental conditions. Ranges of resistances and average daytime values reported in the literature are shown in Table 2.1.

Table 2.1. Canopy Resistance Values Reported for Grass.

Vegetation	Resistance (s/m)	Reference
Prairie	100 - 600	Ripley and Redmann (1976)
Grassland	35 - 280	Dunin et al. (1981)
Shortgrass steppe	200	Parton et al. (1981)
Grassland	100 - 588*	Jones (1983)
Short grass	70	Oke (1987)
Tall grass prairie	100	Stewart and Gay (1989)
Pinegrass clearcut	150	Adams et al. (1991)
Grassland	60 - 200	Rowntree (1991)

* resistance values shown were converted from reported conductance values

Soil Surface Resistance

The soil surface resistance for bare soil is analogous to the canopy resistance for vegetation; the resistance is intended to account for the regulation of the flow of water to the surface, from which it can then be evaporated. Camillo and Gurney (1986) noted that, while physical models have been developed to describe canopy resistance and evaporation from vegetation, similar efforts to describe bare-soil surface resistance and evaporation have been lacking.

A model of soil surface resistance was discussed by Camillo and Gurney (1986) in which resistance is estimated using a non-linear, empirical relationship based on soil moisture content in a very thin (5 mm) surface layer. Another empirical model was developed and tested which estimates the resistance as a linear function of soil moisture in the same thin surface layer.

Lascano et al. (1987) modified a water balance model to more accurately estimate soil and crop evaporation for sparse-canopy conditions by including a soil surface resistance term. The resistance is assumed to be related to the above-canopy aerodynamic resistance and an exponential function of leaf-area index.

In work reported using the Shuttleworth-Wallace model, different approaches have been taken to determine the soil surface resistance. In the original formulation of the model, Shuttleworth and Wallace (1985) noted a lack of work in defining and describing soil surface resistance and used assumed values in discussions of model application and performance. Lefleur and Rouse (1990), working in a wetland area in which the soil surface was always wet, assumed the soil surface resistance to be small and negligible.

Farahani and Bausch (1994) developed a relationship based on ET measurements made early in the season when leaf-area index was very small and soil evaporation was assumed to dominate. The soil surface resistance was modeled as a power function involving soil moisture in a shallow surface layer, soil moisture content at saturation, and an estimated soil surface resistance at saturation.

Massman (1992) developed a model for soil surface resistance based on the soil Bowen ratio, which was expressed as a function of soil moisture, psychrometric constant, and vapor-pressure versus temperature curve. Massman noted that, while the resistance model fit his data well, the soil moisture function could not be quantified or used predictively.

Stannard (1993) needed a simple model for soil surface resistance because no soil surface temperature or near-surface soil moisture data were collected. A model was developed in which resistance at some time after a rainfall was proportional to the amount of water evaporated since the rainfall.

EVAPOTRANSPIRATION UNDER RANGE/PASTURE CONDITIONS

Studies of ET from range and pasture areas have been undertaken for a variety of reasons. Dugas and Mayeux (1991) and Weltz and Blackburn (1993) wanted to quantify evapotranspiration from rangeland in order to determine the quantity of water which could be put to alternate uses. Wight et al. (1986) discussed the importance of ET estimates from rangeland in developing hydrologic and plant growth models. Stewart and Gay (1989) collected ET data from a tallgrass prairie for use in developing and validating remote sensing algorithms for estimating surface fluxes. Wright and Harding (1993) needed ET measurements in order to modify equations used to estimate yield from a water catchment area used for water supply and hydrolelectric generation. A variety of turfgrass studies have been undertaken in order to quantify water use from grasses commonly used in urban areas and improved pastures and the effects of management practices on water use and productivity (Kneebone et al., 1992).

Vegetation types have ranged from irrigated and carefully managed turfgrasses and improved pasture to native pasture and native rangeland. Methods used to measure ET have included soil moisture and water balance measurements (Rawls et al., 1973), eddy correlation (Adams et al., 1991), Bowen-ratio energy-balance (Dugas and Mayeux, 1991), and lysimetry (Parton et al, 1981; Wight et al., 1986; Wright and Harding, 1993).

Methods used to estimate ET have been similar to those used under agricultural conditions. Ritchie et al. (1976) developed an empirical method of independently calculating evaporation from the plant and the soil. Weltz and Blackburn (1993) evaluated a hydrologic simulation model which used the Jensen-Haise ET estimation method with crop coefficients designed for semiarid rangelands. Stewart and Gay (1989), Adams et al. (1991), and Wright and Harding (1993) used the Penman-Monteith equation, with Wright and Harding including a term to account for periods of dormant vegetation. Wight et al. (1986) tested the applicability of three existing cropland and rangeland models in estimating ET from a native range.

Chapter 3

DATA COLLECTION PROCEDURES

The steps involved in acquiring data included identifying suitable sites at which to locate the lysimeters, installing equipment in the field, and developing procedures for making measurements and analyzing data. Sites were needed near a Mesonet weather station so that lysimeter measurements could be made remotely. Lysimeters were then constructed, installed, and connected to the weather stations. Lysimeter, weather, soil moisture, and vegetation data collection and analysis procedures were then developed.

SITE DESCRIPTIONS

Lysimeter sites were chosen to reflect the diversity of climatic conditions, soil types, and vegetation occurring across Oklahoma. Of the approximately 43 million acres comprising the State of Oklahoma, about 15 million acres are in native grasses and an additional 6 million acres are in introduced grasses (David M. Engle, Oklahoma State University Department of Agronomy, personal communication). Due to the importance of range and pasture grasses, therefore, lysimeters were located in range and pasture sites generally representative of large areas of the state.

Lysimeter sites ranged from the low-rainfall High Plains region of the Oklahoma Panhandle, to the moderate-rainfall central prairie area, to the high-rainfall Ouachita Highlands area in the east. The locations of the four installed lysimeters are shown in Figure 3.1. Locations, climatic conditions, terrain, and soil and vegetative conditions for each site are described in the following sections, and are summarized in Table 3.1.

Goodwell

The Goodwell lysimeter was installed in August 1993 in a pasture at the Oklahoma State University Agricultural Experiment Station at Panhandle State University at Goodwell in Texas County. The Mesonet weather station is located at 36° 37' North latitude and 101° 37' West longitude at an elevation of 995 m above

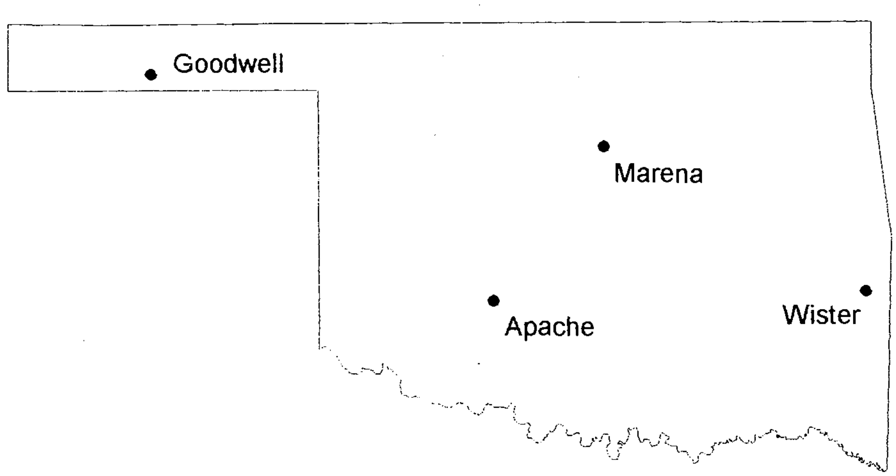

Figure 3.1. Location of Lysimeter Sites.

sea level. The lysimeter is located approximately 30 m south-southwest of the Mesonet station. One-way driving distance to the lysimeter site from Stillwater is 450 km.

Data reported by the Soil Conservation Service (1956) for the period 1910-1955 give an indication of weather conditions in Texas county. Annual average precipitation for the region is approximately 430 mm. The last freeze of the winter usually occurs in mid-April and the first freeze in fall around the end of October, for a frost-free period of about 190 days. Temperatures range from an average of 1.3°C in January to an average of 26.4°C in July and August.

The terrain surrounding the site is relatively flat in all directions, with the only noticeable relief being a 2-m drop in the ground surface occurring 100 m due north of the lysimeter. Unpaved rural roads are located 100 m east and 150 m north of the lysimeter. An isolated, sparse stand of trees is located approximately 150 m northeast of the lysimeter. A photograph of the lysimeter site taken in August 1994 is shown in Figure 3.2.

The soil at the site is a Ulysses clay loam. The Soil Conservation Service (1956) describes this as a deep, moderately fine-textured, calcareous soil. The surface soil is grayish-brown clay loam, with a calcareous subsoil. The soil is well-drained, absorbs water readily, and has a moderate water-storage capacity.

Vegetation consists almost entirely of buffalograss (buchloe dactyloides), a native, warm-season, perennial short grass. Six-weeks fescue (festuca octoflora), a native, warm-season, annual grass, and little barley (hordeum pusillum), a native, cool-season, annual grass are also present. A photograph of the vegetative conditions on the lysimeter at Goodwell taken in August 1994 is shown in Figure 3.3.

Figure 3.2. Photograph of Goodwell Site.

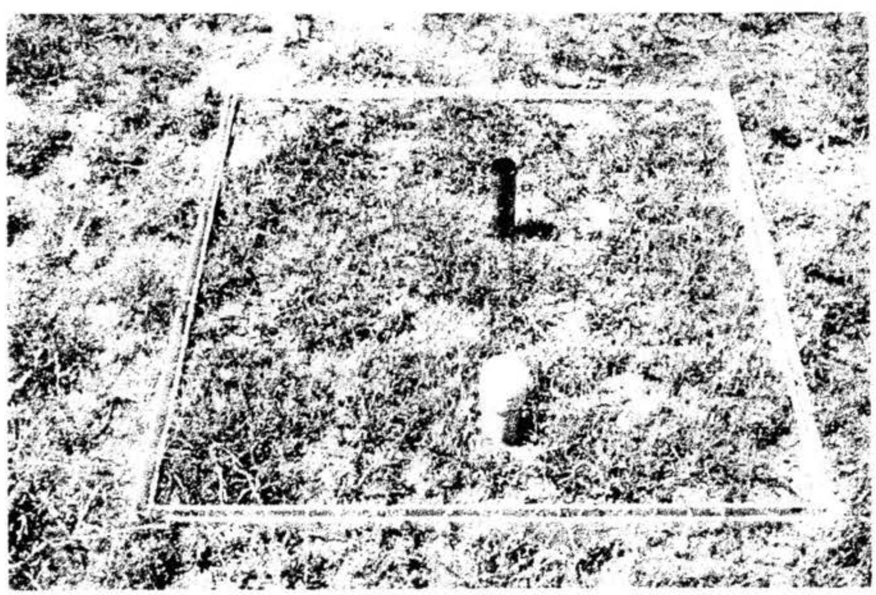

Figure 3.3. Photograph of Lysimeter at Goodwell.

Apache

The Apache lysimeter was installed in October 1993 in a pasture belonging to a private landowner approximately 8 km north-east of the town of Apache in Caddo County. The Mesonet weather station is located at 34° 55' North latitude and 98° 18' West longitude at an elevation of 440 m above sea level. The lysimeter is located approximately 20 m southwest of the Mesonet station. One-way driving distance to the lysimeter site from Stillwater is 230 km.

Data reported by the Soil Conservation Service (1974) for the period 1931-1960 give an indication of weather conditions in Caddo county. Annual average precipitation for the region is approximately 820 mm. The last freeze of the winter usually occurs in mid-March and the first freeze in fall around the end of October, for a frost-free period of about 220 days. Temperatures range from an average of 4.4°C in January, with an average minimum of -2.2°C, to an average of 28.4°C in August, with an average maximum of 36.2°C.

The terrain surrounding the site is flat in all directions, with fields planted to agricultural crops, mostly wheat, on all sides of the pasture. An unpaved rural road is located 200 m south of the lysimeter, and wheat fields are located 300 m to the west and 300 m to the east. Pasture extends more than 1000 m to the north. A photograph of the lysimeter site taken in October 1994 is shown in Figure 3.4.

The soil at the site is a Norge silt loam. The Soil Conservation Service (1974) describes this as a deep soil consisting of a reddish-brown silt loam underlain by a reddish-brown silty clay loam subsoil. The soil is well-drained, has a moderate intake rate, and a high available water capacity, estimated at 0.14-0.17 mm/mm of soil.

The pasture vegetation consists primarily of bermudagrass (cynodon dactylon), a warm-season perennial grass. Japanese brome (bromus japonicus) and little barley (hordeum pusillum), cool-season, annual grasses, are also present. A photograph of the vegetative conditions on the lysimeter at Apache taken in September 1994 is shown in Figure 3.5.

Marena

The Marena lysimeter was installed in June 1993 at the Range Research Station of the Oklahoma State University Department of Agronomy approximately 20 km south and west of Stillwater in Payne County. The Mesonet weather station is located at 36° 4' North latitude and 97° 13' West longitude at an elevation of 330 m. The lysimeter is located 60 m west-southwest of the Mesonet station. One-way driving distance to the lysimeter site from Stillwater is 20 km.

The terrain surrounding the site slopes to the south at about a 3% grade. The Mesonet station is located on a flat area of land, which extends east for 20 m before encountering a sharp rise about 1.5-m high. An unpaved rural road is located 200 m east of the lysimeter, with stands of trees located approximately 100 m east of the road. Isolated trees are found northwest of the lysimeter, with the nearest tree large enough to be of concern approximately 200 m distant. A photograph of the lysimeter site taken in April 1994 is shown in Figure 3.6.

Data reported by the Soil Conservation Service (1990) for the period 1951-1978 give an indication of weather conditions in Payne county. Annual average precipitation for the region is approximately 820 mm. The last freeze of the winter usually occurs in eary April and the first freeze in fall around the end of October, for a frost-free period of about 210 days. Temperatures range from an average of 2.1°C in January, with an average minimum of -4.6°C, to an average of 27.8°C in July and August, with an average maximum of 34.3°C.

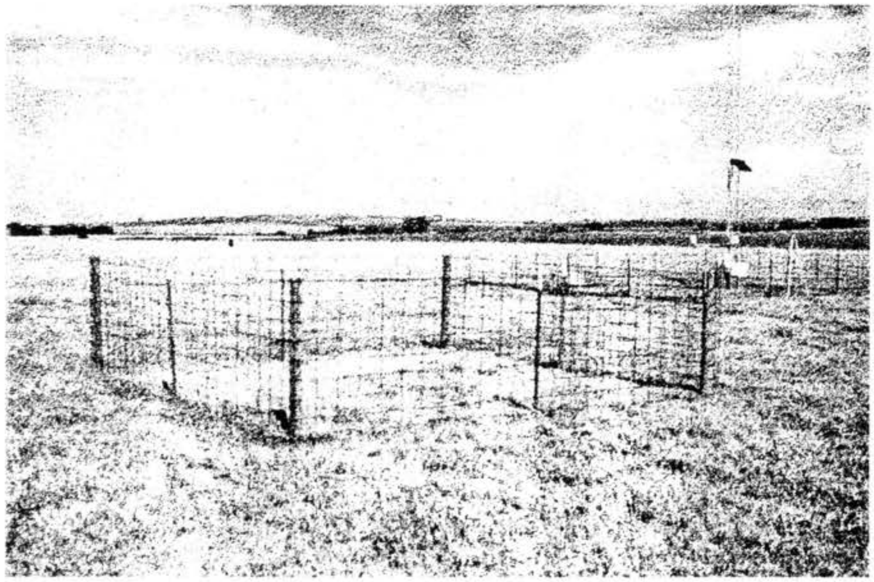

Figure 3.4. Photograph of Apache Site.

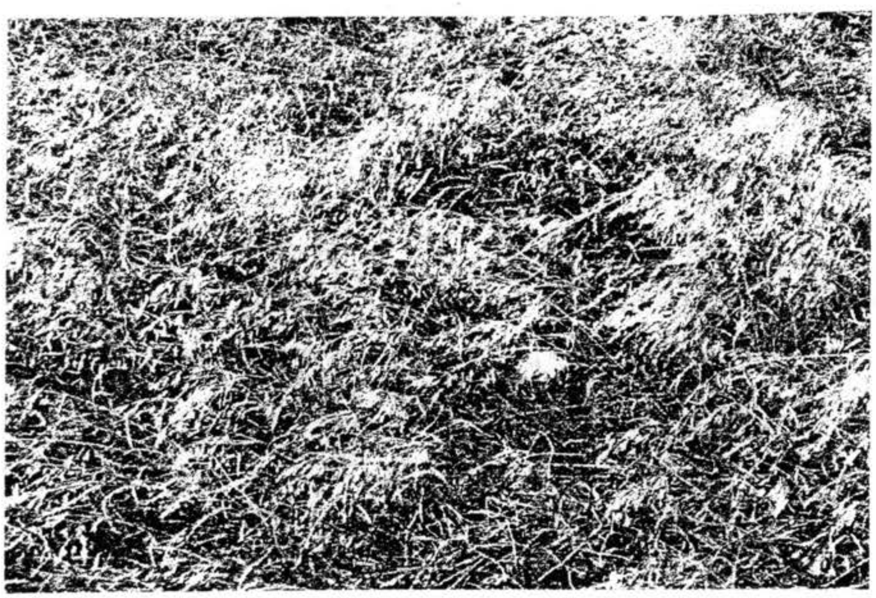

Figure 3.5. Photograph of Lysimeter at Apache.

The soil at the site is a Grainola-Lucien complex. The Soil Conservation Service (1990) describes this as a silty clay loam with underlying shale and sandstone layers. The surface soil consists of a reddish-brown loam with a silty clay loam subsoil. Sandstone and shale layers occur at depths greater than 0.6 m. The soil has a slow permeability and a low to medium available water capacity, estimated to be 0.10-0.20 mm/mm of soil in the upper layers and 0.02-0.20 mm/mm in deeper layers.

Vegetation consists of a mixture of native warm-season and cool-season grasses. Warm-season, perennial grasses include indiangrass (sorghastrum nutans), little bluestem (andropogon scoparius), big bluestem (andropogon gerardi), and switchgrass (panicum virgatum). Cool-season grasses include annuals such as little barley (hordeum pusillum) and Scribner panicum (panicum scribnerianum), and perennials such as Japanese brome (bromus japonicus). Other species identified in the field include forbs such as western ragweed (ambrosia psilostachya), daisy fleabane (erigeron ramosus), and western yarrow (achillea lanulosa). A photograph of the vegetative conditions on the lysimeter at Marena taken in April 1994 is shown in Figure 3.7.

Wister

The Wister lysimeter was installed in July 1993 in a pasture at the Kerr Center for Sustainable Agriculture approximately 8 km north of Poteau in Le Flore County. The Mesonet weather station is located at 34° 59' North latitude and 94° 41' West longitude at an elevation of 150 m. The lysimeter is located 40 m southeast of the Mesonet station. One-way driving distance to the lysimeter site from Stillwater is 350 km.

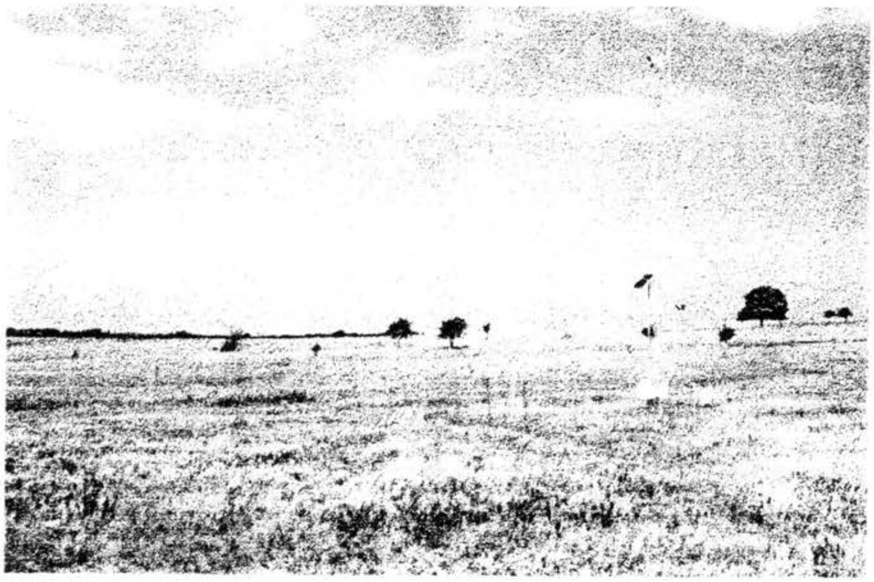

Figure 3.6. Photograph of Marena Site.

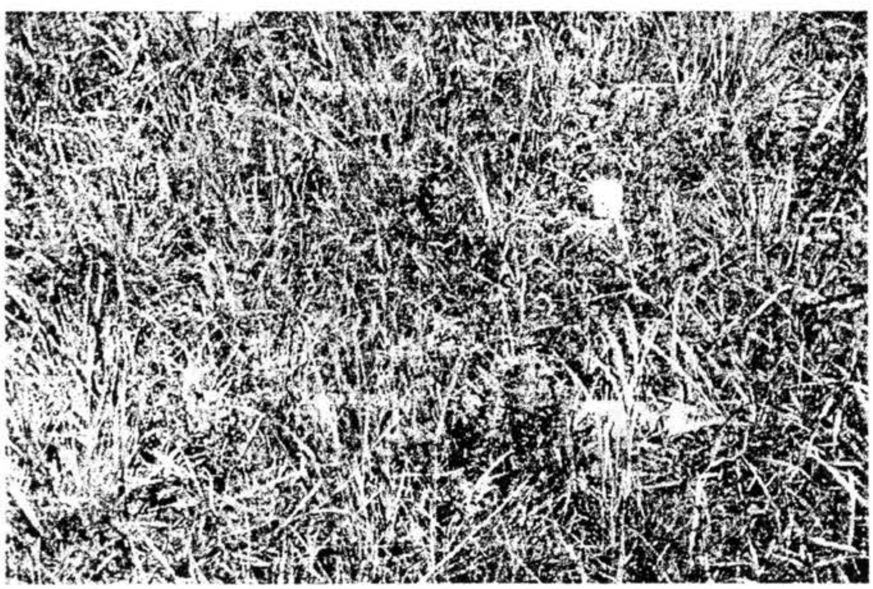

Figure 3.7. Photograph of Lysimeter at Marena.

Data reported by the Soil Conservation Service (1982) for the period 1951-1974 give an indication of weather conditions in LeFlore county. Annual average precipitation for the region is approximately 1140 mm. The last freeze of the winter usually occurs in early March and the first freeze in fall in early November, for a frost-free period of about 240 days. Temperatures range from an average of 4.9°C in January, with an average minimum of -1.5°C, to an average of 28.2°C in August, with an average maximum of 34.8°C.

The terrain surrounding the site is flat in all directions, with a 2-m drop in the ground surface occurring 200 m west of the lysimeter. Fields on all sides of the lysimeter pasture are under grazed-pasture conditions. A paved road is located 200 m north of the lysimeter. A small creek flows around the lysimeter field at a minimum distance of 100 m from the lysimeter, with trees growing along the creek banks. A photograph of the lysimeter site taken in July 1994 is shown in Figure 3.8.

The soil at the site consists of a Wister silt loam. The Soil Conservation Service (1982) describes this as a silt loam with a silty clay subsoil and underlying shale layers. Permeability is slow and available water capacity is high, estimated to be 0.14-0.24 mm/mm of soil.

Vegetation consists primarily of tall fescue (festuca arundinacea), a cool-season, perennial grass. White clover (trifolium repens), a perennial legume, is also present. A photograph of the vegetative conditions on the lysimeter at Wister taken March 1994 is shown in Figure 3.9.

Figure 3.8. Photograph of Wister Site.

Figure 3.9. Photograph of Lysimeter at Wister.

Table 3.1. Summary of Lysimeter Site Conditions.

Site	General description	Dominant vegetation	Soil type
Goodwell	shortgrass prairie	buffalograss	clay loam
Apache	introduced pasture	bermuda	sandy loam
Marena	native prairie	bluestem	clay loam
Wister	introduced pasture	tall fescue	silt loam

DESIGN AND INSTALLATION OF FIELD EQUIPMENT

Evapotranspiration measurements were collected using weighing lysimeters installed near Mesonet weather stations. The lysimeters were designed to be low-cost and relatively easy to install and maintain. Installation was accomplished by hand-digging in order to minimize disturbance of the vegetation around the lysimeter. Access tubes were installed at each site to allow soil water measurements to be made inside and outside the lysimeter. The design and installation procedures for the equipment are detailed in the following sections.

Lysimeter Design

The lysimeters developed for this project are a modification of those designed and installed at Utah State University (Allen and Fisher, 1990). Modifications to the original design involve the placement of the loadcells below ground, and a deepening of the inner and outer tanks. The loadcells are placed approximately 0.4 m below the surface in order to reduce thermal effects on loadcell performance noted by Allen and Fisher. Placing the loadcells below the surface removes them from direct exposure to solar radiation, and still allows them to be accessed for inspection or replacement if necessary. The depths of the inner and outer tanks were increased in order to increase the depth of the artificial impermeable boundary created inside the lysimeter by the bottom of the inner tank.

The lysimeters consist essentially of a soil-filled inner tank suspended from an outer tank. Both tanks have a square surface area (length equal to width). The inner tank has a soil surface area of 0.95 m^2, and a depth of 1.5 m. The outer tank has an outer surface area of 1.05 m^2, and a depth of 1.6 m, resulting in an air gap between inner and outer tanks of about 15 mm on each vertical side and 100 mm at the bottom. The effective surface area for transpiration is taken as 1 m^2, the average surface area of the inner and outer tanks. A gravity drain system is installed to allow periodic, manual removal of excess water from the inner tank in case the soil profile becomes saturated.

Lysimeter weight measurements are made using stainless-steel, shear-beam loadcells. The inner tank is suspended from the outer tank via four loadcells, Revere model SSB-2000. The loadcells are connected to a multiplexer, Campbell Scientific model AM-416, and in turn to a datalogger, Campbell Scientific model CR10T, which are part of a nearby Mesonet weather station. Lysimeter loadcell measurements are made and transmitted as part of the Mesonet data stream.

The expected resolution of lysimeter readings was calculated based on the specifications of the electronic components provided by the manufacturers. The resolutions of the loadcells and of the datalogger were combined to give the resolution of loadcell measurements. The loadcells have a 905 kg (2000 lb) design load capacity, and a rated output of 2 mV/V of excitation. With an excitation voltage of 1.4 V applied, the resolution of the loadcell is 905 kg / (2 mV/V * 1.4 V), or 323 kg/mV. The datalogger has a 13-bit resolution in analog-to-digital signal conversion, so that the voltage range used to measure the incoming signal on the datalogger is divided into 2^{13} or 8192 parts. Using a 2.5 mV input signal range, the input resolution is 2.5 mV / 8192 bits, or 0.000305 mV/bit. Multiplying the two resolutions, (323 kg/mV) and (0.000305 mV/bit), gives 0.099 kg/bit. The method used to make a differential voltage measurement by Campbell Scientific, Inc. dataloggers effectively increases the resolution by a factor of 2. The datalogger makes one measurement, reverses polarity, makes a second measurement, and then averages the two measurements (Mark Hatfield, Campbell Scientific, Inc., personal communication, 1990). If one measurement differs from the other by one bit, the averaging would provide a value with a resolution of half of one bit. The combined resolution of the loadcell and datalogger therefore becomes 0.050 kg/bit. Loadcell measurements available via the Mesonet computer link, however, are rounded off and reported to the nearest 0.1 lb (0.045 kg), so the reported resolution is 0.045 kg. This does not imply that measured resolution is improved, but it does mean that the measured resolution is not degraded through the reporting system.

Lysimeter Fabrication

The lysimeters were built at the Biosystems and Agricultural Engineering Laboratory at Oklahoma State University. Fabrication consisted of the construction of the steel inner and outer tank assemblies and the PVC drain assembly. Assembly drawings for the outer and inner tanks are shown in Figures 3.10 and 3.11, and the complete lysimeter assembly is shown in Figure 3.12.

The inner and outer tanks were constructed of 4.8-mm thick steel plate. The plates were welded together along the seams, and 25 x 75-mm steel channels were welded to the sides and bottom for strengthening. Loadcell brackets were constructed of 6.4-mm thick steel, and were later bolted to the inner and outer tanks.

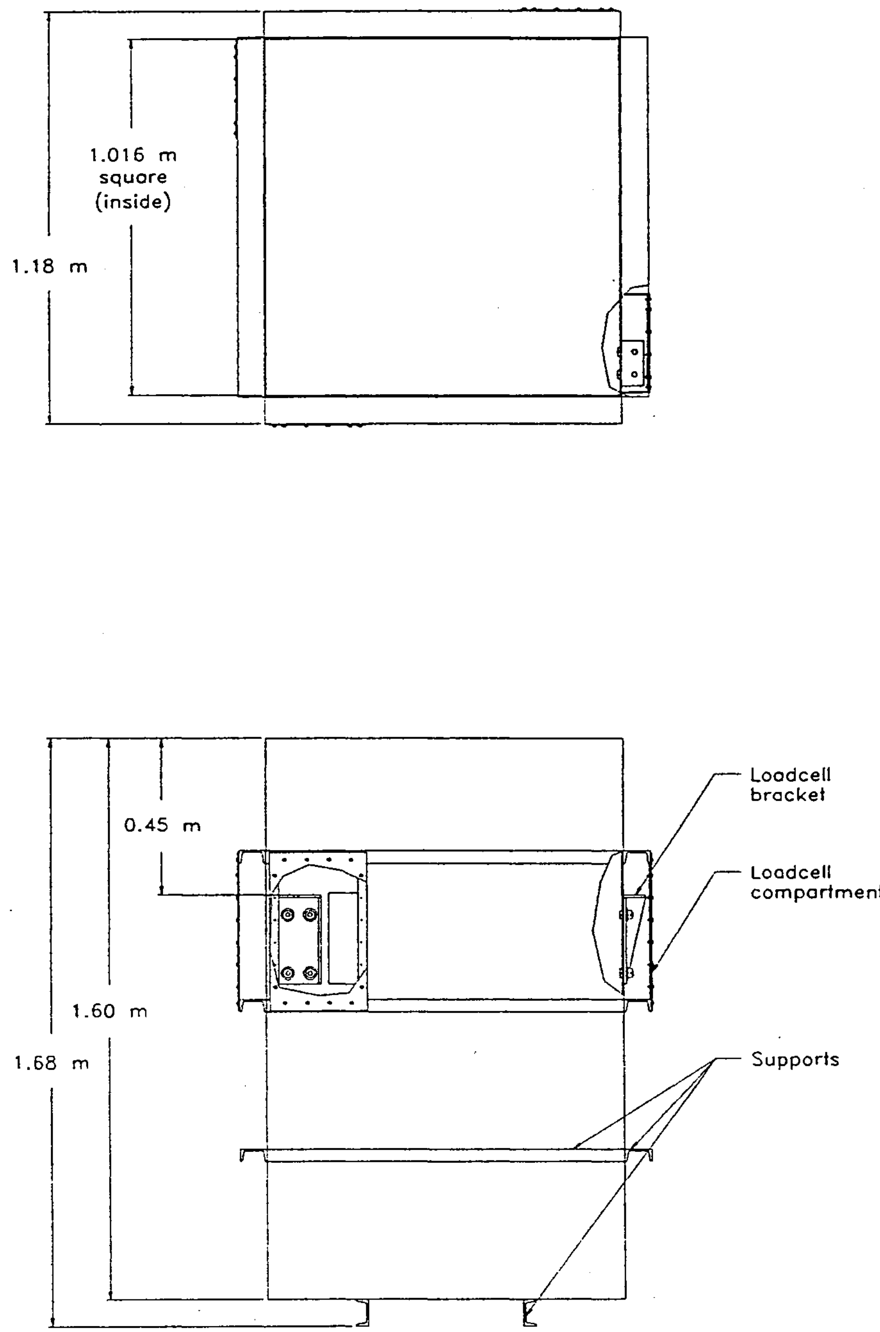

Figure 3.6. Lysimeter Outer Tank Assembly.

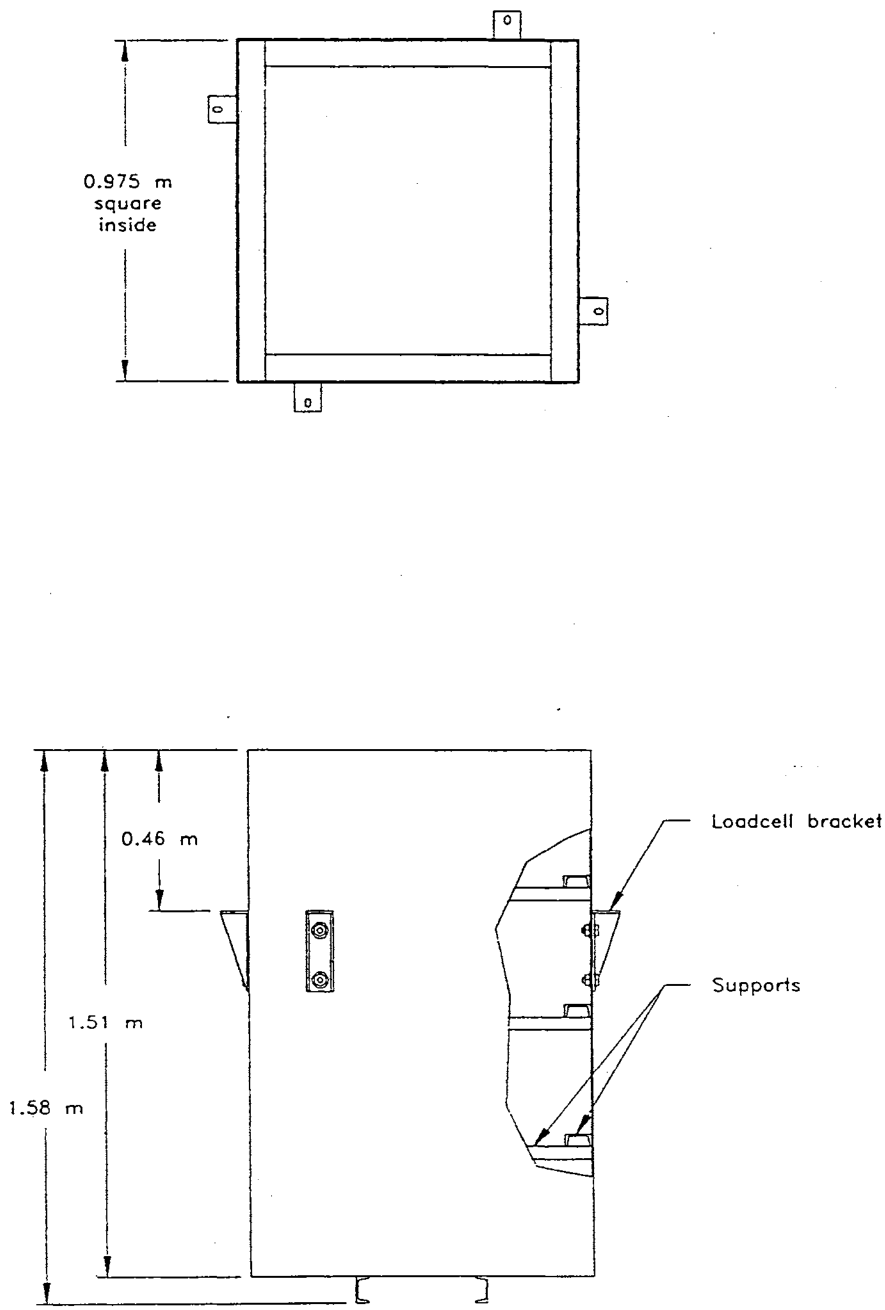

Figure 3.7. Lysimeter Inner Tank Assembly.

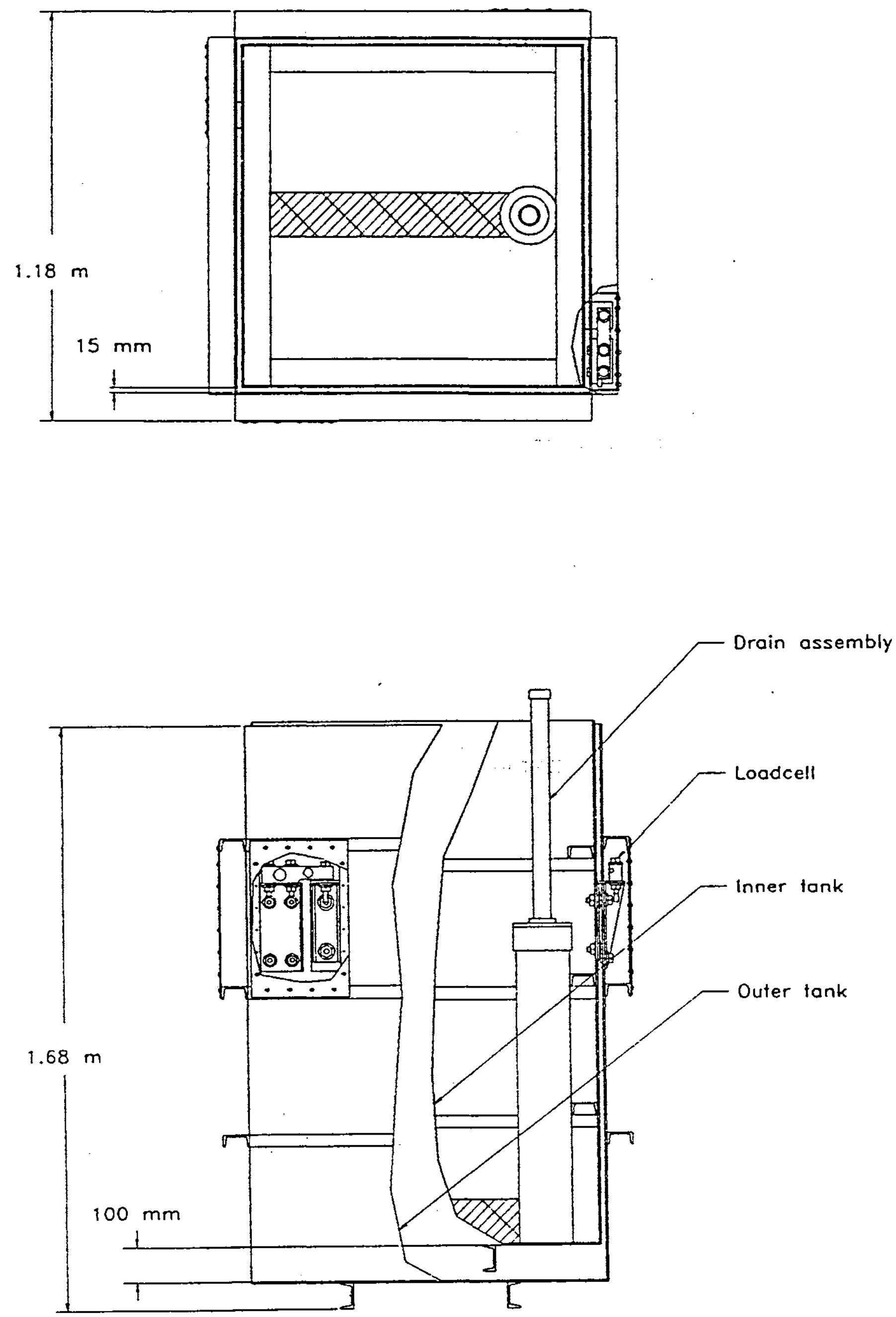

Figure 3.8. Lysimeter Assembly.

Loadcell compartments were constructed of 3-mm thick steel plate, and were welded onto the outer tank. Inner and outer tanks were covered with two coats of white enamel paint. Total constructed weights of the inner and outer tanks were estimated to be 360 kg and 390 kg, respectively.

The drain system consists of a horizontal drain pipe attached to a vertical standpipe. The horizontal pipe is perforated PVC pipe, 150 mm in diameter, covered with several wraps of plastic mesh. The vertical standpipe consists of a 0.9-m length of PVC pipe, 150 mm in diameter, a reducing coupler, and a 0.65-m length of 50-mm diameter PVC pipe. A drawing of the drain assembly is found in Appendix A.

The cost, in 1992, of the materials used to construct one lysimeter was approximately $2900. This included $530 for each loadcell, $480 for steel, and $300 for PVC pipe, electrical cable, bolts, and miscellaneous items. Labor for fabrication and installation is not included.

Lysimeter Installation

The site was prepared by first marking the location for the lysimeter. A square area 1 m on each side was laid out on the ground by inserting flags at each corner and connecting the flags with string to mark each side. A second square was laid out around the first square, with sides parallel to the first square and offset by 0.3 m. Plywood sheets were laid on the ground beyond the second, larger square area to provide a working surface in order to minimize disturbance of the vegetation around the lysimeter. Plastic sheeting was laid out beyond the plywood sheets to provide a place to put excavated soil.

Excavation was begun by making vertical cuts in the surface along the inner and outer markings. A large flat-bladed spade was used to cut the soil to a depth of approximately 0.4 m. A drawing of the flat-bladed spade can be found in Appendix A.

After cutting the soil, shovels were used to remove blocks of soil and vegetation. Sod blocks 0.15-0.3 m deep were removed from the area between the inner and outer marks and were placed on the plastic sheeting. Soil was then removed from this area to a depth of 0.4 m, resulting in a trench around an undisturbed inner area of soil and vegetation.

The inner area was then divided into nine squares, each approximately 0.3 m on a side. The flat-bladed spade was used to cut the squares into blocks 0.3-0.4 m deep in an attempt to preserve the soil structure and plant roots. The blocks were then removed and set aside on the plastic sheeting.

Excavation of the hole was accomplished by removing soil in layers, with each layer removed and placed on a separate pile on the plastic sheeting. Excavation continued to a depth of 1.6 m. The bottom of the hole was then leveled and two small trenches were dug to allow clearance for the bottom support channels on the outer tank.

A steel frame had been constructed for use in lowering the steel tanks into the ground. The frame consisted of welded steel side and top sections which could be easily transported and bolted together at the site. The frame was erected and placed over the hole, and a chain hoist was attached to the frame. Wooden planks were placed over the hole and sections of steel pipe were used to roll the lysimeter outer tank into position over the hole. The tank was attached to the hoist with a steel chain, raised slightly, and the steel rollers and wooden planks were removed. The tank was then lowered into the hole, centered in the hole, and placed on the bottom. The chain hoist was removed and the tank was checked to ensure that it was level.

The inner tank was installed similarly. The wooden planks were placed over the outer tank, the inner tank was rolled into position, and lowered into the outer tank. The inner tank was lowered until it rested on the floor of the outer tank, and was positioned so that it was centered within the outer tank.

The inner tank loadcell brackets were bolted onto the outside of the inner tank. Caulking was applied to the washers and bolt heads so that the inner tank would be water tight.

The drain system was placed inside the inner tank with the horizontal drain pipe laying flat on the floor of the tank. A layer of gravel 150-mm deep was added to cover the horizontal drain pipe, and a layer of sand 50 mm deep was placed on top of the gravel.

Backfilling of the soil began by replacing the soil in the annular area outside the outer tank. The soil was replaced in layers, with soil replaced at the same depth from which it was excavated, and then compacted. This continued until the level of the soil in the outer annular area reached that of the sand inside the inner tank. Backfilling then continued both in the outer annular area and inside the inner tank. When the level in the outer area reached the bottom of the outside loadcell compartments, backfilling was stopped in the outer area.

Backfilling continued inside the inner tank until the level of the soil reached the depth of the sod blocks. The sod blocks were then replaced inside the inner tank. Some trimming on the sides of the blocks was necessary in order to fit the blocks tightly together, and to fit around the vertical standpipe of the drain assembly.

The loadcells were bolted onto the outer tank loadcell brackets, and were temporarily wired into a spare electronic datalogger. The loadcells were bolted to the inner tank loadcell brackets and were tightened in order to raise the inner tank off the floor of the outer tank so that the entire weight of the inner tank was supported by the loadcells. The bolts on two diagonally positioned loadcells were tightened simultaneously until the loadcell readings on the datalogger reached the nominal load rating of the loadcells. The bolts on the other two diagonally opposed loadcells were then tightened until the nominal load rating was reached. This process continued until the top of the inner tank extended about 10 mm above the top of the outer tank.

The loadcell compartment covers were then attached and caulked. The loadcell wires were removed from the datalogger and were placed inside watertight conduit. The conduit extended from each loadcell compartment, around the side of the lysimeter, to a common point at the corner of the lysimeter nearest to the Mesonet station. The annular area outside the outer tank was backfilled to the depth of the soil blocks and the soil blocks were replaced.

The loadcells were connected to the Mesonet weather station via a length of buried cable. A trench was dug 0.3 m deep and a 25-mm diameter PVC pipe was placed in the trench. The cable was run through the PVC pipe and the soil was replaced in the trench.

The loadcell wires were connected to one end of the cable. A square plastic container with a removable cover was used to house the wiring connection. Holes were drilled in the side of the container, loadcell wires and cable were inserted into the holes, and silicon sealant was applied to seal the wiring holes. Each loadcell wire was then connected to a cable wire, soldered, and isolated with a short length of electrical tape. Each connection was waterproofed with silicon sealant. When all connections were completed, the cover was sealed with silicon sealant and replaced on the plastic container. The container was placed in the ground and covered with soil. Wiring of the lysimeter was completed by connecting the other end of the cable to the Mesonet multiplexer.

Thermistors were installed in the soil in the inner tank at depths of 0.1 and 0.3 m below the soil surface. The thermistor wires were also run through the buried PVC pipe and connected to the Mesonet multiplexer.

Installation was completed by erecting a fence around the lysimeter. The fence measured 4.9 m on each side and was constructed of four 1.2-m high by 4.9-m long steel cattle panels secured by eight 1.8-m long steel T-posts. The fence was positioned so that the lysimeter was centered within the fenced area.

Installation of each lysimeter required the equivalent efforts of three people working approximately 20 to 30 hours each. On some days during installation, additional labor was available but it was found that not more than three people could be working at any one time due to the relatively small size of the hole being dug and the equipment being installed. Installation was usually accomplished over a period of three consecutive days.

After the lysimeter was installed, additional labor was required to attach the loadcell wires to the cable connecting the lysimeter to the Mesonet station, dig a trench and bury the cable, calibrate the lysimeter, install neutron-meter access tubes, and erect a fence around the lysimeter area. These tasks required the efforts of one person working approximately 20 hours.

Neutron-Meter Access-Tube Installation

Four neutron moisture probe access tubes were installed within the fenced lysimeter enclosure to allow for periodic soil-water measurements. Steel access tubes, 38 mm in inside diameter, were installed to a depth of 1.4 m, with three tubes installed within the fenced area outside the lysimeter, and one tube installed in the center of the lysimeter inner tank. The layout of the access tubes was similar for all sites and is shown in Figure 3.13.

Soil samples were extracted during the installation of the neutron-meter access tubes at each site for use in calibrating the neutron meter. The soil sampler, an SCS Madera sampler, consisted of a detachable sampling bit and a tubular handle with an adjustable cross-bar (Dickey et al., 1993). The sampling bit had two slits a fixed distance apart designed to allow for spatulas to be inserted in order to trim the soil and extract a sample of known volume. The tubular handle had a series of holes spaced at 0.15-m intervals along its length, allowing the cross-bar to be adjusted and used to measure the depth of the sampler, and as a foot support for inserting the sampler.

The Madera soil sampler purchased from the manufacturer was modified prior to use to meet the dimensional requirements of the steel access tubes installed at the

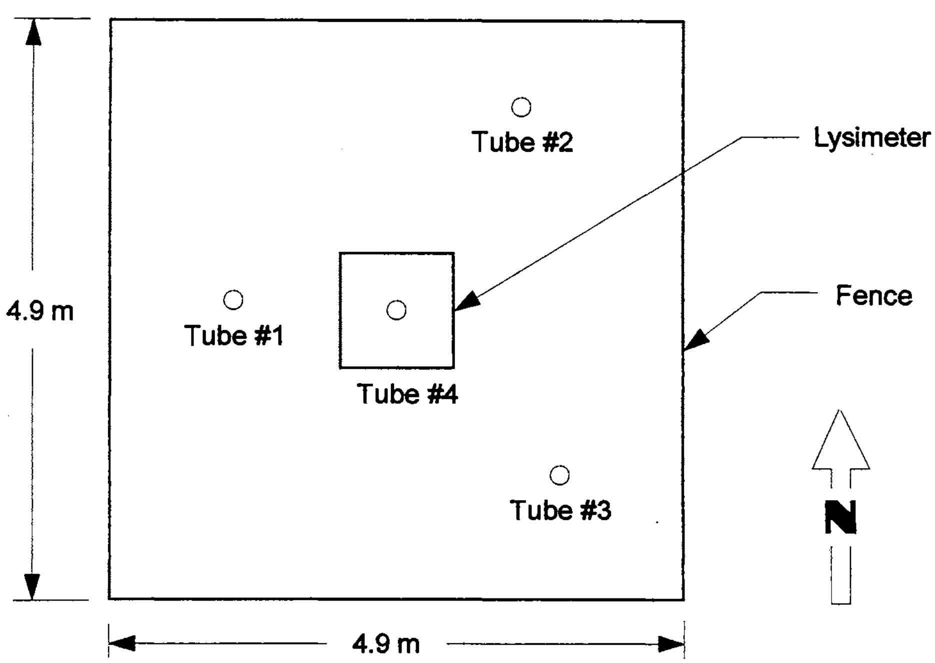

Figure 3.13. Location of Neutron-Meter Access-Tubes

lysimeter sites. The collar on the handle used to attach the sampling bit was modified in order to reduce the outside diameter from 44 mm to 38 mm. The modified sampler then had an outside diameter equal to that of the access tubes. As access-tubes holes were augered and soil samples were removed, the resulting hole had a diameter equal to that of the steel access tubes. This allowed for the access tubes to be installed very tightly in the ground, with virtually no gap between access tube and soil particles.

Access tubes were installed using a screw-type soil auger and the modified Madera soil sampler. The auger was used to remove soil to the depth of the desired sample, and the sampler used to remove the sample. Samples were extracted at 0.15-m depth intervals to a depth of 1.2 m below the soil surface. As each sample was removed from the ground, excess soil was trimmed from the ends of the sampling bit to provide samples of known volume, and the sample was placed in a metal sample can. After the last sample, at the 1.2-m depth, was removed, the auger was used to extend the hole to a depth of 1.4 m. A steel access tube was then inserted into the hole and positioned so that a tube length of 0.15 m remained above the soil surface for use in supporting the neutron meter when soil water measurements were made.

Immediately after installing an access tube, measurements were made with the neutron meter at the same depths as those from which soil samples were taken. A four-minute standard count was taken using the first access tube installed. The neutron probe element was then lowered into the access tube and four 30-second measurements were made at each depth. After completing the series of measurements, the neutron meter was removed and another access tube was installed.

Neutron Meter Calibrations

At each of the four lysimeter sites, calibration equations were developed to convert neutron-meter count measurements to volumetric soil-water contents. Linear relationships were developed using water contents determined gravimetrically from soil samples collected during neutron-meter access-tube installation. Two calibration equations were determined for each site: one equation for the access tubes outside the lysimeter and one for the access tube inside the lysimeter. A separate equation was developed for the lysimeter since the soil had been disturbed and reconstructed, resulting in a soil profile with hydraulic properties likely to be different from those of the soil outside the lysimeter.

The calibration procedure consisted of first determining the bulk density and water content of each soil sample. Soil samples were brought to the lab and were weighed in the metal sample cans in which they had been placed during access-tube installation in the field. The weight of each soil sample and sample can was measured and recorded. The sample cans were then opened and placed in an oven in order to dry the soil samples. The oven was set to approximately 105°C, and the samples were left in the oven for 24-48 hours. The samples were then removed from the oven and the weight of each sample and sample can was measured and recorded. The soil samples were then removed from the cans and the weight of each sample can was measured and recorded.

Bulk density was calculated as

$$\rho_b = \frac{W_{dry}}{V} \qquad (3.1)$$

where

ρ_b = soil bulk density, g/cm^3

W_{dry} = dry weight of the soil sample, g

V = volume of the soil sample, cm^3.

The Madera soil sampler had been designed and built by the manufacturer to provide a constant sample volume of 60 cm^3, so all samples had the same 60 cm^3 sample volume.

Soil-water contents on a weight basis were determined by calculating the weight of water in each sample relative to the weight of dry soil;

$$\theta_w = \frac{W_{water}}{W_{soil}} \tag{3.2}$$

where

θ_w = soil-water content on a weight basis, g/g

W_{water} = weight of water in the soil sample, g

W_{soil} = weight of dry soil, g.

Soil-water contents on a volume basis were then determined from

$$\theta_v = \theta_w \frac{\rho_b}{\rho_w} \tag{3.3}$$

where

θ_v = soil-water content on a volume basis, mm^3/mm^3

θ_w = soil-water content on a weight basis, g/g

ρ_b = soil bulk density, g/cm^3

ρ_w = density of water, g/cm^3.

The density of water was assumed to be 1 g/cm^3.

After determining the soil-water contents of the soil samples, calibration equations were developed to relate neutron-meter count measurements to soil-water contents. At each depth, the four neutron-meter measurements were averaged to give an average count. The average count was then converted to a relative count ratio by dividing the average count by the standard count.

Calibration equations were developed by linear regression of volumetric water content against relative count ratio to give calibration equations of the form

$$\theta = aR + b \qquad (3.4)$$

where

θ = soil-water content on a volume basis, mm^3/mm^3

R = relative count ratio

a = slope

b = intercept.

Calibration equations for the access tubes outside the lysimeters were developed by combining data from the three access tubes outside the lysimeter. Equations for use inside the lysimeter were developed from measurements made at the one access tube inside the lysimeter.

LYSIMETER OPERATION

The procedure used in obtaining lysimeter measurements involves the averaging of multiple readings. Fisher and Allen (1991) recommended this approach, rather than taking a single reading, in order to improve measurement accuracy. In order to integrate multiple lysimeter measurements with other Mesonet measurements, each loadcell on the lysimeter was read every 30 seconds. At the end of a 15-minute interval, the 30 readings taken for each loadcell during this interval were averaged and the average value was reported. The total weight of the lysimeter was then found by summing the four loadcell average voltage readings and converting the voltage to a weight. Evapotranspiration was estimated as the change in average weight from one time interval to the next.

Integration of the lysimeters with the automated weather stations of the Mesonet allowed for the continuous collection of lysimeter measurements. Lysimeter measurements were made automatically and relayed by the weather station as an integral part of the Mesonet data stream.

MESONET WEATHER DATA

The Oklahoma Mesonetwork (Mesonet) is an extensive network of automated weather stations deployed across the state of Oklahoma. The network consists of 111 weather stations operating continuously in diverse, often remote locations, measuring and reporting weather information in near-real-time (Elliott et al., 1994). The Mesonet is a long-term project created and operated by Oklahoma State University and the University of Oklahoma.

The Mesonet weather stations make continuous, automatic measurements of a variety of weather and soil parameters and report the data at 15-minute intervals. The data are reported via radio telemetry and the Oklahoma Law Enforcement Telecommunications System, with the data from all the weather stations being ingested at the Oklahoma Climatological Survey located at the University of Oklahoma. The data are then made available for dissemination to users via a computer bulletin-board system and over the Internet. The capabilities and operation of the Oklahoma Mesonetwork are described in detail by Brock et al. (1995).

Variables measured and reported by all Mesonet weather stations include solar radiation, air temperature, relative humidity, atmospheric pressure, wind speed and direction, rainfall, precipitation, and bare and sod soil temperatures. Additional variables measured at a subset of Mesonet sites include air temperature and wind speed at different heights, soil temperatures at multiple depths, and leaf wetness. The variables measured at the Mesonet stations at which the lysimeters were located are listed in Table 3.2.

Table 3.2. Parameters Measured by Weather Stations at Lysimeter Sites.

Parameter	Location	Units
Solar radiation	2 m height	W/m^2
Air temperature	1.5 and 9 m heights	°C
Wind speed	2 and 10 m heights	m/s
Relative humidity	1.5 m height	%
Rainfall	0.5 m height	mm
Atmospheric pressure	0.5 m height	kPa
Wind direction	10 m height	° from North
Soil temperatures under bare soil	50 and 100 mm depths	°C
Soil temperatures under vegetation	50, 100, and 300 mm depths	°C

SOIL WATER MEASUREMENTS

Soil water measurements were made periodically at the lysimeter sites in order to quantify and compare the water status of the lysimeters with that of the fields they are meant to represent. Measurements were made using a neutron soil-moisture meter (Troxler model 3330), and the four neutron-meter access tubes installed at each site.

Prior to operation of the neutron meter, each access tube was checked for the presence of standing water. The probe element of the neutron meter, which was lowered into the access tube and performed the actual water measurement, could be damaged if immersed in water. Any standing water found in the access tubes was removed.

A shield, or standard, count reading was obtained with the neutron meter prior to actual soil water measurements. The neutron meter was turned on and allowed to warm up for a period of five to ten minutes. The meter was placed on Access Tube #1 and, with the probe element positioned within the body of the neutron meter, a shield count lasting four minutes was taken and recorded.

Water-content readings were taken at 0.15-m intervals below the soil surface. The probe element was lowered into the access tube to a depth of 1.2 m and a series of four readings, each lasting 30 seconds, was taken and recorded. The probe was then raised 0.15 m and another series of four 30-second readings was taken and recorded. Measurements were taken in this manner at 0.15-m intervals until the last series, at a depth of 0.15 m, was taken. The neutron meter was then removed and placed on the next access tube and another series of measurements was taken. This process was repeated until readings were made at each of the four access tubes.

Actual volumetric water contents were calculated based on the average readings, the shield count, and a calibration equation determined for each site. At each depth, the average of the four 30-second readings was divided by the shield count to obtain a relative count. The relative count was then input to the calibration equation and a volumetric water content was calculated. The resulting water contents were then used to plot moisture profiles for each access tube and to estimate the total water content of the soil profile.

VEGETATION MEASUREMENTS

Measurements were made to quantify the amount of soil surface covered by vegetation, and the structure and activity of the vegetation. The structure of the vegetation included estimates of plant height and leaf-area index, and the activity of the vegetation specified the periods of active growth and of dormancy.

Leaf-area index and ground cover measurements were made using the pin frame method described by Bonham (1989). A wooden frame was constructed which consisted of a horizontal frame member with holes drilled in it attached to vertical support members. The horizontal member was 0.3 m long with 10 vertical holes spaced 30 mm apart. The support members provided a stable base and supported the horizontal member 0.6 m above the surface. A pin 1 m long was sharpened to a point on one end and was able to be moved and fit into each of the vertical holes. A drawing of the pin frame is shown in Appendix A.

Using the pin-frame method, the pin was inserted into one of the holes and lowered at a certain angle until it contacted either a plant surface or the soil surface. If the pin contacted a plant surface, the contact was recorded, the plant part was moved aside, and the pin continued to be lowered until another contact was made. This continued until the pin reached the soil surface, and the total number of plant contacts was recorded. The pin was then removed from the frame, inserted into the next hole in the frame, and another set of pin contacts was counted and recorded. After all holes were sampled, LAI estimates were made using equations relating the angle of the pin and the number of pin contacts to LAI.

Relationships developed between leaf-area index and pin contacts for different pin angles are discussed by Bonham (1989). One relationship involving pin contacts obtained at a pin angle of 32.5° (relative to vertical) is

$$LAI = 1.1 C_{32.5} \qquad (3.5)$$

where

LAI = leaf-area index

$C_{32.5}$ = number of pin contacts with pin at an angle of 32.5°.

Based on the height and width of the pin frame, and the pin angle, the resulting LAI is an average obtained over a 0.12 m^2 surface area.

A relationship involving pin contacts at two pin angles, 13° and 52°, is

$$LAI = 0.23C_{13} + 0.78C_{52} \quad (3.6)$$

where

C_{13} = number of pin contacts with pin at an angle of 13°

C_{52} = number of pin contacts with pin at an angle of 52°.

Based on the height and width of the pin frame, and the 52° angle, the resulting LAI value represents an average over an area of approximately 0.24 m^2.

Each time an LAI measurement was to be made with the pin frame, a random location on the lysimeter, inside the fence, or outside the fence was chosen and the pin frame was set down on the ground. The pin was inserted into the first hole and pin contacts were counted and recorded at each of the pin angles. The pin was then moved to the next hole and another series of contacts was made and recorded. This was repeated for all 10 holes in the pin frame. Readings from the 10 pin holes were then averaged. For each pin angle, the 10 readings at that angle were averaged, and the average value was used to estimate LAI.

The point-frame method can also be used to estimate vegetative cover by adjusting the angle of the pin relative to the surface. With the pin perpendicular to the surface, the fraction of the soil surface covered by vegetation can be estimated. In each hole, the pin is lowered until a contact is made. If the pin contacts a plant surface, the fractional area of surface represented by the pin is assumed to be covered by vegetation, and no further contacts are necessary. The fractional surface area represented by each pin is determined by the number of pin holes used. If the frame has 10 pin holes, for example, each hole would represent 10% of the area (Bonham, 1989).

The activity of the vegetation was observed in order to characterize periods of active growth and dormancy. During active periods, the vegetation within the lysimeter fence and on the lysimeter was visually compared to that in the field outside the fence. Because the lysimeter was meant to represent conditions in the larger field, it was important that conditions inside and outside the lysimeter fence be similar. At all lysimeter sites, cattle grazed periodically in the fields outside the lysimeter fence, and at one site, the field was periodically cut for hay. On several occasions, it was necessary to trim the vegetation within the lysimeter fence and on the lysimeter to match the conditions in the field outside.

DATA SUMMARY METHODS

Data collected at the lysimeter sites were analyzed and summarized to provide daily estimates of the conditions at each lysimeter site. Data included lysimeter weight measurements and weather variables from the Mesonet weather stations.

Lysimeter Data

Evapotranspiration measurements provided by each lysimeter were determined by the change in weight of the lysimeter from one time period to the next. For the daily time period used in this research effort, lysimeter weight changes were determined at 24-hour intervals.

The 24-hour interval chosen for daily ET determination was from sunrise on one day to sunrise the following day. The sunrise-to-sunrise period was chosen based on suspected thermal effects on the lysimeter loadcells, discussed later in

Chapter 5. Analysis of loadcell readings reported at 15-minute intervals throughout the day suggested that the loadcell readings reached a steady-state value during the period around sunrise.

The weight of the lysimeter at sunrise was determined as the average weight during the 1-hour period centered at sunrise. The 1-hour period included four 15-minute weight readings; two readings before sunrise, and two readings after sunrise. A 1-hour average weight was used in order to further remove some of the variability in loadcell readings due to thermal effects.

The time of sunrise was determined for each day of the year at each site based on the latitude and longitude of the site. Calculated sunrise times were then rounded to the nearest 15 minutes in order to coincide with the Mesonet reporting interval of 15 minutes. Throughout the year at each site, the actual time of sunrise, of course, changed, but due to rounding to the nearest 15 minutes, the reported sunrise time did not necessarily change from one day to the next. During those days, which made up the majority of the year, the length of the day was 24 hours. Occasionally, the sunrise time rounded to the nearest 15 minutes would change by one 15-minute interval from one day to the next. This had a slight effect on the apparent day length, the day being 23 hours and 45 minutes long if the sunrise time moved one 15-minute interval earlier, or 24 hours and 15 minutes long if the sunrise time moved one 15-minute interval later. Sunset times were also determined and rounded to the nearest 15 minutes. Sunrise and sunset times used for each site are found in Appendix F.

Weather Data

Daily summaries of various weather parameters were made from Mesonet data reported at 15-minute intervals. The parameters were summarized for the same sunrise-to-sunrise periods as the lysimeter data in order to characterize weather conditions experienced by the soil and vegetation in the lysimeters. Summaries were also made for the period from sunrise to sunset to characterize conditions during the sunlit daytime period when the majority of evaporation and transpiration was likely to occur. Daily values calculated for the weather parameters at each site are described below, and are summarized in Table 3.3.

Solar radiation was totaled for the 24-hour sunrise-to-sunrise period. For each 15-minute period, the average radiation flux in W/m^2 was multiplied by the 15-minute time interval to give an estimate of the total radiant energy during the interval. The 15-minute values were then summed over the 24-hour period to obtain the daily total solar radiation.

Maximum, minimum, and average air temperatures were determined at a height of 1.5 m above the ground surface. The maximum and minimum temperatures which occurred during the 24-hour sunrise-to-sunrise period were recorded. The average temperature was determined for the daytime, sunrise-to-sunset period by

Table 3.3. Daily Values Calculated for Weather Parameters at Lysimeter Sites.

Parameter	Location	Value	Units
Solar radiation	2 m	24-h total	MJ/m^2
Air temperature	1.5 m	24-h maximum	°C
		24-h minimum	°C
		daytime mean	°C
Relative humidity	1.5 m	24-h maximum	%
		24-h minimum	%
Dew-point temperature	1.5 m	24-h average	°C
Vapor-pressure deficit	1.5 m	daytime average	kPa
Precipitation	0.5 m	24-h total	mm
Wind	2 m	24-h total wind run	km
		24-h day-night wind ratio	
		daytime average speed	m/s
Atmospheric pressure	0.5 m	24-h mean	kPa

summing the 15-minute air temperature measurements during this period and dividing the total by the number of 15-minute intervals.

Maximum and minimum relative humidities were determined at a height of 1.5 m above the ground surface for the 24-hour sunrise-to-sunrise period.

A daily average dew-point temperature was calculated for the 24-hour sunrise-to-sunrise period by averaging the dew-point temperatures for each 15-minute interval throughout the 24-hour period. Dew-point temperature was calculated for each 15-minute interval based on relative humidity and air temperature using the relationship found in Cuenca (1989),

$$T_d = \left(\frac{RH}{100}\right)^{1/8}(112 + 0.9T_a) - 112 + 0.1T_a \tag{3.7}$$

where

T_d = dew-point temperature, C

RH = relative humidity, %

T_a = air temperature, C.

An estimate of the daily vapor pressure deficit was obtained by averaging the vapor pressure deficits calculated for each 15-minute interval for the daytime period of each day. The daytime period was used so that vapor pressure deficit was estimated for the same time period as other parameters, including net radiation and wind speed. Measured air temperature and relative humidity were used to calculate the vapor pressure deficit from

$$D = e_s(T_a) - e_a(T_a) \tag{3.8}$$

where

D = vapor pressure deficit, kPa

$e_s(T_a)$ = saturation vapor pressure at air temperature T_a, kPa

$e_a(T_a)$ = actual vapor pressure at air temperature T_a, kPa.

The saturation vapor pressure was calculated from the equation developed by Tetons (Jensen et al., 1990)

$$e_s(T_a) = \exp\left(\frac{16.78T_a - 116.9}{T_a + 237.3}\right) \tag{3.9}$$

The actual vapor pressure was calculated from the definition of relative humidity

$$e_a(T_a) = RHe_s(T_a) \tag{3.10}$$

where

RH = relative humidity.

Total rainfall was calculated for the 24-hour sunrise-to-sunrise period by summing the rainfall amount reported by the raingage for each 15-minute interval.

Wind movement was summarized for the 24-hour sunrise-to-sunrise period in a manner which allowed daytime and nighttime wind movement to also be identified if desired. The windrun, which expresses wind movement as a distance, was calculated by multiplying the wind speed for each 15-minute interval by the length of the interval. The windrun was calculated for the daytime, sunrise-to-sunset period and for the nighttime, sunset-to-sunrise period, and totaled to provide the 24-hour total windrun. The day-night wind ratio was determined by dividing the daytime windrun by the nighttime windrun. Average daytime wind speed was calculated by averaging the 15-minute wind speeds for the daytime, sunrise-to-sunset period.

The average atmospheric pressure was determined for the 24-hour sunrise-to-sunrise period by averaging the 15-minute measurements for the 24-hour period.

Chapter 4

THE EVAPOTRANSPIRATION MODEL

The evapotranspiration model used in this study is based on surface energy balance and heat and mass transfer relationships. The physically based model, developed by Shuttleworth and Wallace (1985), is intended to describe the evapotranspiration process occuring over a vegetated surface, regardless of the vegetative conditions. It was developed by reinterpreting and rederiving the Penman-Monteith model by explicitly including evaporation from sparse canopies with exposed soil surfaces, which the Penman-Monteith method excluded by assuming full-canopy conditions and negligible evaporation from the soil surface.

SHUTTLEWORTH-WALLACE MODEL

The model presented by Shuttleworth and Wallace (1985) describes the evaporation process from a two-component system consisting of the crop and the soil surface. The system is composed of two layers: the in-canopy layer, which extends from the soil surface to a level of mean air flow within the canopy, and the above-canopy layer, which extends from the level of mean air flow to a reference height in the atmospheric boundary layer above the canopy.

Individual components in the surface energy balance are considered in each layer, and mass and energy transfer are accounted for in resistance terms. Net radiant energy is partitioned into sensible, latent, and soil heat fluxes from both the plant and soil components. The control over the heat transfer processes exerted by the plant and soil surfaces are expressed in terms of surface resistances. Transfer between the surfaces and the atmospheric boundary layer above the surface is expressed in terms of aerodynamic resistances. A diagram detailing the energy and resistance terms is shown in Figure 4.1.

The Shuttleworth-Wallace model is developed by combining the surface energy balance equation with latent heat and sensible heat transfer equations from both the crop and soil components in each layer. The sum of the latent heat fluxes from both components gives the total latent heat flux from the plant and soil system,

$$\lambda E = \lambda E_c + \lambda E_s \tag{4.1}$$

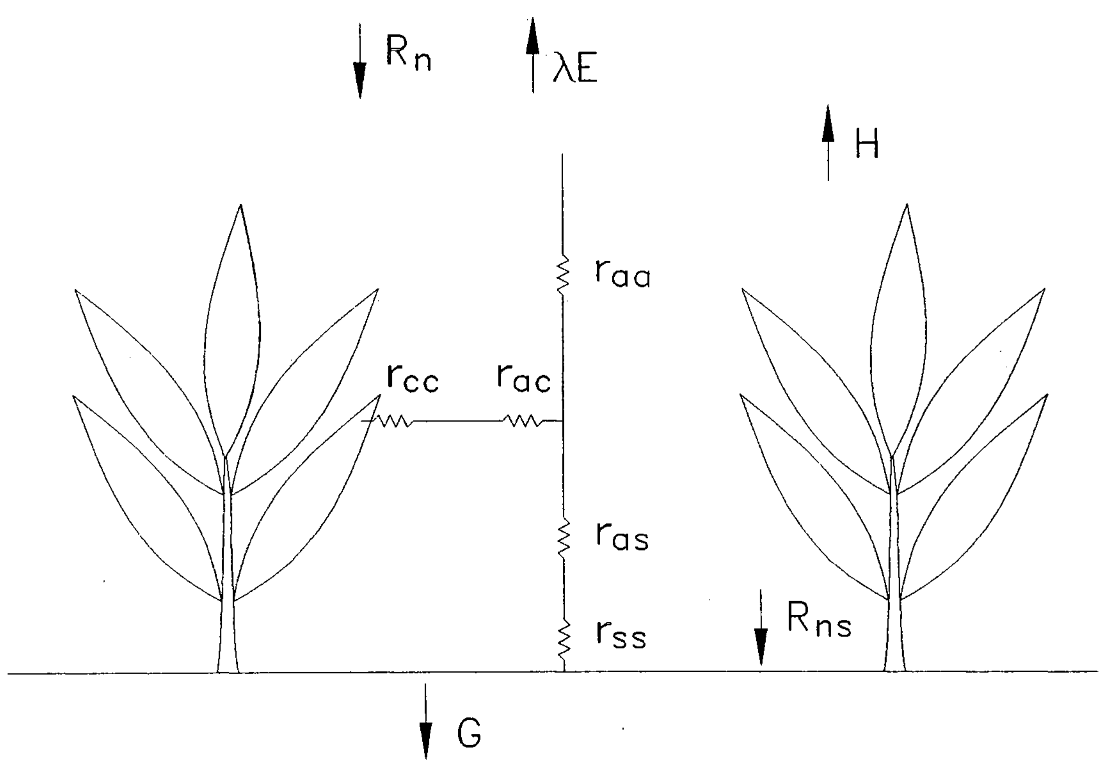

Figure 4.1. Energy and Resistance Terms Used in the Shuttleworth-Wallace Model.

where

λE = latent heat flux from the crop and soil system

λE_c = latent heat flux from the crop

λE_s = latent heat flux from the soil.

The latent heat flux from the in-canopy layer is examined first. Water vapor which passes through stomatal openings on leaf surfaces or exists in the near-surface layer of soil is available and evaporates into the boundary layer of air surrounding the leaf or soil surface. Turbulent air moving with the canopy interacts with surface boundary layers and transfers water vapor from the surface boundary layers to the turbulent air circulating within the canopy. A hypothetical level within the canopy, called the level of mean flow, exists at which the in-canopy air flow interacts with the above-canopy flow. The in-canopy air flow is assumed to transfer water vapor from the plant and soil surfaces to this level.

Latent heat flux can be expressed as

$$\lambda E = \frac{\rho c_p}{\gamma} K \frac{de}{dz} \tag{4.2}$$

where

ρ = air density

c_p = specific heat of air

γ = psychrometric constant

K = diffusion coefficient of water vapor in air

de/dz = vapor pressure gradient of the air.

This can be rewritten by expressing the diffusion coefficient, K, as a resistance, r, by inverting K to give an equation for latent heat flux of the form

$$\lambda E = \frac{\rho c_p}{\gamma r} \frac{de}{dz} \tag{4.3}$$

The latent heat flux from the crop component can be expressed in two ways. First, it can be calculated as the flux from the plant leaf to the boundary layer surrounding the leaf surface, as

$$\lambda E_c = \frac{\rho c_p}{\gamma r_{cc}} \frac{de_{lo}}{dz} \tag{4.4}$$

where

r_{cc}= resistance of the plant leaf to water vapor transfer

de_{lo}/dz = vapor pressure gradient from the leaf to the boundary layer.

The vapor pressure gradient can be expressed as the difference in saturation vapor pressures between the leaf and the leaf boundary layer, and the latent heat flux equation rewritten as

$$\lambda E_c = \frac{\rho c_p}{\gamma} \frac{(e_s(T_l) - e_s(T_o))}{r_{cc}} \tag{4.5}$$

where

$e_s(T_l)$ = saturation vapor pressure of the leaf based on the leaf temperature

$e_s(T_o)$ = saturation vapor pressure in the leaf boundary layer based on the boundary layer air temperature.

Secondly, latent heat flux can be expressed as the flux from the leaf boundary layer to the level of mean air flow,

$$\lambda E_c = \frac{\rho c_p}{\gamma r_{ac}} \frac{de_{om}}{dz} \tag{4.6}$$

where

r_{ac} = aerodynamic resistance of the canopy to in-canopy flow

de_{om}/dz = vapor pressure gradient from the leaf boundary layer to the level of mean air flow.

The vapor pressure gradient can be expressed as the difference in vapor pressures between the leaf boundary layer and the level of mean flow, and the latent heat flux equation rewritten as

$$\lambda E_c = \frac{\rho c_p}{\gamma} \frac{\left(e_s(T_o) - e(T_m)\right)}{r_{ac}} \tag{4.7}$$

where

$e_s(T_o)$ = saturation vapor pressure at the boundary layer limit based on the boundary layer air temperature

$e(T_m)$ = actual vapor pressure at the level of mean flow based on the mean flow air temperature.

The two latent heat fluxes represent the same quantity of water vapor moving from the leaf surface to the atmosphere and, by the principle of mass conservation, must be equal. Equations 4.5 and 4.7 can be rewritten in terms of $e_s(T_o)$ and equated to eliminate $e_s(T_o)$ to give

$$\lambda E_c = \frac{\rho c_p}{\gamma} \frac{\left(e_s(T_l) - e(T_m)\right)}{r_{ac} + r_{cc}} \tag{4.8}$$

The resulting equation expresses the evaporation from the crop in terms of leaf and air temperatures and two crop resistances.

Leaf temperature is difficult to measure, however, and other relationships are introduced in order to eliminate it from the equation. The saturation vapor-pressure versus temperature relationship is used to relate the leaf and air temperatures by assuming that the slope of the curve between two points can be approximated by a straight line joining the two points. The slope of the saturation vapor-pressure versus temperature relationship is approximated by

$$\Delta = \frac{e_s(T_l) - e_s(T_m)}{T_l - T_m} \tag{4.9}$$

and when solved in terms of $e_s(T_l)$ is written as

$$e_s(T_l) = e_s(T_m) + \Delta(T_l - T_m) \tag{4.10}$$

This is then substituted into Equation 4.8 to give

$$\lambda E_c = \frac{\rho c_p}{\gamma} \frac{\left(e_s(T_m) + \Delta(T_l - T_m) - e(T_m)\right)}{r_{ac} + r_{cc}} \tag{4.11}$$

The sensible heat flux from the leaf surface to the level of mean air flow is written as

$$H_c = \rho c_p \frac{(T_l - T_m)}{r_{ac}} \tag{4.12}$$

where

ρ = air density

c_p = specific heat of air

r_{ac} = aerodynamic resistance of the canopy to in-canopy flow

T_l - T_m = leaf-to-air temperature difference.

Solving the sensible heat flux equation in terms of the leaf-to-air temperature difference gives

$$T_l - T_m = \frac{H_c r_{ac}}{\rho c_p} \tag{4.13}$$

This is then substituted into Equation 4.11 to eliminate the leaf temperature term, resulting in

$$\lambda E_c = \frac{\rho c_p}{\gamma} \frac{\left(e_s(T_m) - e(T_m) + \Delta r_{ac} H_c / \rho c_p\right)}{r_{ac} + r_{cc}} \tag{4.14}$$

The sensible heat flux term can be eliminated by introducing the surface energy balance relationship for the canopy surface,

$$R_n = \lambda E_c + H_c + R_{ns} \tag{4.15}$$

where

R_n = net radiation at the top of the canopy

λE_c = latent heat flux from the plant canopy

H_c = sensible heat flux from the canopy

R_{ns} = net radiation at the soil surface.

The net radiation at the soil surface, R_{ns}, is the amount of energy passing through the canopy and reaching the soil surface, and which is unavailable for direct use by the plants. Solving the energy balance equation for the sensible heat flux and substituting into Equation 4.14 results in

$$\lambda E_c = \frac{\rho c_p}{\gamma} \frac{\left(e_s(T_m) - e(T_m) + \Delta r_{ac}(R_n - R_{ns} - \lambda E_c)/\rho c_p\right)}{r_{ac} + r_{cc}} \tag{4.16}$$

which is then rearranged and solved for λE_c to give an expression for the latent heat flux from the plant canopy to the level of mean air flow,

$$\lambda E_c = \frac{\Delta(R_n - R_{ns}) + \rho c_p\left(e_s(T_m) - e(T_m)\right)/r_{ac}}{\Delta + \gamma(1 + r_{cc}/r_{ac})} \tag{4.17}$$

An expression for the latent heat flux from the soil surface to the level of mean air flow is developed in a similar manner. The latent heat flux from the soil surface to the boundary layer above the surface is written as

$$\lambda E_s = \frac{\rho c_p}{\gamma} \frac{\left(e_s(T_s) - e_s(T_{os})\right)}{r_{ss}} \tag{4.18}$$

where

$e_s(T_s)$ = saturation vapor pressure at the soil surface based on the soil surface temperature

$e_s(T_{os})$ = saturation vapor pressure at the boundary layer limit based on the boundary layer air temperature

r_{ss} = resistance to water vapor transfer from the soil surface.

The latent heat flux from the boundary layer above the soil surface to the level of mean flow is written as

$$\lambda E_s = \frac{\rho c_p}{\gamma} \frac{\left(e_s(T_{os}) - e(T_m)\right)}{r_{as}} \tag{4.19}$$

where

$e(T_m)$ = actual vapor pressure at the level of mean flow based on the mean flow air temperature

r_{as} = aerodynamic resistance of the soil surface to in-canopy flow.

By the principle of mass conservation, Equations 4.18 and 4.19 can be combined to eliminate $e_s(T_{os})$, resulting in

$$\lambda E_s = \frac{\rho c_p}{\gamma} \frac{\left(e_s(T_s) - e(T_m)\right)}{r_{as} + r_{ss}} \tag{4.20}$$

The slope of the saturation vapor-pressure versus temperature relationship is written in terms of the soil surface and mean flow temperatures as

$$\Delta = \frac{e_s(T_s) - e_s(T_m)}{T_s - T_m} \tag{4.21}$$

The sensible heat flux from the soil surface to the level of mean flow is written as

$$H_s = \rho c_p \frac{(T_s - T_m)}{r_{as}} \tag{4.22}$$

The energy balance at the soil surface is

$$R_{ns} = \lambda E_s + H_s + G \tag{4.23}$$

where

R_{ns} = net radiation at the soil surface

λE_s = latent heat flux from the soil surface

H_s = sensible heat flux from the soil surface

G = soil heat flux.

Equations 4.21, 4.22, and 4.23 are substituted into Equation 4.20 to eliminate the soil surface temperature term, resulting in an expression for the latent heat flux from the soil surface to the level of mean flow,

$$\lambda E_s = \frac{\Delta(R_{ns} - G) + \rho c_p \left(e_s(T_m) - e(T_m)\right)/r_{as}}{\Delta + \gamma(1 + r_{ss}/r_{as})} \tag{4.24}$$

The latent heat fluxes from the crop and soil components within the canopy are now defined in terms of net radiant energy, water vapor transfer resistances, and a vapor pressure deficit. The vapor pressure deficit, however, is the deficit at the level of mean air flow within the canopy, which would be difficult to locate and measure. The vapor pressure deficit at this level must be eliminated or related to another, more easily determined quantity.

The transfer of latent heat from the level of mean flow within the canopy to the atmospheric boundary layer above the canopy is determined in a similar manner to that within the canopy. The latent heat flux from the level of mean flow to a reference height above the canopy can be expressed as

$$\lambda E = \frac{\rho c_p}{\gamma} \frac{\left(e(T_m) - e(T_z)\right)}{r_{aa}} \tag{4.25}$$

where

$e(T_m)$ = actual vapor pressure at the level of mean flow based on the mean flow air temperature

$e(T_z)$ = actual vapor pressure at a reference height above the canopy based on the air temperature at the reference height

r_{aa} = aerodynamic resistance to water vapor transfer of the mean flow.

The slope of the saturation vapor-pressure versus temperature relationship is written in terms of the air temperatures at the mean flow level and the reference height as

$$\Delta = \frac{e_s(T_m) - e_s(T_z)}{T_m - T_z} \tag{4.26}$$

The sensible heat flux from the mean flow to the reference height is expressed as

$$H = \rho c_p \frac{(T_m - T_z)}{r_{aa}} \tag{4.27}$$

Equations 4.26 and 4.27 are combined to eliminate the mean flow-to-reference height air temperature difference, and the resulting equation is substituted into Equation 4.25 to yield an expression for the saturation vapor pressure deficit at the mean flow level,

$$e_s(T_m)-e(T_m)=e_s(T_z)-e(T_z)+\frac{\Delta H r_{aa}}{\rho c_p}-\frac{\lambda E \gamma r_{aa}}{\rho c_p} \tag{4.28}$$

The energy balance equation for the system

$$H=R_n-G-\lambda E \tag{4.29}$$

is substituted into Equation 4.28 to eliminate the sensible heat flux term, giving

$$e_s(T_m)-e(T_m)=e_s(T_z)-e(T_z)+\frac{r_{aa}}{\rho c_p}\left(\Delta(R_n-G)-(\Delta+\gamma)\lambda E\right) \tag{4.30}$$

The resulting equation expresses the vapor pressure deficit of the air at the mean flow level within the canopy in terms of energy components, an aerodynamic resistance, and the vapor pressure deficit of the air at the reference height in the atmospheric boundary layer above the canopy.

Equation 4.30 can be substituted into the latent heat flux equations for the crop and soil components to eliminate the expression for the vapor pressure deficit at the mean flow level. Substituting Equation 4.30 into Equations 4.17 and 4.24 results in expressions for the latent heat flux from the crop and soil components,

$$\lambda E_c=\frac{\Delta(R_n-R_{ns})+\rho c_p\left[e_s(T_z)-e(T_z)+\frac{r_{aa}}{\rho c_p}\left(\Delta(R_n-G)-(\Delta+\gamma)\lambda E\right)\right]/r_{ac}}{\Delta+\gamma(1+r_{cc}/r_{ac})} \tag{4.31}$$

$$\lambda E_s=\frac{\Delta(R_{ns}-G)+\rho c_p\left[e_s(T_z)-e(T_z)+\frac{r_{aa}}{\rho c_p}\left(\Delta(R_n-G)-(\Delta+\gamma)\lambda E\right)\right]/r_{as}}{\Delta+\gamma(1+r_{ss}/r_{as})} \tag{4.32}$$

These can be combined using Equation 4.1 to yield an expression for the total latent heat flux from the crop and soil system. The resulting equation can then be rearranged to express the latent heat flux in terms of the crop and soil components and the surface and aerodynamic resistances in a form similar to the Penman-

Monteith equation. The resulting set of equations is the evapotranspiration model for sparse canopies proposed by Shuttleworth and Wallace (1985):

$$E = \frac{C_c PM_c + C_s PM_s}{\lambda} \tag{4.33}$$

where

E = evapotranspiration from crop and soil, mm/d

PM_c = evaporation from the crop, estimated by a term similar to that in the Penman-Monteith method

PM_s = evaporation from the soil, estimated by a term similar to that in the Penman-Monteith method

C_c = canopy resistance coefficient

C_s = soil surface resistance coefficient

λ = latent heat of vaporization, MJ/kg.

The equations describing the evaporation from the crop canopy and from the soil are similar to the Penman-Monteith equation in that they relate evaporation to the energy components and atmospheric parameters driving the evaporation process, and to the surface and aerodynamic resistance terms controlling evaporation. The crop and soil evaporation equations are

$$PM_c = \frac{\Delta(R_n - G) + \left[\rho c_p DK - \Delta r_{ac}(R_{ns} - G)\right]/(r_{aa} + r_{ac})}{\Delta + \gamma\left(1 + r_{cc}/(r_{aa} + r_{ac})\right)} \tag{4.34}$$

$$PM_s = \frac{\Delta(R_n - G) + \left[\rho c_p DK - \Delta r_{as}(R_n - R_{ns})\right]/(r_{aa} + r_{as})}{\Delta + \gamma\left(1 + r_{ss}/(r_{aa} + r_{as})\right)} \tag{4.35}$$

where

R_n = net radiation at the top of the canopy, MJ/m^2d

G = soil heat flux, MJ/m^2d

ρ = density of air, kg/m^3

c_p = specific heat of air, MJ/kgC

D = vapor pressure deficit at the reference height, kPa

Δ = slope of the saturation vapor pressure versus temperature curve, kPa/C

γ = psychrometric constant, kPa/C

R_{ns} = net radiation at the soil surface, MJ/m^2

K = dimensional constant to convert to daily flux, 86400 s/d

r_{aa} = aerodynamic resistance of the mean canopy flow, s/m

r_{ac} = aerodynamic resistance of the canopy to in-canopy flow, s/m

r_{as} = aerodynamic resistance of the soil surface to in-canopy flow, s/m

r_{cc} = canopy resistance, s/m

r_{ss} = soil surface resistance, s/m.

The expressions for the canopy and soil surface resistance coefficients are written in terms of the surface and aerodynamic resistances, as

$$C_c = \frac{1}{\left(1 + R_c R_a / R_s (R_c + R_a)\right)} \tag{4.36}$$

$$C_s = \frac{1}{\left(1 + R_s R_a / R_c (R_s + R_a)\right)} \tag{4.37}$$

$$R_a = (\Delta + \gamma) r_{aa} \tag{4.38}$$

$$R_c = (\Delta + \gamma) r_{ac} + \gamma r_{cc} \tag{4.39}$$

$$R_s = (\Delta + \gamma) r_{as} + \gamma r_{ss}. \tag{4.40}$$

ESTIMATION OF METEOROLOGICAL PARAMETERS

In order to use the Shuttleworth-Wallace model for estimating evapotranspiration, a number of parameters must be measured or estimated.

Meteorological parameters are needed to describe the energy and atmospheric conditions driving the evaporation process. Information about the activity and structure of the vegetation and plant canopy, and the availability of soil water is needed to estimate resistance parameters which regulate evaporation from plant and soil surfaces.

Meteorological parameters include those which are directly measured or can be calculated from measured values using established relationships, and those which are not measured and must be estimated using empirical relationships.

Saturation Vapor Pressure

The saturation vapor pressure is a measure of the water vapor content of saturated air at a given temperature. Several methods are in use for estimating the saturation vapor pressure of the air based on the air temperature. The formula developed by Tetens is easy to use and provides accurate estimates in the range of temperatures commonly encountered (Jensen et al., 1990):

$$e_s(T_a) = \exp\left(\frac{16.78T_a - 116.9}{T_a + 237.3}\right) \qquad (4.41)$$

where

$e_s(T_a)$ = saturation vapor pressure, kPa

T_a = air temperature, C.

Saturation Vapor Pressure versus Temperature Relationship

The equation for estimating the saturation vapor pressure can be differentiated to determine the slope of the saturation vapor pressure versus temperature relationship. Differentiation of the Tetens equation, Equation 4.41, gives the slope of the curve,

$$\Delta = \frac{4098 e_s(T_a)}{(T_a + 237.3)^2} \tag{4.42}$$

where

Δ = slope of saturation vapor pressure-temperature curve, kPa/C.

Actual Vapor Pressure

The actual vapor pressure is a measure of the water vapor content of the air under the prevailing temperature and humidity conditions of the atmosphere. Actual vapor pressure can be determined using the definition of relative humidity (Rosenberg et al., 1983),

$$RH = \frac{e(T_a)}{e_s(T_a)} \tag{4.43}$$

where

RH = relative humidity

$e(T_a)$ = actual vapor pressure, kPa.

Solving for $e(T_a)$ allows the actual vapor pressure to be determined from measurements of relative humidity and temperature using the expression

$$e(T_a) = RH e_s(T_a). \tag{4.44}$$

Latent Heat of Vaporization

The latent heat of vaporization is the amount of energy required to change water at a given temperature from the liquid to the vapor phase. The latent heat of vaporization can be estimated as a function of air temperature using an equation developed by Harrison (Jensen et al., 1990),

$$\lambda = 2.501 - 0.002361T_a \tag{4.45}$$

where

λ = latent heat of vaporization, MJ/kg.

Psychrometric Constant

The psychrometric constant relates the sensible heat gained from moving air to the sensible heat converted into latent heat (Jensen et al., 1990) and can be calculated from the expression

$$\gamma = \frac{c_p P}{0.622\lambda} \tag{4.46}$$

where

γ = psychrometric constant, kPa/C

c_p = specific heat of air, 1.013 kJ/kgC

P = atmospheric pressure, kPa.

Air Density

The density of the air can be accurately calculated based on the atmospheric pressure and the virtual temperature of the air (Jensen et al., 1990) using the equation

$$\rho = 3.486\frac{P}{T_v} \tag{4.47}$$

where

ρ = density of moist air, kg/m^3

T_v = virtual temperature, K.

The virtual temperature, which accounts for the effects of moisture on buoyancy (Rosenberg et al., 1983), can be calculated from the expression

$$T_v = \frac{T_a}{1 - 0.378\frac{e(T_a)}{P}} \tag{4.48}$$

Net Radiation

Net radiation is a measure of the amount of energy available for use at the earth's surface, and provides energy for plant growth, heating of the soil and atmosphere, and evaporation of water. Net radiation is composed of shortwave and longwave radiation, and is dependent on reflective properties of the surface, the temperature of the surface, and the water vapor content of the atmosphere (Jensen et al., 1990).

Net radiation can be estimated as a linear function of solar radiation and relationships have been reported for a variety of surfaces in many parts of the world (Jensen et al., 1990). The relationship chosen is that reported by Ritchie for a variety of vegetated surfaces in Texas (Ritchie, 1971), and is of the form

$$R_n = 0.76(1-\alpha)R_s - 0.84 \tag{4.49}$$

where

R_n = net radiation, MJ/m^2

R_s = solar radiation, MJ/m^2

α = surface albedo.

The surface albedo is a measure of the reflectivity of the surface to solar radiation. Albedo is dependent on surface vegetative and moisture conditions, and varies for different types of vegetation and for different heights and growth stages of the vegetation (Oke, 1987). The albedo of exposed soil varies with soil properties and with the moisture content of the soil surface, with dry surfaces having higher albedos than wet surfaces.

Soil Heat Flux

Soil heat flux is a measure of the amount of energy used in heating the soil profile. The movement of heat in the soil and the amount of heat stored in the soil are dependent on the structural properties and moisture content of the soil, and on the amount of energy available at the soil surface.

In many ET estimation methods, the soil heat flux is assumed to be small and is often neglected. Under conditions of a full canopy, with the soil surface completely shaded, the net radiation at the soil surface is small and little energy is involved in heating the soil. As the amount of exposed soil surface increases, however, the amount of energy that goes into heating the soil also increases.

Several methods have been used to estimate soil heat flux when actual measurements were not available. Daily soil heat flux has been estimated based on the difference in mean air temperature and the average air temperature for the previous three days, and an empirical specific heat coefficient (Wright, 1982; Cuenca, 1989). When necessary measurements have not been available, soil heat flux has been assumed to be proportional to some other term in the surface energy balance, such as sensible heat or net radiation (Brutsaert, 1982), or net radiation at the soil surface (Shuttleworth and Wallace, 1985). An empirical coefficient is used to account for vegetative cover and energy availability at the soil surface. An equation relating soil heat flux to net radiation would be of the form

$$G = kR_n \tag{4.50}$$

where

G = soil heat flux, MJ/m^2

k = empirical coefficient.

The value of the coefficient k is dependent on surface conditions, including vegetative cover and moisture, and can vary from small, negligable values for vegetated surfaces such as grass to values around 0.4 for bare soil (Brutsaert, 1982).

In-Canopy Net Radiation at the Soil Surface

For a surface with a vegetative cover, the amount of energy incident on the soil surface has been reported to vary depending on the density and structure of the vegetation (Pearson and Ison, 1987). In-canopy net radiation at the soil surface is often modeled as a logarithmic function of net radiation, leaf-area index, and an empirical extinction coefficient to account for canopy architecture (Oke, 1987; Shuttleworth and Wallace, 1985). Extinction coefficients have been reported for different plant canopies and for grasses (Ripley and Redmann, 1976; Pearson and Ison, 1987).

Net radiation at the soil surface inside the plant canopy can be estimated from the relation (Oke, 1987; Shuttleworth and Wallace, 1985)

$$R_{ns} = R_n \exp(-C_r LAI) \tag{4.51}$$

where

R_{ns} = net radiation at the soil surface, MJ/m^2d

R_n = net radiation at the canopy surface, MJ/m^2d

C_r = extinction coefficient, dimensionless

LAI = leaf area index, dimensionless.

The extinction coefficient, C_r, for grasses has been reported to be in the range of 0.3 to 0.7 (Ripley and Redmann, 1975; Pearson and Ison, 1987).

ESTIMATION OF RESISTANCE PARAMETERS

The Shuttleworth-Wallace model requires the estimation of surface and aerodynamic resistances which describe the control of the evaporation process exerted by plant and soil surfaces and by the atmosphere. These resistances are estimated using plant canopy and soil properties, and weather parameters.

Aerodynamic Resistances

Aerodynamic resistances describe the transfer of water vapor from canopy and soil surfaces into the atmosphere. Aerodynamic resistances to in-canopy air flow regulate the transfer of water vapor from plant and soil surfaces within the canopy. The aerodynamic resistance of the mean air flow regulates the transfer of water vapor from within the canopy to the atmospheric boundary layer above the canopy.

Aerodynamic Resistance of the Mean Flow

Estimation of the aerodynamic resistance of the mean flow is often based on the wind speed in the boundary layer above the canopy, and the displacement height and roughness length of the canopy (Shuttleworth and Wallace, 1985; Jensen et al., 1990; Massman, 1992; Stannard, 1993; Farahani and Bausch, 1994). Displacement height and roughness length are assumed to be fixed fractions of the canopy height. Two roughness lengths are sometimes specified; a roughness length for momentum transfer, and a roughness length for heat transfer, both of which are related to canopy height.

The aerodynamic resistance of mean flow is estimated based on the logarithmic wind profile and is of the form

$$r_{aa} = \frac{\ln\left[(z_u - d + z_{om})/z_{om}\right]\ln\left[(z_v - d + z_{ov})/z_{ov}\right]}{k^2 u_{zu}} \tag{4.52}$$

r_{aa} = aerodynamic resistance of the mean flow, s/m

d = zero-plane displacement height, m

z_u = height of the wind-speed measurement, m

z_v = height of the humidity measurement, m

z_{om} = roughness height for momentum transfer, m

z_{ov} = roughness height for heat and vapor transfer, m

u_{zu} = average wind speed at reference height, m/s

k = van Karman constant, 0.41

The zero-plane displacement height is assumed to be fixed at a constant fraction of crop height (Shuttleworth and Wallace, 1985; Jensen et al., 1990; Wallace et al., 1984) with a commonly used expression being

$$d = \frac{2}{3}h \tag{4.53}$$

where

d = displacement height, m

h = canopy height, m.

Roughness heights are assumed to be constant fractions of vegetation height (Shuttleworth and Wallace, 1985; Jensen et al., 1990; Wallace et al., 1984). The roughness height for momentum transfer is estimated from

$$z_{om} = 0.13h \tag{4.54}$$

where

z_{om} = roughness height for momentum transfer, m.

The roughness height for vapor transfer is estimated based on the roughness height for momentum transfer from

$$z_{ov} = 0.1 z_{om} \tag{4.55}$$

where

z_{ov} = roughness height for vapor transfer, m.

Aerodynamic Resistance of the Canopy to In-Canopy Flow

Introduced in the Shuttleworth-Wallace model, the aerodynamic resistance of the canopy to in-canopy flow is a relatively new term and has not been addressed extensively in the literature. Several methods have been proposed which estimate a bulk resistance based on leaf width, an extinction coefficient to describe the decrease in wind speed and turbulence with depth inside the canopy, and wind speed at the top of the canopy. The bulk resistance is then scaled by leaf-area index to account for the density of the canopy. The relationship proposed by Shuttleworth and Gurney (1990), and slight variations of the relationship, have been used (Lafleur and Rouse, 1990; Stannard, 1993; Farahani and Bausch, 1994) and are of the form

$$r_{ac} = \frac{r_b}{2LAI} \tag{4.56}$$

where

r_{ac} = aerodynamic resistance of canopy to in-canopy flow, s/m

r_b = bulk aerodynamic resistance, s/m

LAI = leaf-area index, dimensionless.

The bulk aerodynamic resistance is estimated from

$$r_b = \frac{100}{n}\left(\frac{w}{u_h}\right)^{1/2}\left(1 - \exp\left(\frac{-n}{2}\right)\right)^{-1} \tag{4.57}$$

where

w = leaf width, mm

u_h = wind speed at height of canopy, m/s

n = extinction coefficient.

The windspeed at the top of the canopy can be estimated from the logarithmic wind profile equation (Jensen et al., 1990),

$$u_h = u_z\left(\frac{h}{z}\right)^{0.2} \qquad (4.58)$$

where

u_h = wind speed at height of canopy, m/s

u_z = wind speed at the height of the wind-speed measurement, m/s

h = canopy height, m

z = height of the wind-speed measurement, m.

Shuttleworth and Wallace (1985), Ham and Heilman (1991), and Massman (1992), however, reported that a relationship to adequately describe the resistance could not be determined, and that a constant resistance value could be used instead.

Aerodynamic Resistance of the Soil Surface to In-Canopy Flow

Several methods proposed to estimate the aerodynamic resistance of the soil surface to in-canopy flow have been based on the logarithmic wind profile. Shuttleworth and Wallace (1985) assumed that the wind speed profile was logarithmic only above the canopy, and that it varied linearly within the canopy. The aerodynamic resistance was estimated by interpolating between the vegetative limits of bare soil and full canopy, defined as having an LAI of 4, using the relationship

$$r_{as} = \frac{1}{4} LAI\, r_{as}(\alpha) + \frac{1}{4}(4 - LAI)\, r_{as}(0) \qquad (4.59)$$

where

$$r_{as}(\alpha)=\frac{\ln[(z-d)/z_o]}{k^2u}\frac{h}{n(h-d)}\left[\exp(n)-\exp[n(1-(d+z_o)/h)]\right] \quad (4.60)$$

$$r_{as}(0)=\frac{\ln(z/z_{os})\ln\left[(d+z_o)/z_{os}\right]}{k^2u} \quad (4.61)$$

where

r_{as} = aerodynamic resistance of the soil surface to in-canopy flow, s/m

LAI = leaf-area index

$r_{as}(\alpha)$ = aerodynamic resistance under full-canopy conditions, s/m

$r_{as}(0)$ = aerodynamic resistance under bare-soil conditions, s/m

h = canopy height, m

d = zero-plane displacement height, m

z_o = roughness height, m

z = height of wind speed measurement, m

u = wind speed at the height of the wind speed measurement, m/s

k = van Karman constant, 0.41

n = extinction coefficient.

The relationship developed by Stannard (1993) was derived assuming that the logarithmic wind profile under sparse-canopy conditions extended into the canopy and down to the soil surface. The resistance was assumed to regulate transport in the region extending from the soil surface to the level of mean flow, assumed to be at half the canopy height, resulting in the relationship

$$r_{as}=\frac{\ln\left(\frac{0.5z+z_h}{z_h}\right)\ln\left(\frac{z-d+z_o}{z_o}\right)}{k^2u} \quad (4.62)$$

where

r_{as} = aerodynamic resistance of the soil surface to in-canopy flow, s/m

z = height of wind speed measurement, m

d = zero-plane displacement height, m

z_h = roughness length for sensible heat, m

z_o = roughness length for momentum, m

u = wind speed at the height of the wind speed measurement, m/s

k = van Karman constant, 0.41.

Others, including Ham and Heilman (1991) and Massman (1992), concluded that adequate relationships could not be reliably determined due to variability and uncertainty in in-canopy measurements, and suggested using constant values for the resistance.

Canopy Resistance

Canopy resistance is modeled by estimating the stomatal resistance of individual plant leaves, and scaling leaf stomatal resistance by the density of the canopy. The canopy resistance model is of the form

$$r_{cc} = \frac{r_{st}}{2LAI} \tag{4.63}$$

where

r_{cc} = canopy resistance, s/m

r_{st} = stomatal resistance, s/m

LAI = leaf-area index.

Stomatal resistance is modeled by relating stomatal conductance, the inverse of resistance, to atmospheric and soil water parameters that influence stomatal behavior, as

$$r_{st} = \frac{1}{g_c} \tag{4.64}$$

where

r_{st} = stomatal resistance, s/m

g_c = stomatal conductance, m/s.

Stomatal conductance is often estimated using the model proposed by Stewart (1988) as a maximum conductance multiplied by functions which modify the conductance based on atmospheric and water stress. The model is of the form

$$g_c = g_{max}\, g(R_s) g(D) g(T_a) g(\theta) \tag{4.65}$$

where

g_c = stomatal conductance, m/s

g_{max} = maximum conductance, m/s

$g(R_s)$ = function for stomatal response to solar radiation

$g(D)$ = function for stomatal response to vapor-pressure deficit

$g(T_a)$ = function for stomatal response to air temperature

$g(\theta)$ = function for stomatal response to soil water availability.

Expressions for each function are determined based on meteorological or soil-water parameters and are fit to provide response curves similar in shape to those shown in Figure 2.1.

The function for stomatal response to solar radiation from Stewart (1988) has been used extensively, and is of the form

$$g(R_s) = \frac{R_s(R_{s\,max} + c_1)}{R_{s\,max}(R_s + c_1)} \tag{4.66}$$

where

R_s = daily solar radiation, MJ/m^2

R_{smax} = maximum daily solar radiation under clear-sky conditions, MJ/m^2

c_1 = fitting parameter.

R_{smax} can be estimated by examining solar radiation measurements throughout the year and determining the maximum radiation incident at the site. It can also be estimated using the method outlined in Jensen et al. (1990) based on the latitude and elevation of the site. The parameter, c_1, determines the amount of curvature in the function and is a fitting parameter detemined during modeling.

Stomatal response to vapor-pressure deficit has been modeled as a linear function for deficits up to a certain value, followed by a constant value, as shown in Figure 2.1. A function proposed by Massman and Kaufmann (1991) approximates this response and is of the form

$$g(D)=\frac{1}{1+bD} \qquad (4.67)$$

where

D = vapor pressure deficit, kPa

b = fitting parameter.

Functions for stomatal response to temperature have been proposed by Jarvis (1976) and Avissar et al. (1985). While the functional forms are different, the response functions can be adjusted to provide similar results. The function proposed by Jarvis (1976) is of the form

$$g(T_a)=\left(\frac{T_a-T_l}{b-T_l}\right)\left(\frac{T_h-T_a}{T_h-b}\right)^a \qquad (4.68)$$

where

T_a = air temperature, C

T_h = high temperature limit, C

T_l = low temperature limit, C

$a = (T_h - b)/(b - T_l)$

b = fitting parameter.

High and low temperature limits, T_h and T_l, are chosen to describe the temperature range under which the plant stomates remain active. The fitting parameter, b, is used to adjust the function to give maximum response in the temperature range at which plant stomates are most active.

The stomatal response function proposed by Avissar et al. (1985) uses a threshold concept. The function remains at a maximum value until a certain temperature is reached, after which the response function falls off and reaches and maintains a minimum value. The function is of the form

$$g(T_a)=\frac{1}{1+\exp(-S(T_a-b))} \tag{4.69}$$

where

T_a = air temperature, C

S = slope coefficient

b = fitting parameter to set the point at which the response function has a value of 0.5.

By adjusting the values of b and S, the temperature at which stress begins to occur and stomatal conductance begins to decrease, and the rate of decrease, can be changed.

Stomatal response to soil moisture availability has been related to leaf water potential and to soil moisture deficit. Evapotranspiration has often been reported to be affected by limited soil water availability, and functions to describe the effect have varied (see for example Howell et al., 1979). Linear and exponential functions have been used to indicate a reduction in ET from potential amounts with decreasing available water, with reported onsets of reduction ranging from 0% to 100% depletion. The relationship proposed by Ritchie (1973) suggests that a reduction in ET does not occur until available water depletion reaches a critical value, after which a linear decrease occurs. Using this method to describe stomatal response to soil water availability would suggest a function of the form

$$g(\theta) = 1 \qquad \text{for } \theta > \theta_c \tag{4.70}$$

$$g(\theta) = \frac{\theta}{\theta_c} \qquad \text{for } \theta < \theta_c \tag{4.71}$$

where

θ = available water content

θ_c = critical value of available water content at which water stress begins.

Soil Surface Resistance

A soil surface resistance is included in the Shuttleworth-Wallace model to account for evaporation from exposed soil surfaces. The soil surface resistance depends on a soil resistance, which describes the resistance of the soil to the transfer of water vapor, and the amount of surface area of the exposed soil. The soil resistance must be divided by the surface area of exposed soil per unit ground area to provide an estimate of soil surface resistance.

The soil surface resistance is modeled based on the soil water content in the soil layer near the surface, and a two-stage bare-soil evaporation concept (see, for example, Jensen et al., 1990). During the first stage, water is available in the near-surface layer and the rate of evaporation is controlled mainly by atmospheric demand. When the soil-water content has been depleted to a certain degree and the surface has begun to dry, physical properties of the soil control the rate of evaporation, and the evaporation rate decreases with time.

The soil surface resistance is modeled to simulate the effects on evaporation during the two stages. During the first stage, when the soil exerts minimal control, the soil resistance takes on a minimum value and maintains that value until a certain amount of water has evaporated. The soil surface resistance is then calculated based on the soil resistance and the amount of surface area under bare soil conditions. The model for the first stage is written as

$$r_{ss} = \frac{r_{s\,min}}{(1 - C_x)} \qquad \text{for } \Sigma ET < W_e \tag{4.72}$$

where

r_{ss} = soil surface resistance, s/m

r_{smin} = minimum soil resistance, s/m

C_x = vegetative cover fraction

ΣET = cumulative evaporation, mm

W_e = maximum cumulative evaporation during the first stage, mm.

When the maximum cumulative evaporation has been reached, the soil dries and soil resistance increases. This is modeled as a linear increase in resistance, with the resistance increasing a constant amount each day. The second-stage model is

$$r_{ss} = \frac{r_{s\,min}}{(1 - C_x)} + r_{drying}t \qquad \text{for } \Sigma ET > W_e \text{ and } r_{ss} < r_{ssmax} \tag{4.73}$$

where

r_{drying} = daily increase in resistance as soil dries, s/m/d

t = time since beginning of second stage evaporation, d

r_{ssmax} = maximum soil surface resistance.

Soil surface resistance continues to increase each day as the soil dries until a maximum resistance value, r_{ssmax}, is reached. The resistance value then remains at this maximum value until the soil is wetted.

Chapter 5

DATA COLLECTION RESULTS

The results of this research effort involve both the measurement and modeling of evapotranspiration. The measurement of evapotranspiration was accomplished by installing lysimeters and collecting lysimeter and weather data remotely via the Mesonet weather station network. Information related to the vegetation at the lysimeter sites, as well as soil moisture measurements, were collected periodically. Lysimeter and weather data collected by the Mesonet weather stations were used to estimate resistance parameters descriptive of the surface control and water vapor transfer into the atmosphere.

LYSIMETER CALIBRATION AND OPERATION

Calibration

After the four lysimeters were installed in the field, each lysimeter was individually calibrated to ensure that the electronic loadcells were operating correctly and to account for slight voltage losses due to the long cables connecting the loadcells to the Mesonet datalogger. The calibration factor obtained was then used to adjust reported changes in weight to indicate actual weight changes.

Each calibration was performed by connecting the loadcell wires to the cable and the cable to a spare datalogger independent of the Mesonet station. The datalogger was programmed to make a series of measurements for each loadcell at 10-second intervals during a 2-minute period. At each 10-second interval, 20 consecutive readings were taken for each loadcell, and the average of the 20 readings was calculated and reported. This resulted in a reporting of 12 average values for each loadcell during each 2-minute period.

At the beginning of the calibration, a steel plate was laid across the top of the inner lysimeter tank. A steel weight was then placed on top of the plate, a series of readings was taken, and average values were calculated and reported. At the beginning of each 2-minute interval, another steel weight was placed on top of the weights already on the lysimeter and another series of measurements was made. This continued until 8 weights had been added to the lysimeter.

The weights were then removed one at a time and measurements were made in the same manner as when the weights were added. At the beginning of each 2-minute interval, the top-most weight was removed and a series of readings was taken and averaged. This continued until all weights had been removed. The total amount of time required to perform each calibration was 32 minutes. The weights of the steel applied varied from approximately 5 kg to 15 kg, with a total weight of 94 kg applied.

A calibration equation relating the actual weight applied to the apparent weight detected was obtained using linear regression. The calibration equation is of the form

$$W_{actual} = mW_{apparent} \qquad (5.1)$$

where

W_{actual} = actual weight applied, kg

$W_{apparent}$ = apparent weight detected by the lysimeter, kg

m = slope, or calibration coefficient.

Results of the lysimeter calibrations for each site are shown in Table 5.1. The calibration coefficients indicate that the apparent weight changes reported by the lysimeter were slightly less than the actual weight changes, in the range of 2.2 to 3.3%. The high correlation coefficients, r^2, indicate that the weight changes reported by the lysimeter could be adjusted to more accurately reflect actual weight changes.

Table 5.1. Summary of Lysimeter Calibrations.

	Calibration coefficient	r^2
Goodwell	1.022	0.9996
Apache	1.025	0.9998
Marena	1.033	0.9997
Wister	1.029	0.9996

Operation

The operation of the lysimeters was accomplished remotely via connection to the Mesonet station near each lysimeter. The datalogger at the weather station was programmed to make lysimeter measurements at 30-second intervals by sending an excitation voltage to each loadcell and measuring the signal voltage from the loadcell. At 15-minute intervals, the average of the 30 30-second measurements taken during the period was calculated and reported for each loadcell.

At the end of each day, a data file containing loadcell voltages was created on the Mesonet computer operated by the Oklahoma Climatological Survey. The data file contained average signal voltages for each loadcell at 15-minute intervals throughout the day. The daily data files were then made available for downloading.

The data contained in the data files then had to be converted from voltages to weights. The calibration supplied by the loadcell manufacturer was first used to convert the signal voltages to weight units. The calibration coefficients determined during the field calibrations of the installed lysimeters were then applied. This resulted in weight measurements for each loadcell which were totaled to arrive at the total weight of the lysimeter at each 15-minute interval.

Problems Encountered

Following installation, lysimeter data were downloaded and examined to evaluate lysimeter performance and to detect problems in lysimeter operation.

Thermal Effects

While the Mesonet provided lysimeter measurements at 15-minute intervals, examination of the data suggested that the loadcell signals were being influenced by a thermal effect on the measurement system. Immediately after sunrise, the lysimeter reported a rapid weight loss and continued to lose weight throughout the day. During the nighttime hours, the lysimeter appeared to regain some of the weight lost during the day. The timing of the apparent weight losses and gains coincided with the daily cycle of air temperature, suggesting a thermal effect on lysimeter measurements.

On a daily time scale, the apparent weight gain partially offset the apparent weight loss. Examination of air temperatures, as well as other factors which may have been influencing loadcell measurements such as humidity and windspeed, indicated that weather conditions were often stable and calm in the early morning hours preceding sunrise. By confining the examination of lysimeter data to the sunrise period, it was reasoned that if there were thermal effects influencing lysimeter readings, they would be similar from one day to the next, and the suspected thermal influence on loadcell readings would be minimal. This would result in having lysimeter weights at one time each day, and would allow the determination of lysimeter weight changes, and evapotranspiration, on a daily, rather than 15-minute, time scale.

Two series of lysimeter measurements illustrating the suspected thermal effect are shown in Figures 5.1 and 5.2. Lysimeter weight and air temperature measurements reported at 15-minute intervals for a three-day period in July at Goodwell are shown in Figure 5.1. The correlation in temperature and weight curves can be seen, with a rapid weight loss beginning soon after sunrise followed by a partial weight gain during the night.

A second series of measurements at Goodwell is shown in Figure 5.2 for a period in November. During this period, the vegetation in the lysimeter was dormant, radiant energy amounts and air temperatures were low, and little evapotranspiration would have been expected to occur. On each of these days, however, the lysimeter reported an apparent loss in weight of over 2 kg, equivalent to a 2-mm depth of water. After sunset, the weight of the lysimeter increased, and returned to within about 0.25 kg of the weight at sunrise on two days and to the same weight on one day. On a daily time scale, very small net changes in weight occurred, as was expected, despite the apparent weight losses and gains reported throughout the day.

Possible sources of thermally induced noise include; the datalogger and multiplexer to which the cable carrying the loadcell signals is connected; the cable itself, which ranged in length from approximately 20 m to 60 m among the four sites; the connection joining the cable and the individual loadcell wires; and, the loadcells. Since the electrical signals from the loadcell and the changes in weight being measured were small, even small amounts of noise in the measurement system electronics could affect lysimeter measurements.

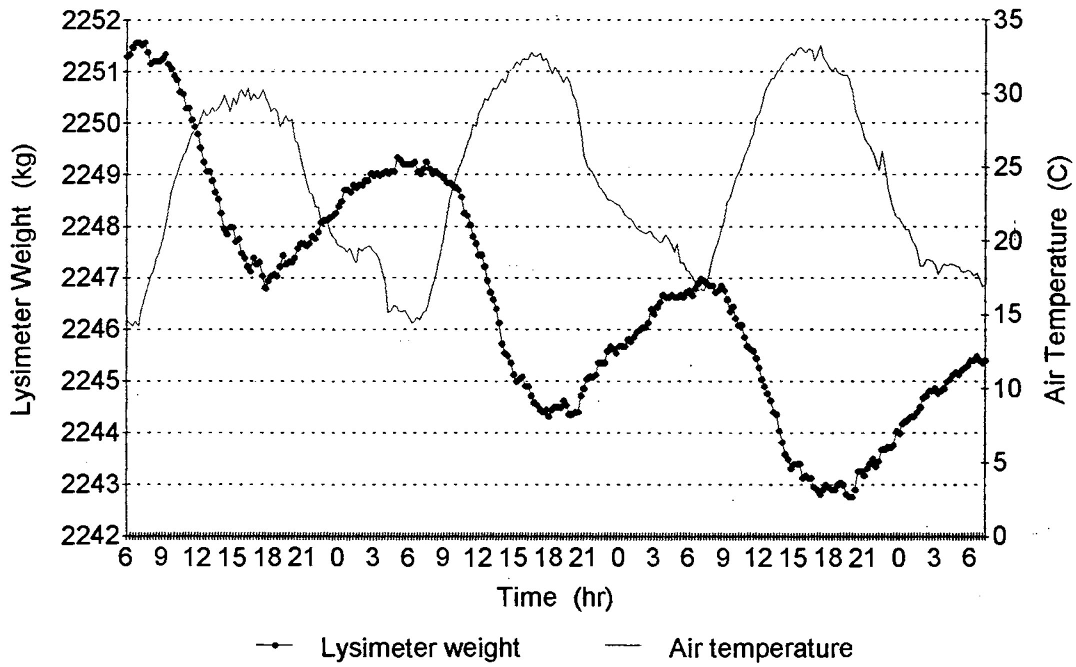

Figure 5.1. Lysimeter Readings Showing Suspected Thermal Influence for 3 Days at Goodwell.

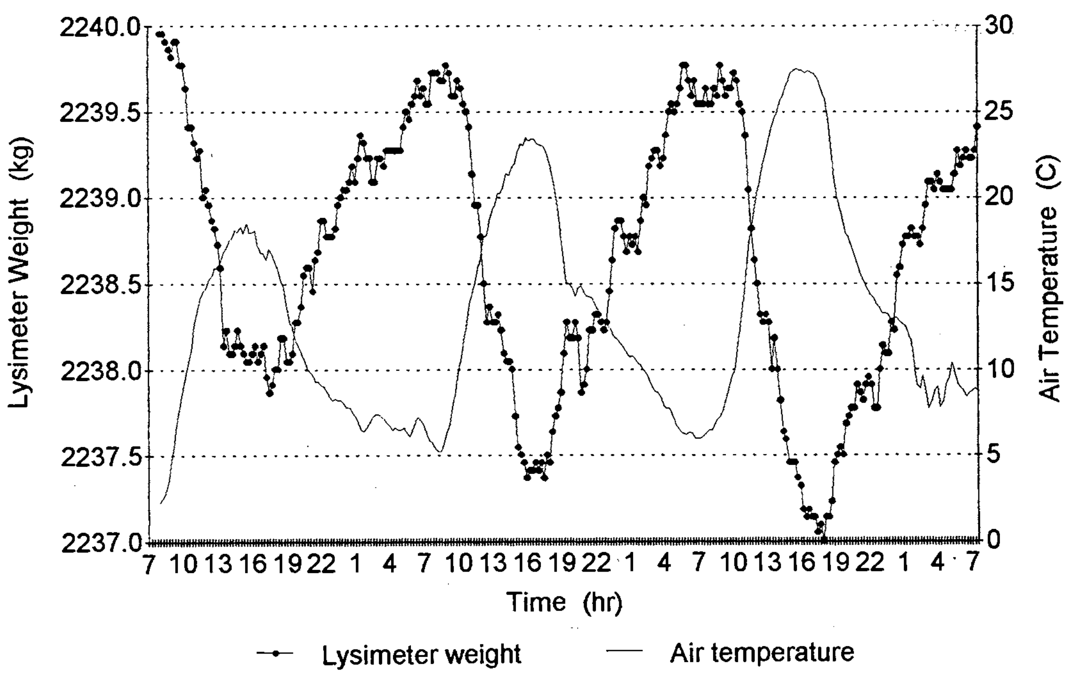

Figure 5.2. Lysimeter Readings Showing Suspected Thermal Influence During Days with Zero ET.

For the purposes of the research work reported here, ET measurements on a daily time scale were adequate, and the source of and possible solutions to the problem of thermal effects on lysimeter measurements at shorter time scales are being pursued.

Wiring

When the lysimeter loadcells were originally wired into the buried cables and connected to the dataloggers, the loadcell wire-to-cable connection was not placed in an enclosed container. After heavy spring rains, erratic loadcell readings occurred at Marena and Wister, which were later attributed to corrosion in the cable wiring. Soil water had seeped into the wiring, causing corrosion which affected the electrical properties of the wires and electrical signals in the wires. Since excitation and signal voltages used in making loadcell measurements were very small, noise in the voltage signals caused by the corrosion resulted in loss of data.

Several configurations were tested which would secure the wiring connection from water damage but still allow the connection to be accessed easily. A waterproof connection was constructed which consisted of a sealable plastic container with a removable top. Holes were bored into the sides of the container, the loadcells wires and cable were passed through the holes, and the wires were connected to the cable inside the container. The wiring holes were sealed on the inside and outside of the container with silicon sealant, and the top was placed on the container and sealed with sealant. The container was then buried approximately 0.3 m below the soil surface. Cable connections at Apache, Marena, and Wister were repaired in this manner. Loadcell readings at Goodwell never exhibited problems due to water damage and the waterproof connection was not installed.

Sealing the cable connection appeared to solve the wiring problems at Marena and Wister. After a very intense rainfall at Apache in June 1995, water appeared to have entered the plastic connection container and loadcell readings were affected. Loadcell and cable wires had to be repaired and the container resealed.

Flooding

On several occasions, the lysimeters at Marena and Wister were flooded and data were unusable. The air space between the inner and outer tanks filled with water, causing a buoyant force to be exerted on the inner tank. As water leaked in or drained out, the buoyant force changed, and lysimeter weight measurements were unreliable.

Flooding of the lysimeters could have resulted from several different conditions. It is possible that a heavy rain could have caused surface runoff in the field outside the outer tank, and that water flowing overland reached the lysimeter and flowed into the outer tank. A heavy rain could also have caused ponding of water on the surface of the inner tank, which then overflowed and drained into the outer tank. Water could also have entered the outer tank underground if the loadcell compartments on the outer tank walls were not properly sealed.

Based on examination of rainfall and lysimeter data, it appears that the flooding was caused by water entering the outer tank through the loadcell compartments. On several occasions, lysimeter data showed fluctuating lysimeter weights, suggesting changes in buoyant forces, long after a rainfall event. On other occasions, when soil water contents were high, a relatively small amount of rainfall would result in flooding of the lysimeter. As water later drained out through the loadcell compartments, lysimeter weight increased due to decreasing buoyancy.

When the water level inside the outer tank reached the lowest level of the cutouts in the tank wall, drainage ceased and the buoyant force remained constant.

During lysimeter installation, the loadcell compartments were sealed with silicon sealant prior to backfilling of the soil around the outer tank. It appears that one or more loadcell compartments were not completely sealed, allowing soil water to drain into and out of the compartments and the outer tank.

When flooding occurred, a visit to the lysimeter site was necessary and water in the outer tank had to be pumped out. A small-diameter plastic hose was inserted into the space between the inner and outer tanks and lowered until it reached the bottom of the outer tank. The hose was attached to a portable electric pump and the water was pumped out.

Repair work was done on the lysimeter at Wister in July 1995 in an attempt to seal the loadcell compartments. The loadcell compartments were exposed by removing the soil around the loadcell compartments outside the outer tank. Sealant originally applied during lysimeter installation was removed and new sealant was applied. A bead of sealant was then applied around the loadcell compartments and a layer of heavy plastic sheeting was sealed into place. A second layer of plastic sheeting was then placed around the sealed compartment and the soil was backfilled.

Gopher Damage

The lysimeter at Apache was damaged periodically by gophers burrowing in the soil outside the lysimeter. Several loadcell wires were damaged or completely severed by gophers burrowing in the field. Damage resulted in erratic loadcell and lysimeter measurements or the complete loss of loadcell measurements until the damage could be found and repaired.

Loadcell wires are protected below ground inside flexible steel conduit for most of their length but are exposed for short lengths in two places. On each loadcell, a 150-mm length of wire is unprotected after it leaves the loadcell compartment on the outer lysimeter tank and before it enters a steel conduit on the side of the tank. At the other end of the conduit, the wire is exposed for 300 mm before it enters a plastic container and is connected to the cable leading to the Mesonet station. The cable is protected inside PVC conduit until it reaches the fence around the Mesonet station.

One loadcell wire was completely severed between the loadcell compartment and the steel conduit. The soil around the loadcell compartment had to be excavated to a depth of 0.6 m in order to expose the damaged wire and allow repair. The five individual leads in the wire were spliced back together, taped, and sealed with silicon sealant and waterproof tape.

Several wires were damaged at the other end of the conduit where the four loadcell wires come together and are connected to the cable. The plastic insulation on the wires was chewed and individual lead wiring was exposed. The damaged areas were cut and removed, and the wires were spliced back together and sealed.

EVAPOTRANSPIRATION MEASUREMENTS

Lysimeters were installed in the summer and fall of 1993. Electrical connection of the lysimeters to the Mesonet stations took place approximately six months following lysimeter installation. This provided time for the disturbed and reconstructed soil inside the lysimeters to settle and damaged vegetation around the lysimeter to regrow before any measurements were made.

Lysimeter measurements were used to obtain estimates of evapotranspiration at daily time intervals. Average lysimeter weights were determined at sunrise on each day, and daily ET amounts were estimated as the change in average lysimeter weight from one day to the next. Daily ET values from each site are presented and discussed in the following sections.

Periods of Data Collected

Daily ET measurements are reported for the period beginning the last week of January 1994 through July 1995 at Apache, Marena, and Wister, and the middle of May 1994 through July 1995 at Goodwell. The lysimeters were operated continuously during these periods, and the data were collected and examined to ensure proper lysimeter operation.

Daily ET measurements at Goodwell are shown in Figures 5.3 through 5.6. During this period, the lysimeter operated with almost no problems, with only one day of missing data.

Daily ET measurements at Apache are shown in Figures 5.7 through 5.11. Beginning in August 1994, electrical problems in the loadcell wires due to gopher damage began to occur. Intermittent wiring problems occurred in August and September 1994 and were repaired so that October 1994 data was complete. From November 1994 through March 1995, intermittent wiring problems due to gopher damage resulted in periods of missing data. Heavy rains in June 1995 caused water to enter into the loadcell wire-datalogger cable connection box, resulting in damage to the wires and loss of data.

Daily ET measurements at Marena are shown in Figures 5.12 through 5.16. In March 1994, heavy rains caused the lysimeter to flood, saturating and damaging the loadcell wires and datalogger cable. A search for a solution to the problem of sealing the wire-cable connections resulted in periods of lost data from March through September 1994. Periodic flooding and pumping out of the lysimeter resulted in periods of lost data from March through June 1995.

Daily ET measurements at Wister are shown in Figures 5.17 through 5.21. Heavy rains and saturated soil resulted in flooding of the lysimeter and lost data from January through March 1994. Periods of lost data through August 1994 were due to water damage to the loadcell wires and datalogger cable. A period of complete data in September and half of October 1994 was followed by flooding problems and no data from the middle of October 1994 through most of February 1995.

Daily ET Measurements

Daily ET measurements are shown for the four sites in Figures 5.3 through 5.21. In each figure, lysimeter measurements of ET are shown along with total daily solar radiation and precipitation for 24-hour periods from sunrise one day to sunrise on the following day. Solar radiation measurements are shown to provide an indication of the radiant energy available to drive the evaporation process during each day. Precipitation events are shown to indicate the timing and amounts of rainfall incident at each site which provided water for evaporation and for replacement of depleted soil water. Precipitation amounts and lysimeter measurements for days with rainfall are shown with negative signs, indicating that the change in water content of the soil was opposite in direction (atmosphere to soil) from ET (soil to atmosphere).

Data were plotted with the same vertical scale on all graphs to allow visual comparison of ET measurements between sites. The range of daily ET values measured under different vegetative and climatic conditions at the four sites can be visually observed, as well as the influence of varying weather conditions. Average daily ET values for all four sites are compared on a monthly basis in Figure 5.22.

Daily ET measurements shown in Figures 5.3 through 5.21 are summarized for each site in Tables 5.2 through 5.5. Daily average, maximum, and minimum ET values are listed for each month. Standard deviations are listed to give an indication of the variability of ET measurements during each month. The values listed in Tables 5.2 through 5.5 were determined using lysimeter data collected during days in which no precipitation was reported. The number of days without precipitation during which ET measurements were collected and used to determine the values in the tables are shown, as well as the number of days of missing data for each month. Appendix D contains a complete listing of daily ET measurements for each site.

In viewing the graphs of ET measurements in Figures 5.3 through 5.21, several aspects of the evaporation process can be observed qualitatively. Influences such as vegetative cover conditions, climatic conditions, precipitation events, and available soil-water contents, as well as day-to-day variability, can be observed in the figures.

The activity of the vegetation and the climatic conditions at each site can be described in general by observing the change in ET rates throughout the year. In early spring, an increase in ET rates signals the beginning of active vegetative growth. As growth continues, ET rates increase and reach a maximum in early summer. Hot, dry periods in summer result in a lack of available water to the plants, and ET rates appear to decline. In late summer and early fall, ET rates decline as vegetative growth slows and the dormant period begins. Throughout the winter, ET rates are very low, and reflect small amounts of water evaporating from soil and plant surfaces.

The dependence of evapotranspiration on cover conditions and available water can be observed by briefly discussing ET measurements collected at each site. At Goodwell, the vegetation consisted mainly of buffalograss, a shortgrass species, which covered approximately 50% of the soil surface area. The other 50% of the surface consisted of bare soil. ET rates were relatively low all year, with maximum daily rates in the range of 4 to 5 mm/d. ET rates could be seen to decline a few days after a rainfall. Low rainfall amounts resulted in less water available for the vegetation, and the large areas of exposed soil surface allowed soil water to evaporate quickly.

At Apache, the vegetation consisted primarily of bermudagrass which covered approximately 80% of the soil surface. The density of the vegetation varied from dense clumps to sparse patches, with areas of bare soil also present. Higher rainfall and a higher density of vegetation resulted in higher ET rates, with maximum rates in the range of 6 to 8 mm/d. ET rates persisted longer after a rainfall before beginning to decline, suggesting that there was more soil water available to support plant transpiration and evaporation from exposed soil surfaces.

The Marena site had a mixture of native grass species which included warm-season and cool-season grasses, the distribution of which changed continuously depending on the growth stage of each species. The vegetation covered approximately 70% of the soil surface, with the density of the vegetation varying greatly between dense clumps, sparse areas, and bare-soil patches. Maximum ET rates were similar to those at Apache, in the range of 6 to 8 mm/d.

At Wister, the vegetation consisted almost entirely of a uniform cover of tall fescue. Some sparsely vegetated and bare-soil areas were present, but in general the vegetation was fairly dense and covered approximately 95% of the surface area. Maximum ET rates were generally in the range of 6 to 8 mm/d, with 10 mm/d exceeded on some days. Frequent rainfall allowed the vegetation to maintain relatively high ET rates throughout the year, except in the middle of summer when ET rates dropped as a result of soil water depletion. Climatic conditions were mild enough that the vegetation remained active throughout the winter.

Increases in ET soon after precipitation events can be seen on many occasions at all sites. After a rainfall, free water was present when plant and soil surfaces were wetted. When sufficient solar radiation became available, free water on the surfaces evaporated readily. After the surfaces dried, ET rates decreased and were again under the control of plant and soil evaporative mechanisms.

During periods of dormant vegetation, changes in weight measured by the lysimeters were due to evaporation of water from exposed soil and wet plant surfaces. Evaporation during periods of dormant vegetation can be seen at Goodwell, Apache, and Marena: the vegetation at Wister remained active all year. Low levels of solar radiation and cold temperatures during winter resulted in low evaporation rates even soon after a rainfall when surfaces were wet and free water was available.

Throughout Figures 5.3 through 5.21, the variability in ET amounts from one day to the next can be seen. Changes in conditions such as radiant energy or water availability, air temperature, or relative humidity can result in a several-fold change in ET. Dugas and Mayeux (1991) commented on the variability of daily ET amounts and cautioned against methods which use one or a few daily ET measurements to infer average ET rates.

Lysimeter measurements made during precipitation events resulted in weight changes which were negative in sign, meaning that a net gain in weight had occurred. Since the lysimeter reported the change in weight from one day to the next, the combined effects of rainfall and evapotranspiration were measured, but the contribution of each was unknown. During rainfall events, however, solar radiation is usually low, humidity is high, and ET rates would be expected to be small. The lysimeter could therefore be used to provide an estimate of the rainfall amount. Rainfall amounts estimated with the lysimeter were compared to tipping-bucket raingage measurements at each site and are shown in Figures 5.23 through 5.26.

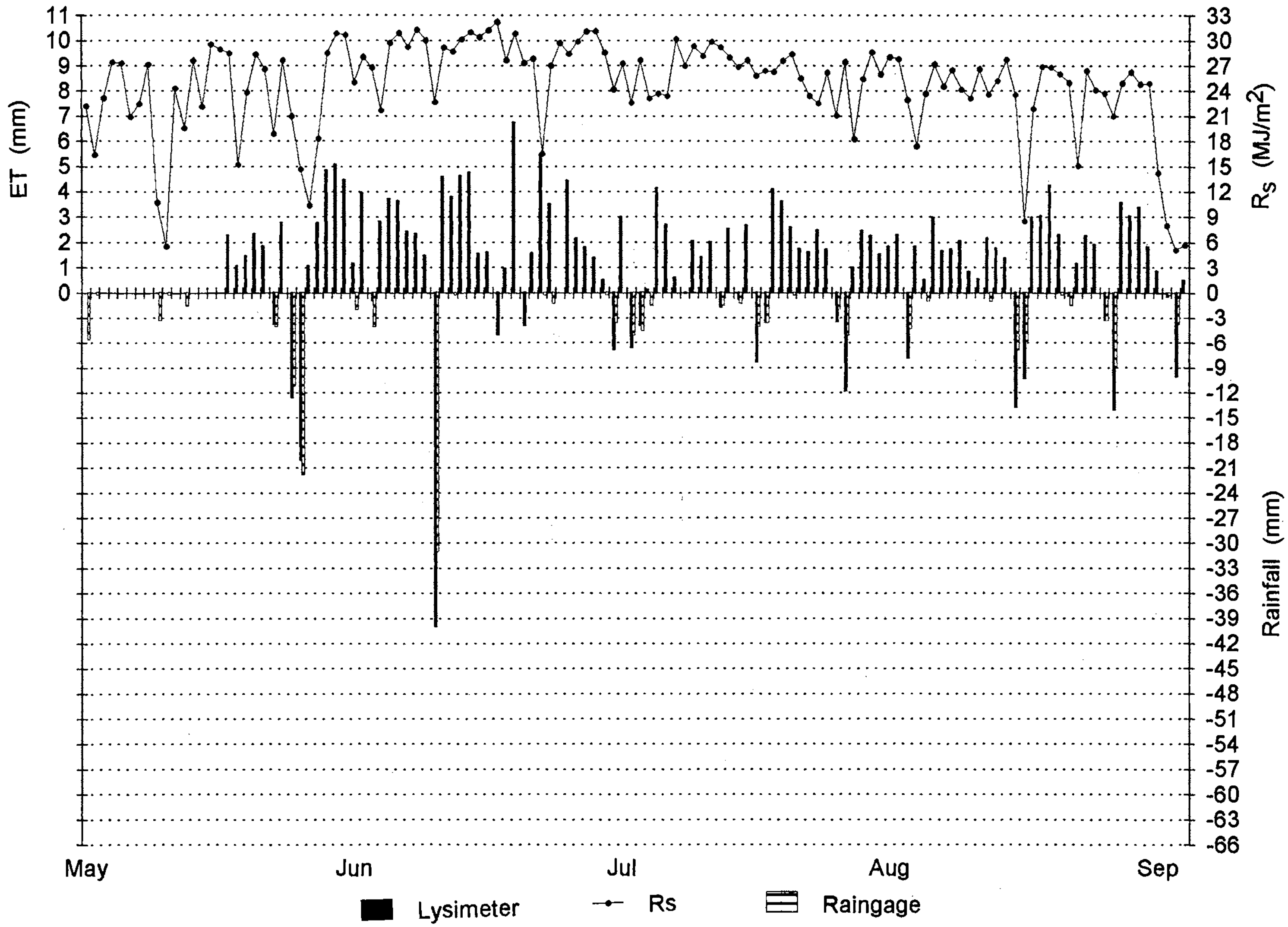

Figure 5.3. Daily ET Measurements at Goodwell from May through August 1994.

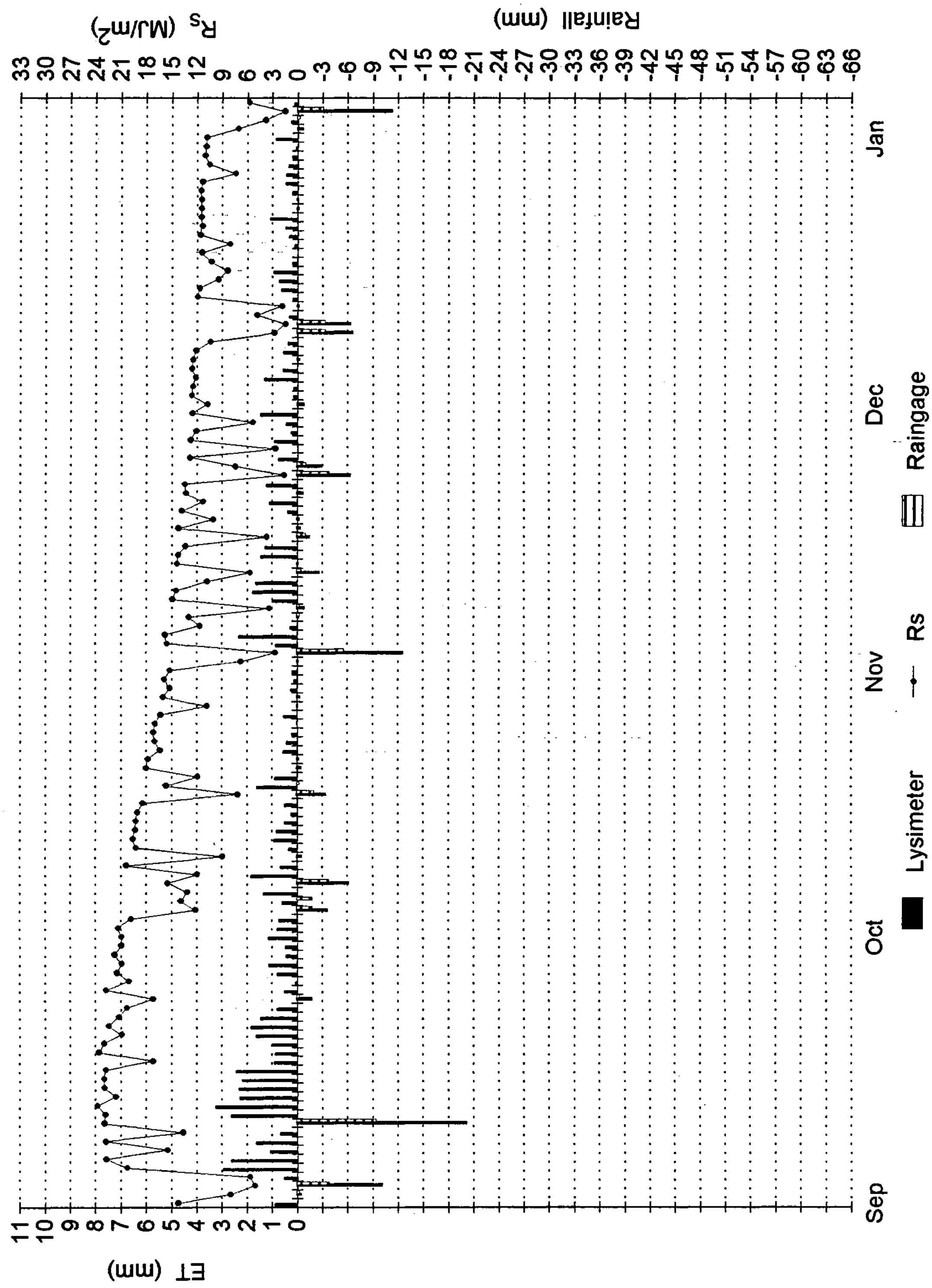

Figure 5.4. Daily ET Measurements at Goodwell from September through December 1994.

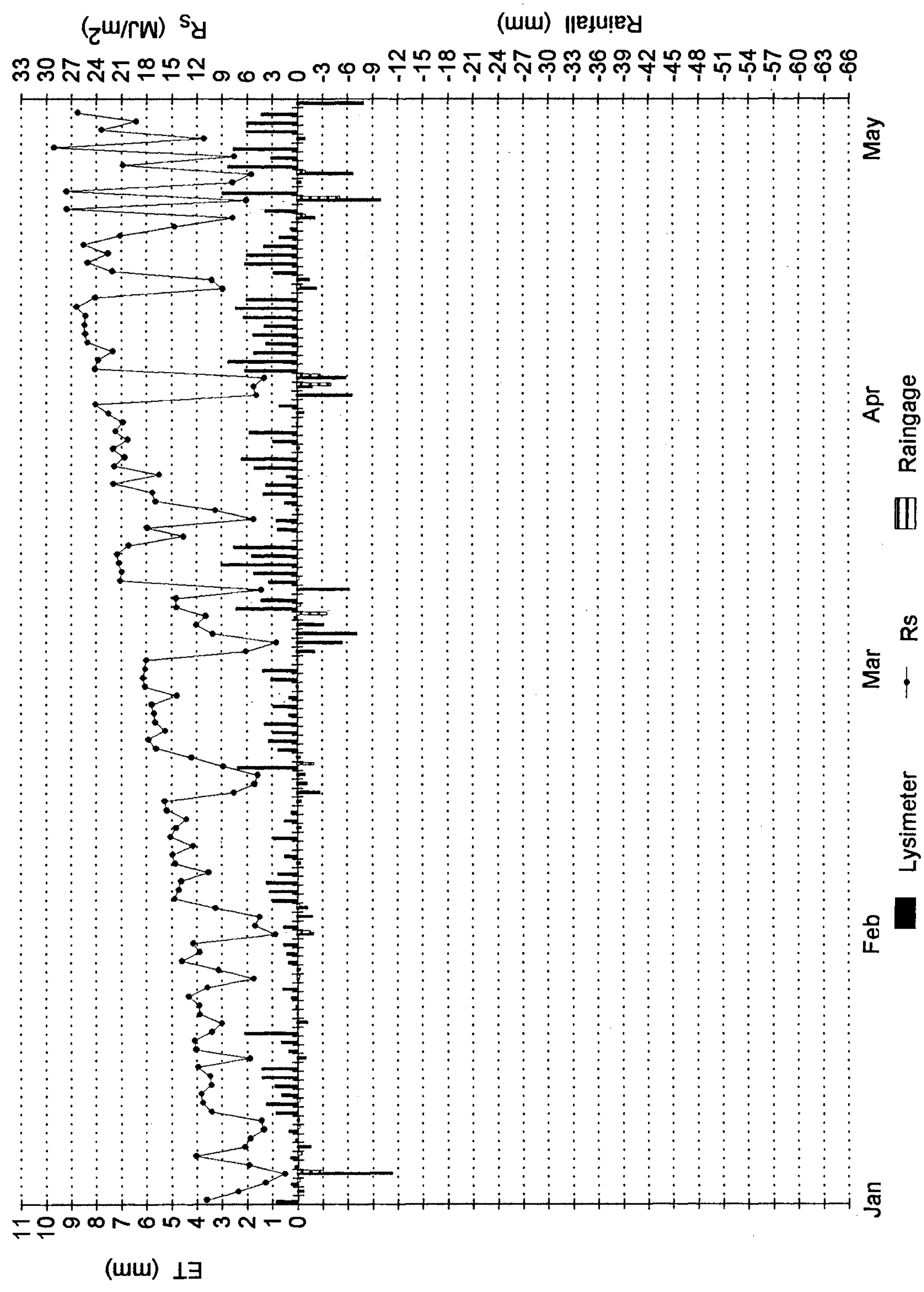

Figure 5.5. Daily ET Measurements at Goodwell from January through April 1995.

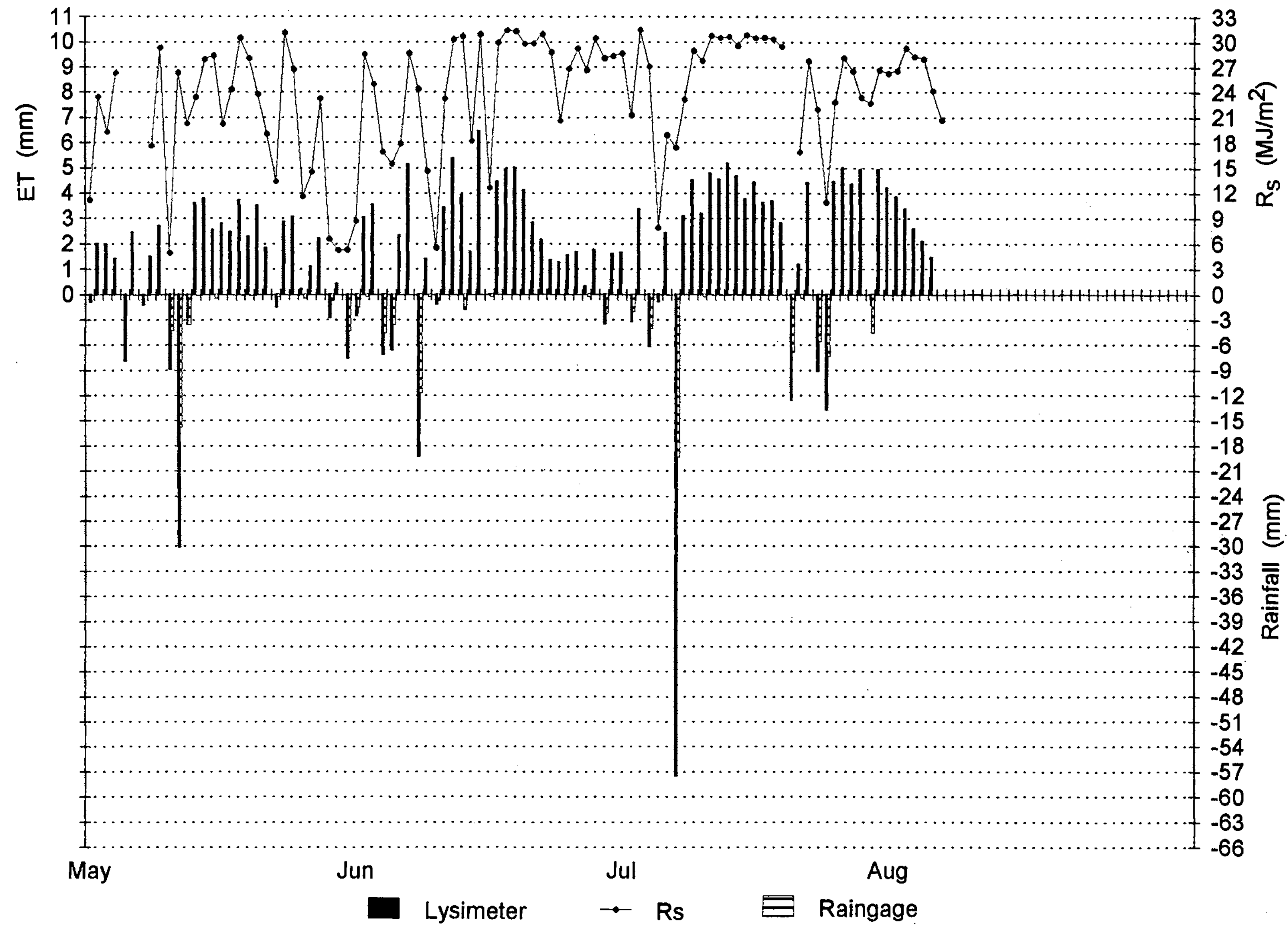

Figure 5.6. Daily ET Measurements at Goodwell from May through July 1995.

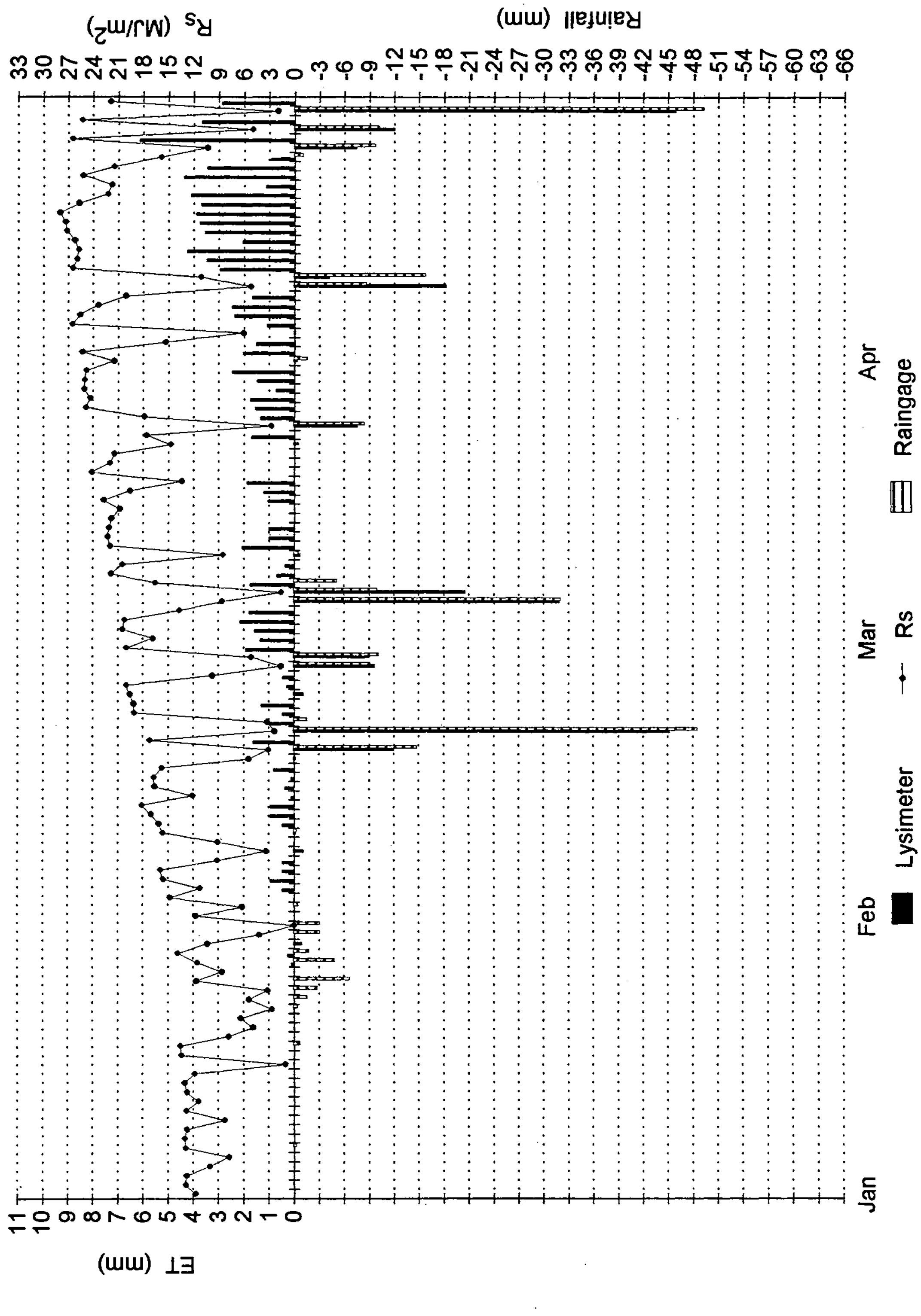

Figure 5.7. Daily ET Measurements at Apache from January through April 1994.

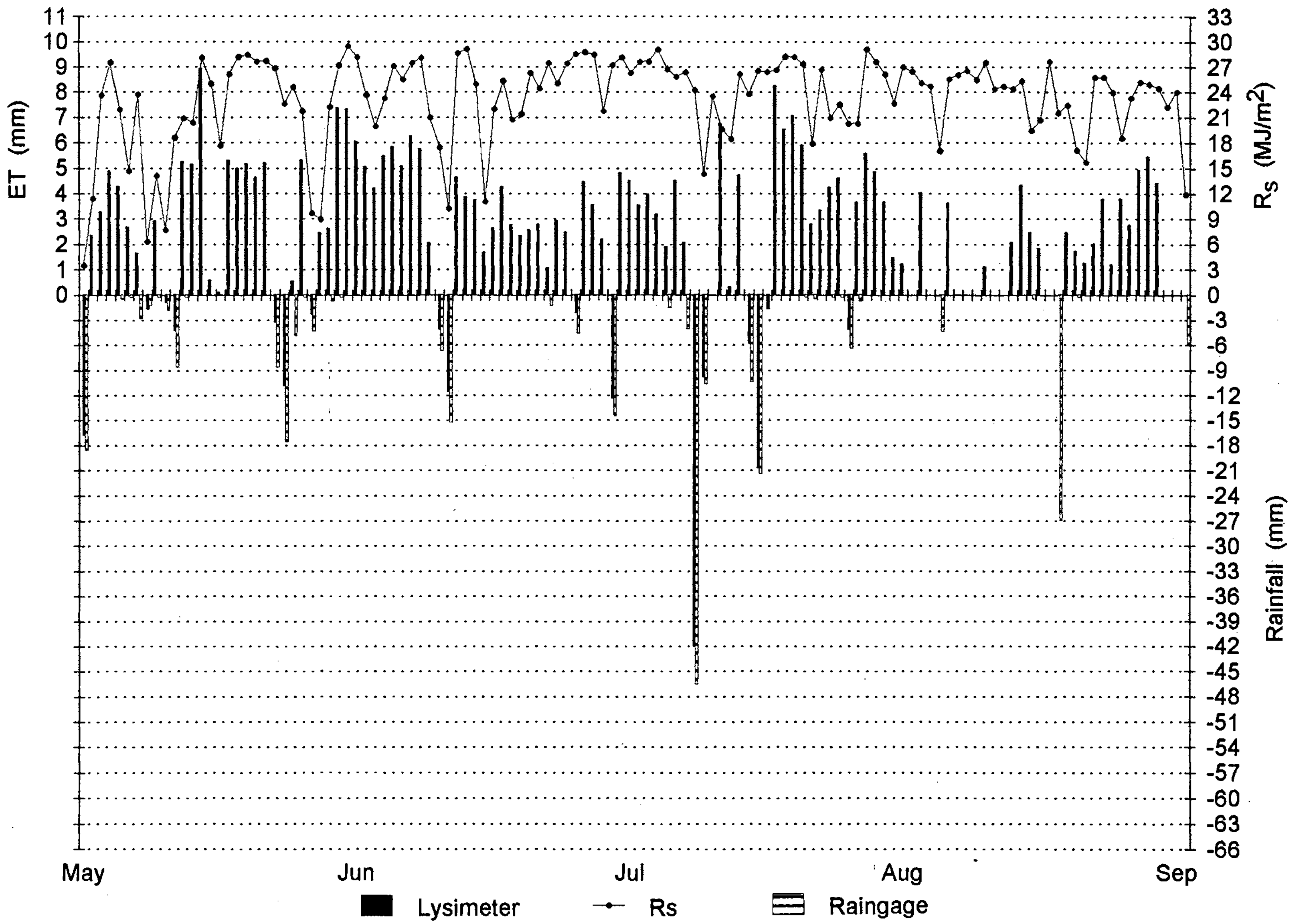

Figure 5.8. Daily ET Measurements at Apache from May through August 1994.

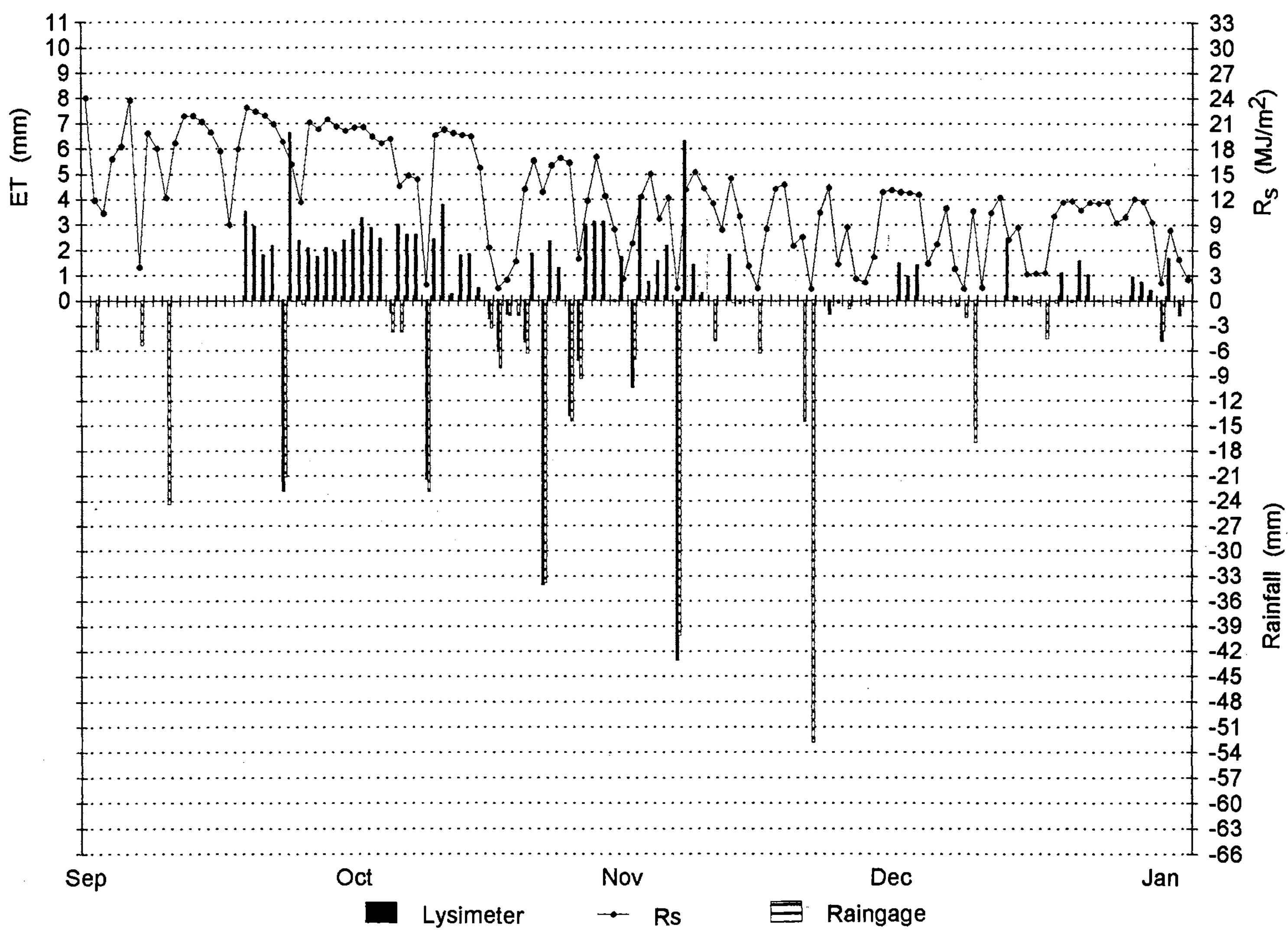

Figure 5.9. Daily ET Measurements at Apache from September through December 1994.

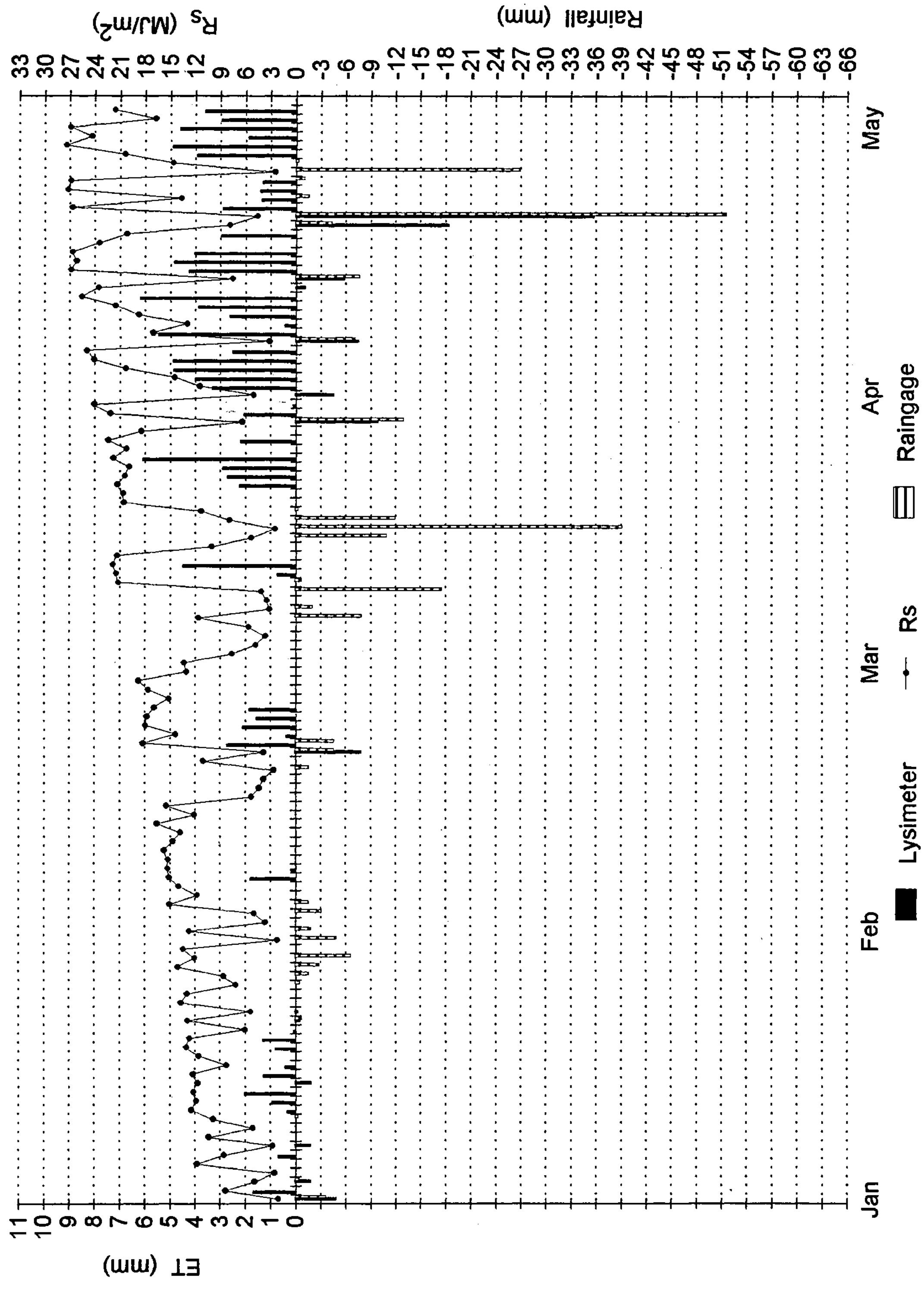

Figure 5.10. Daily ET Measurements at Apache from January through April 1995.

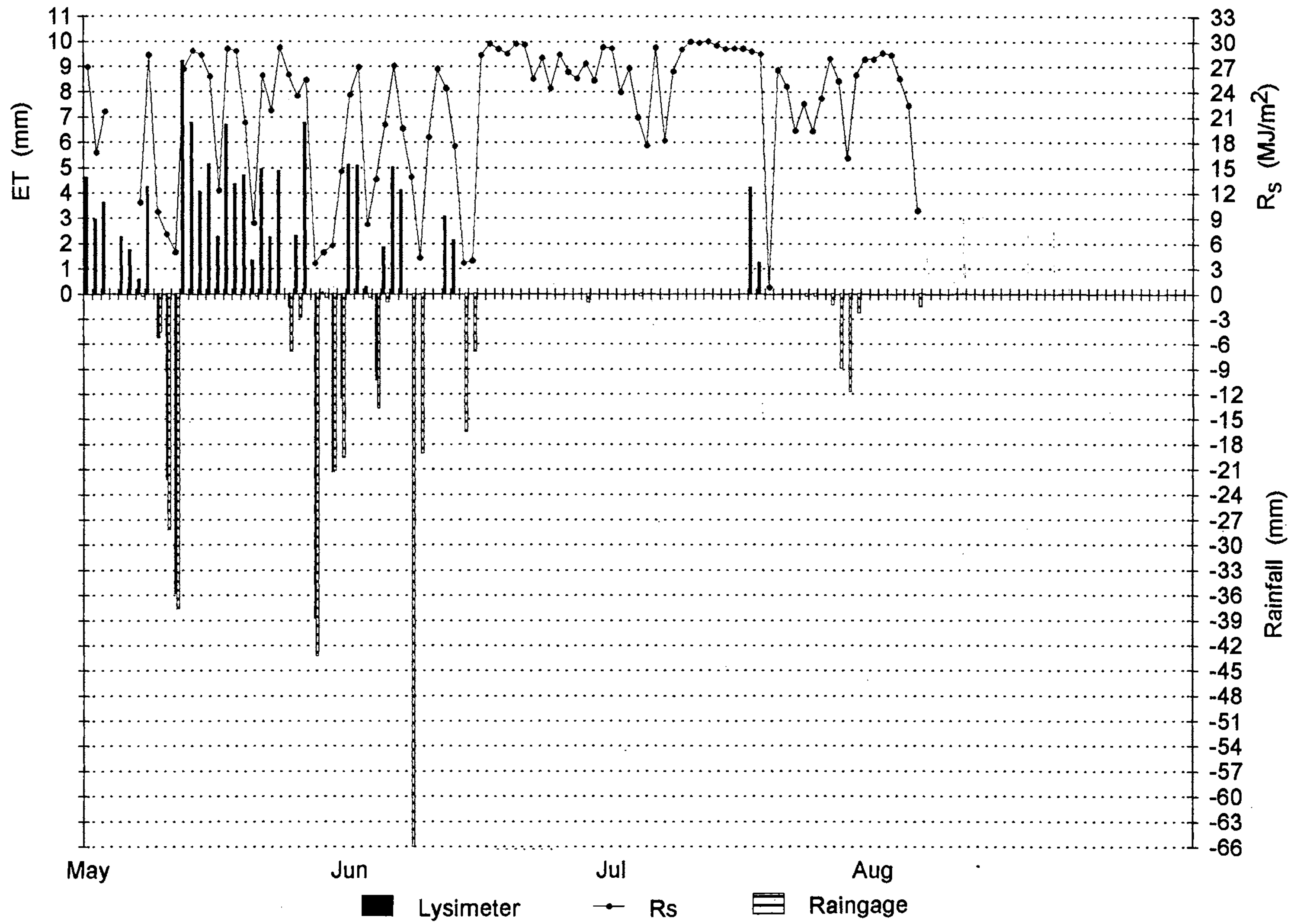

Figure 5.11. Daily ET Measurements at Apache from May through July 1995.

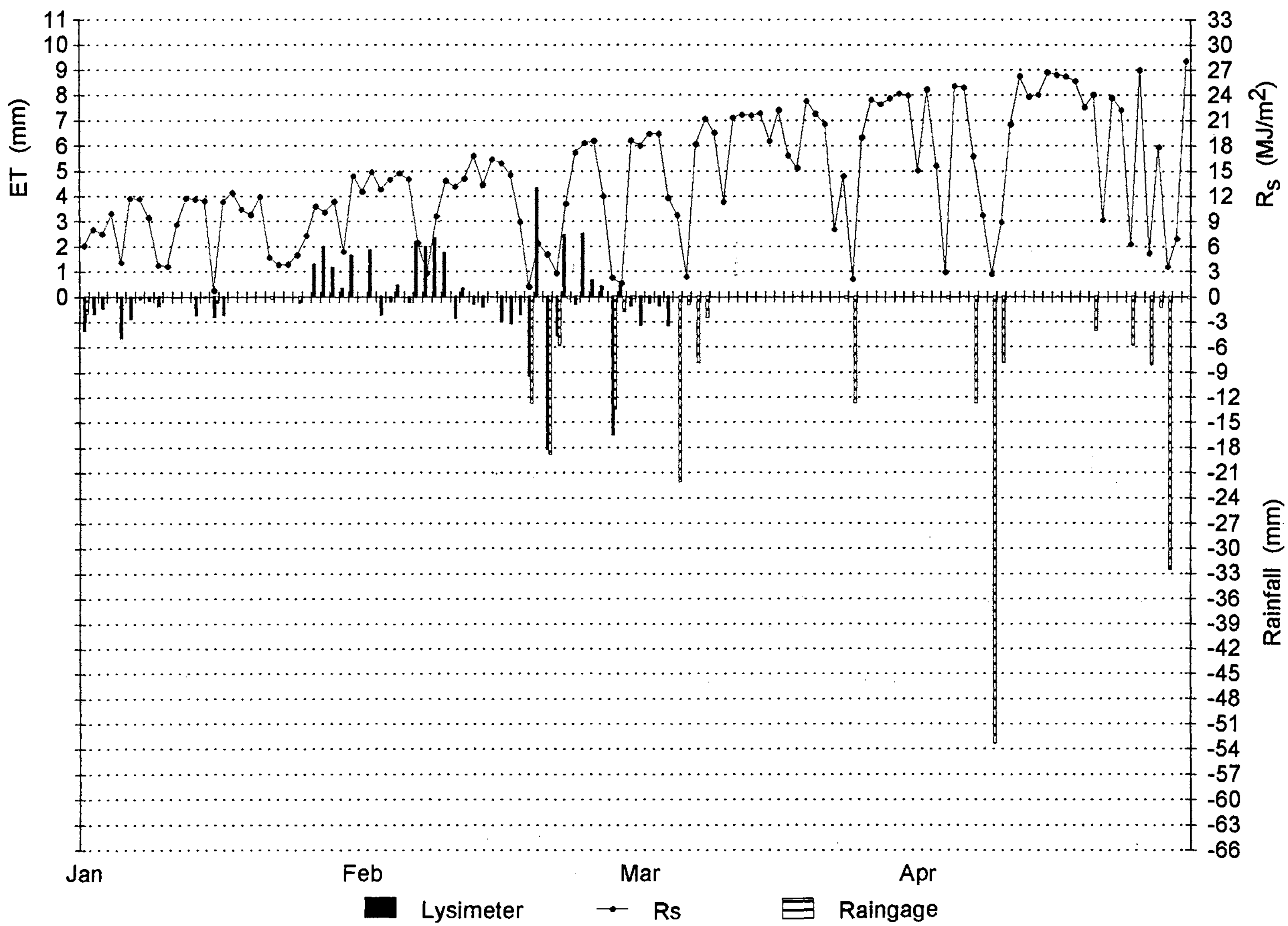

Figure 5.12. Daily ET Measurements at Marena from January through April 1994.

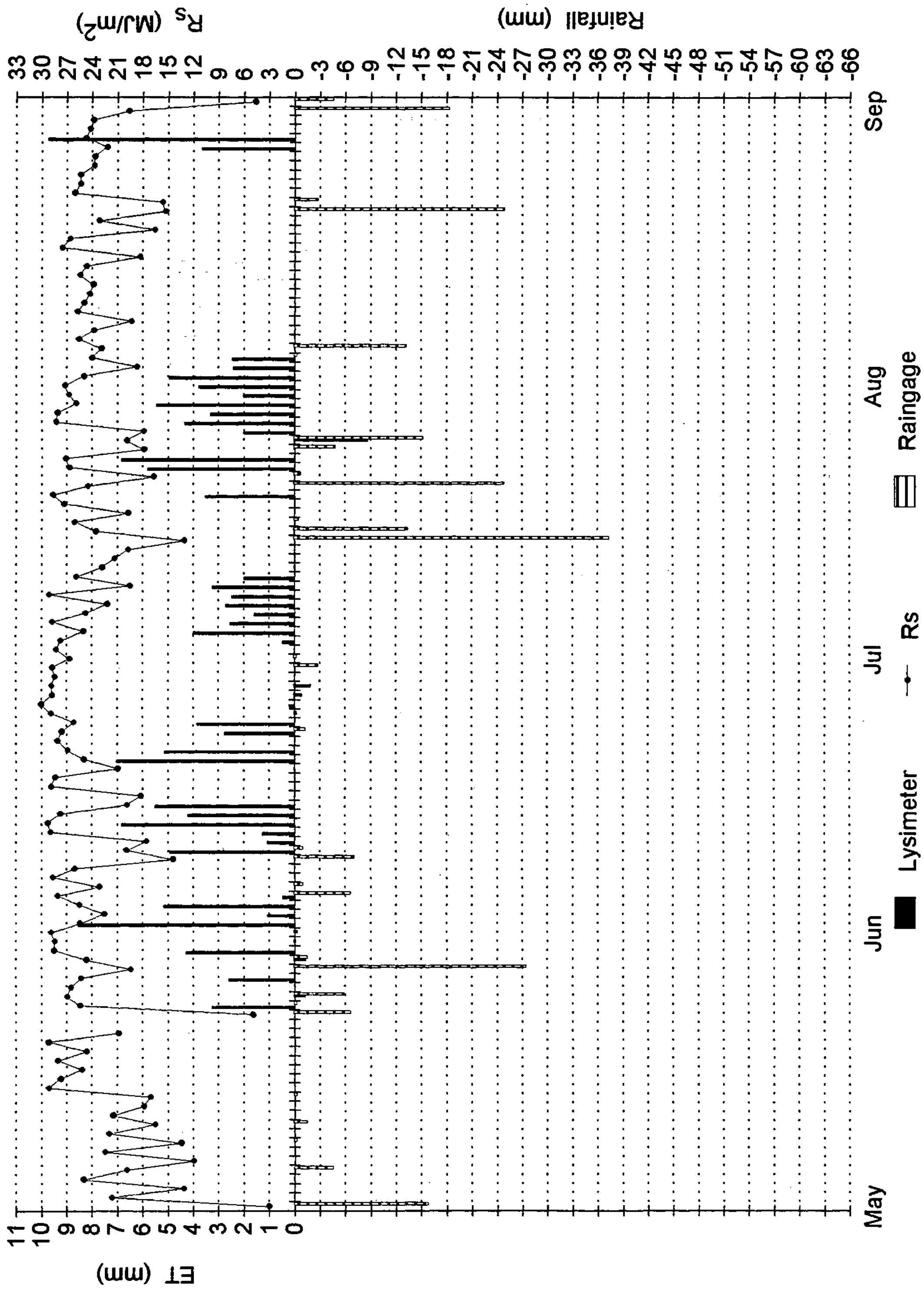

Figure 5.13. Daily ET Measurements at Marena from May through August 1994.

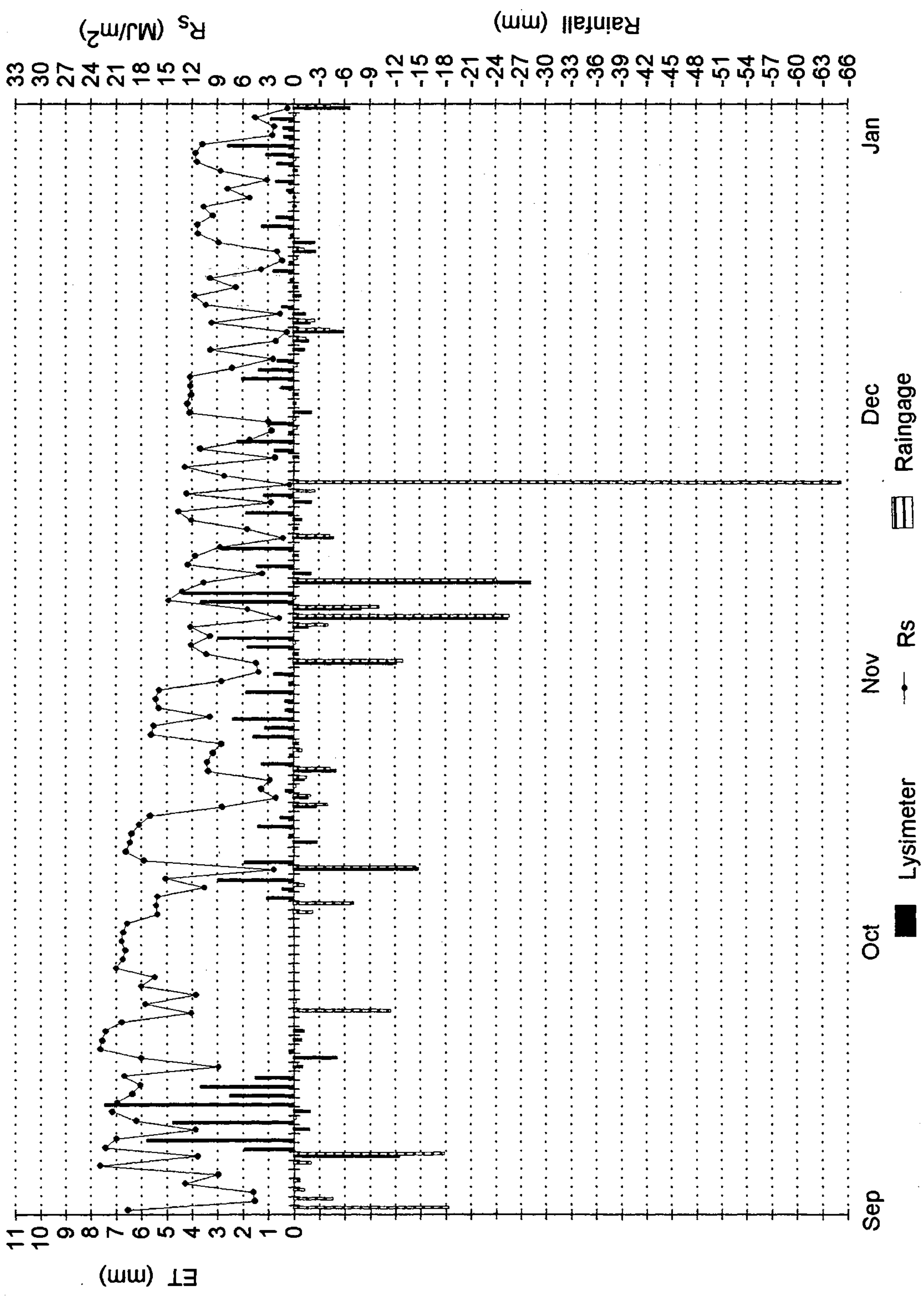

Figure 5.14. Daily ET Measurements at Marena from September through December 1994.

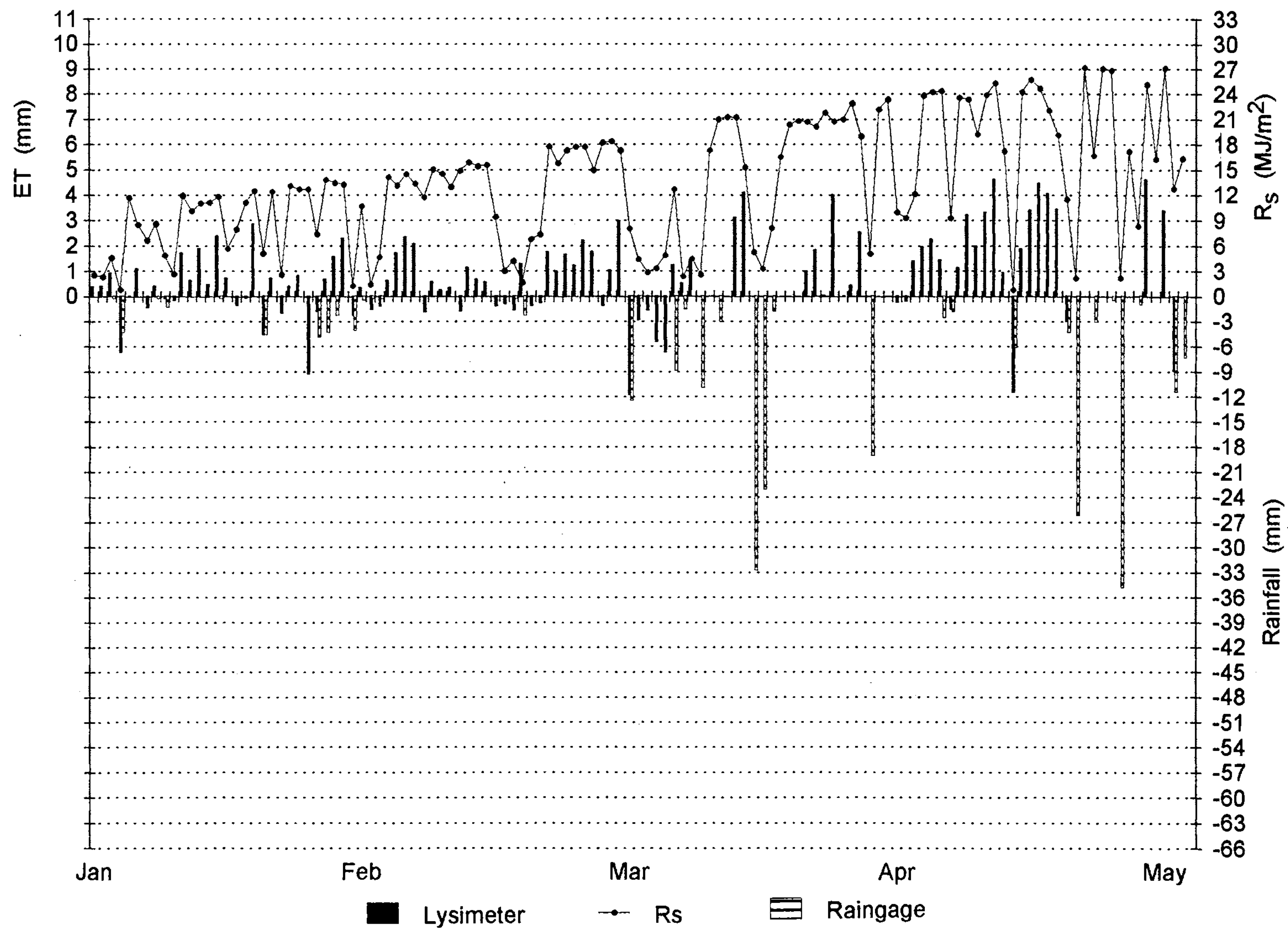

Figure 5.15. Daily ET Measurements at Marena from January through April 1995.

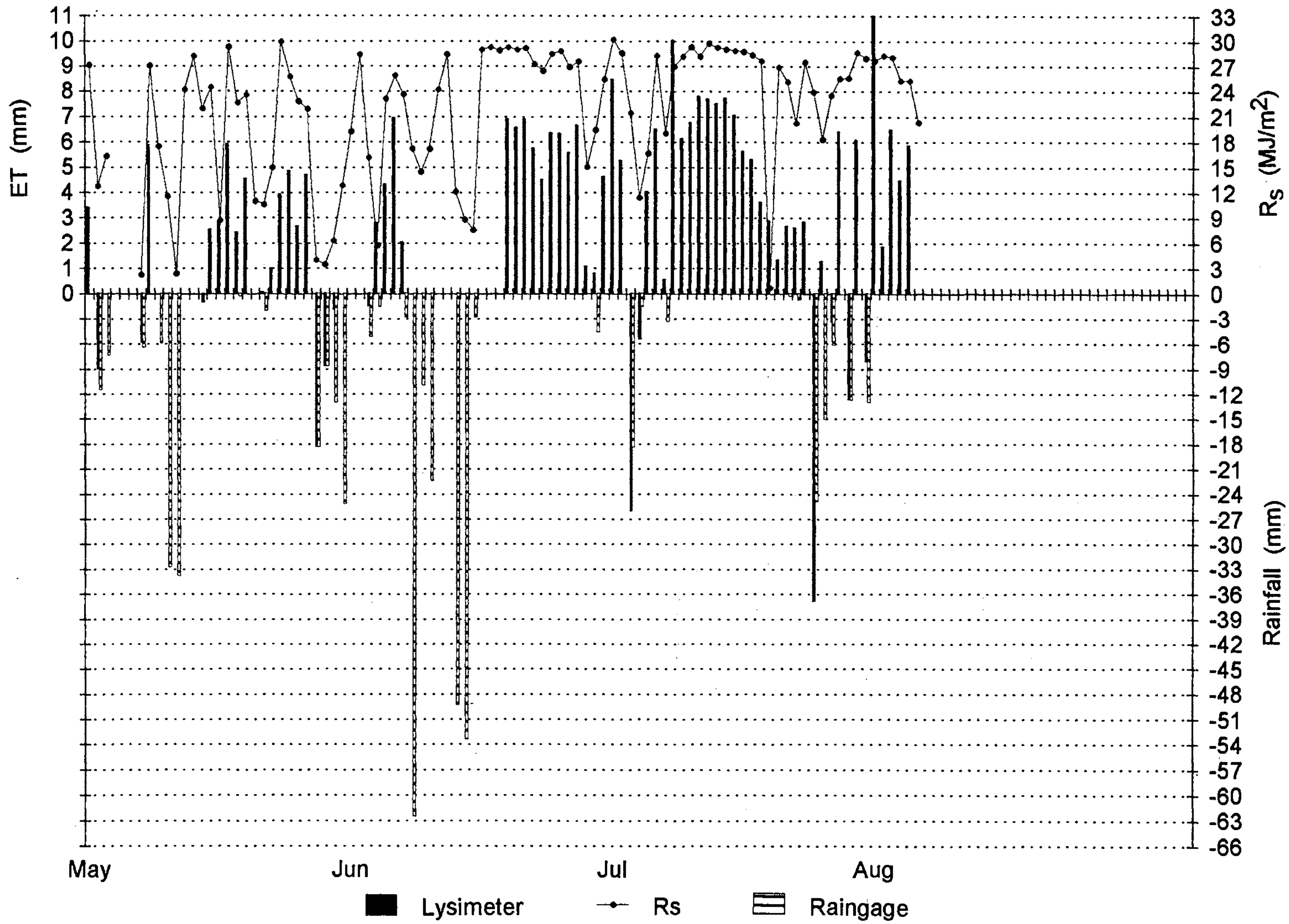

Figure 5.16. Daily ET Measurements at Marena from May through July 1995.

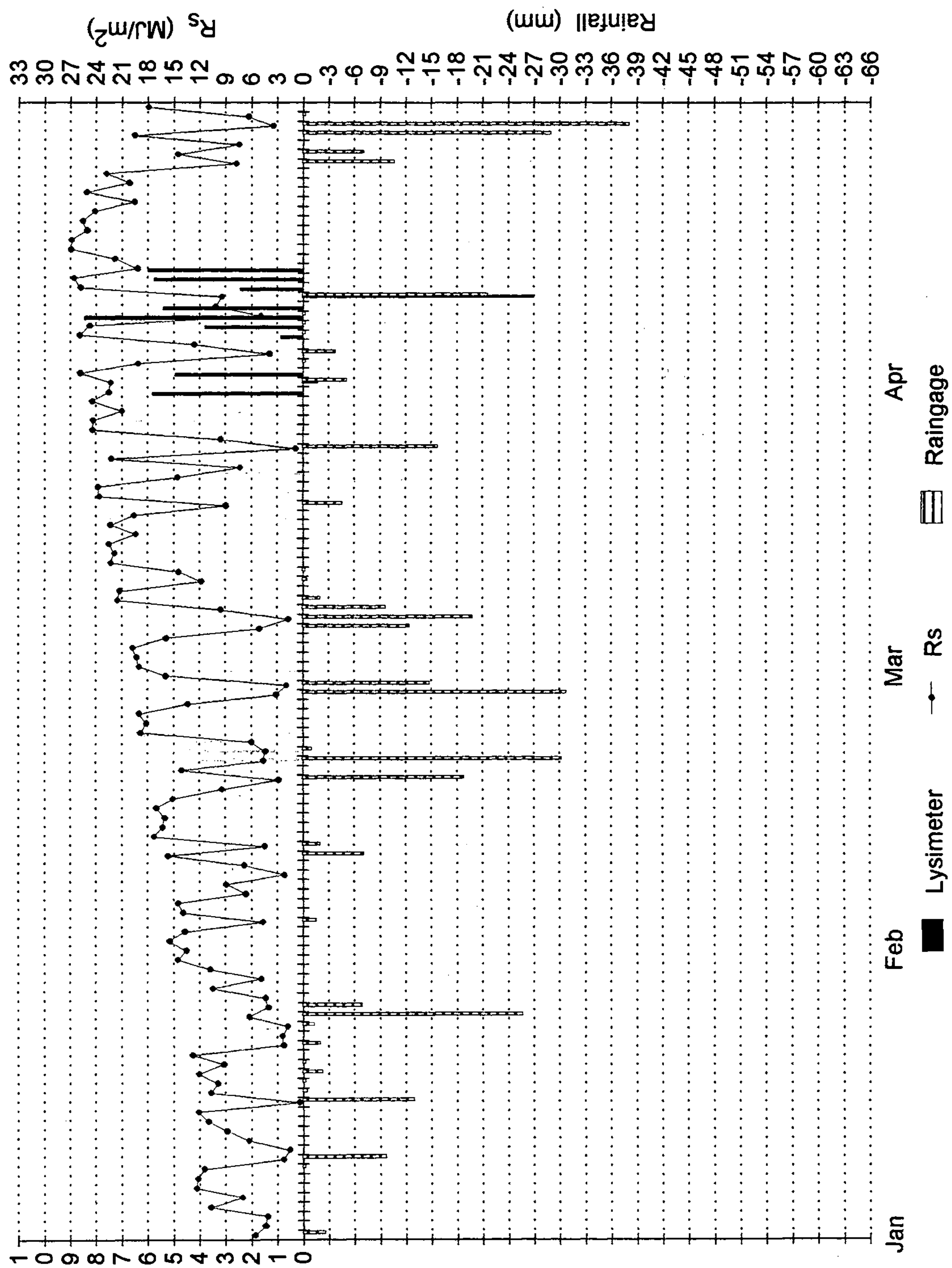

Figure 5.17. Daily ET Measurements at Wister from January through April 1994.

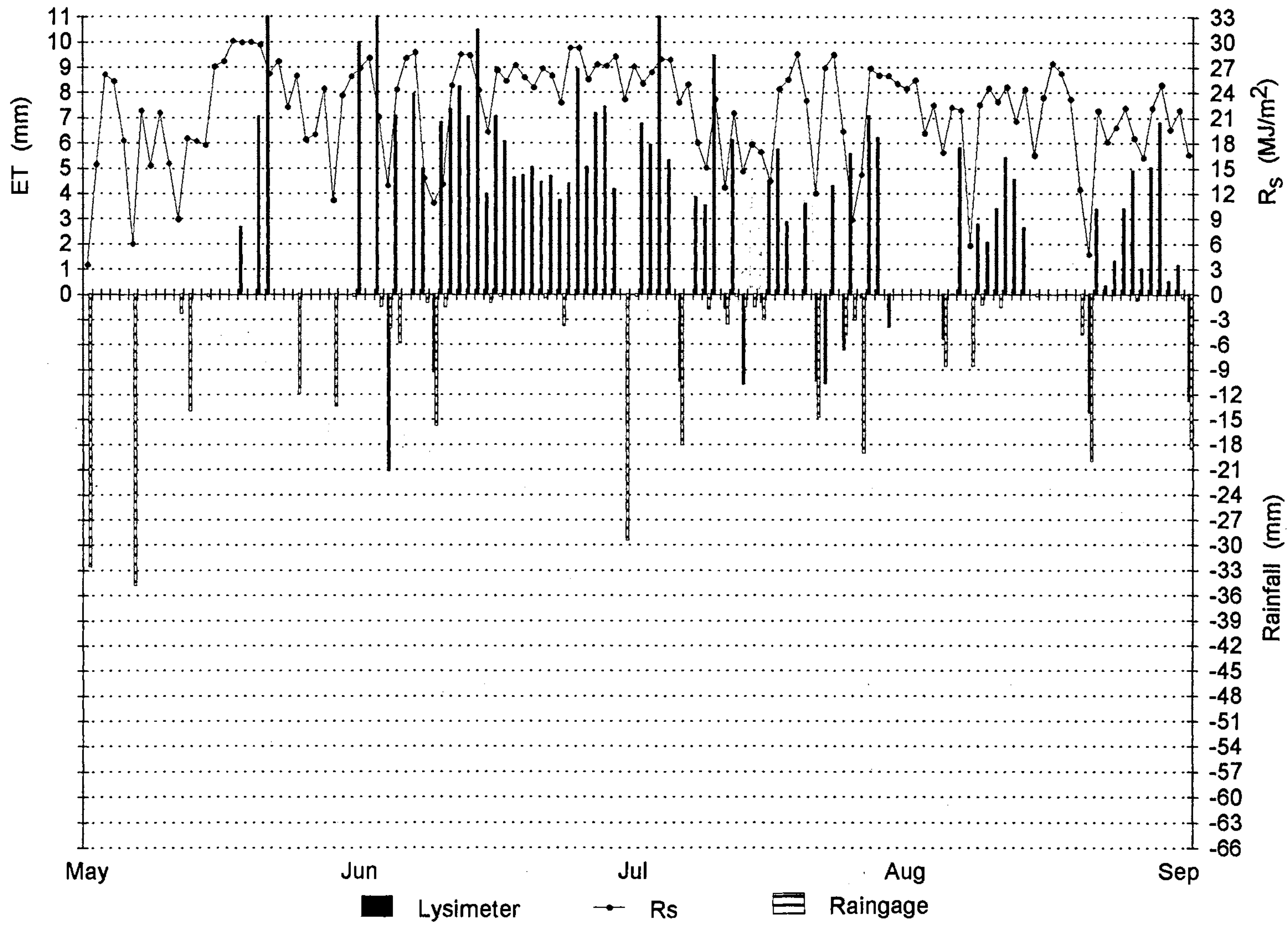

Figure 5.18. Daily ET Measurements at Wister from May through August 1994.

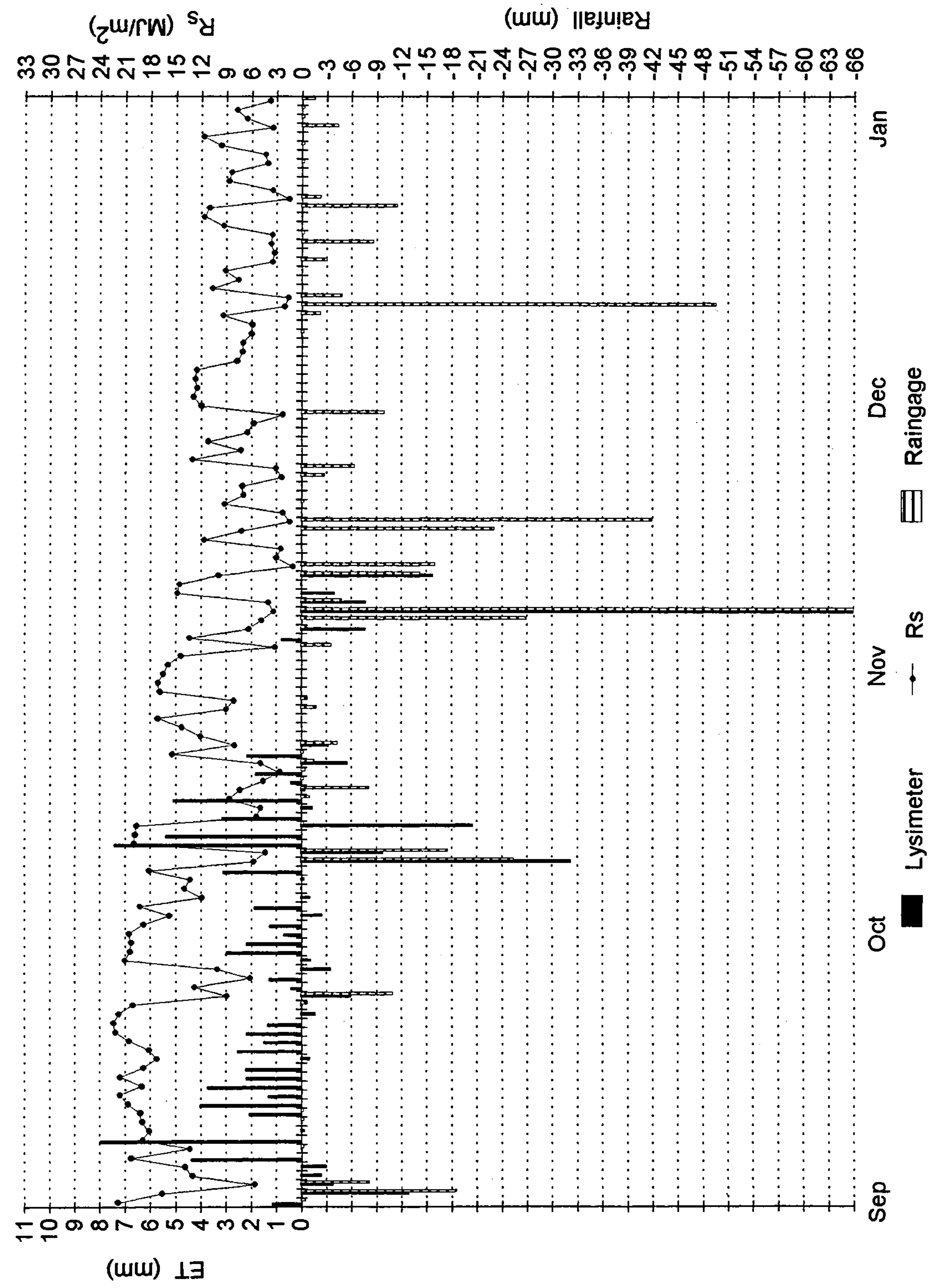

Figure 5.19. Daily ET Measurements at Wister from September through December 1994.

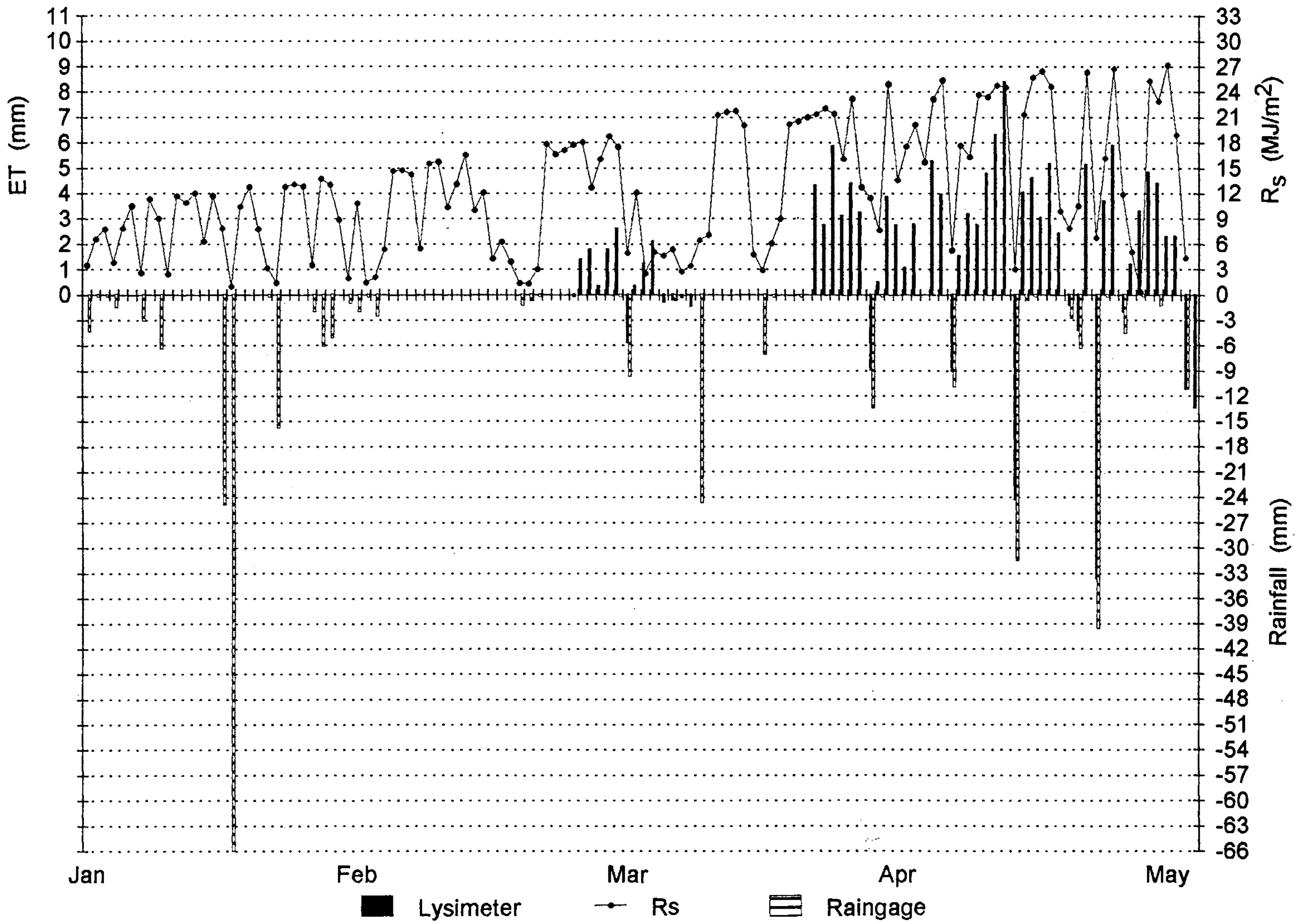

Figure 5.20. Daily ET Measurements at Wister from January through April 1995.

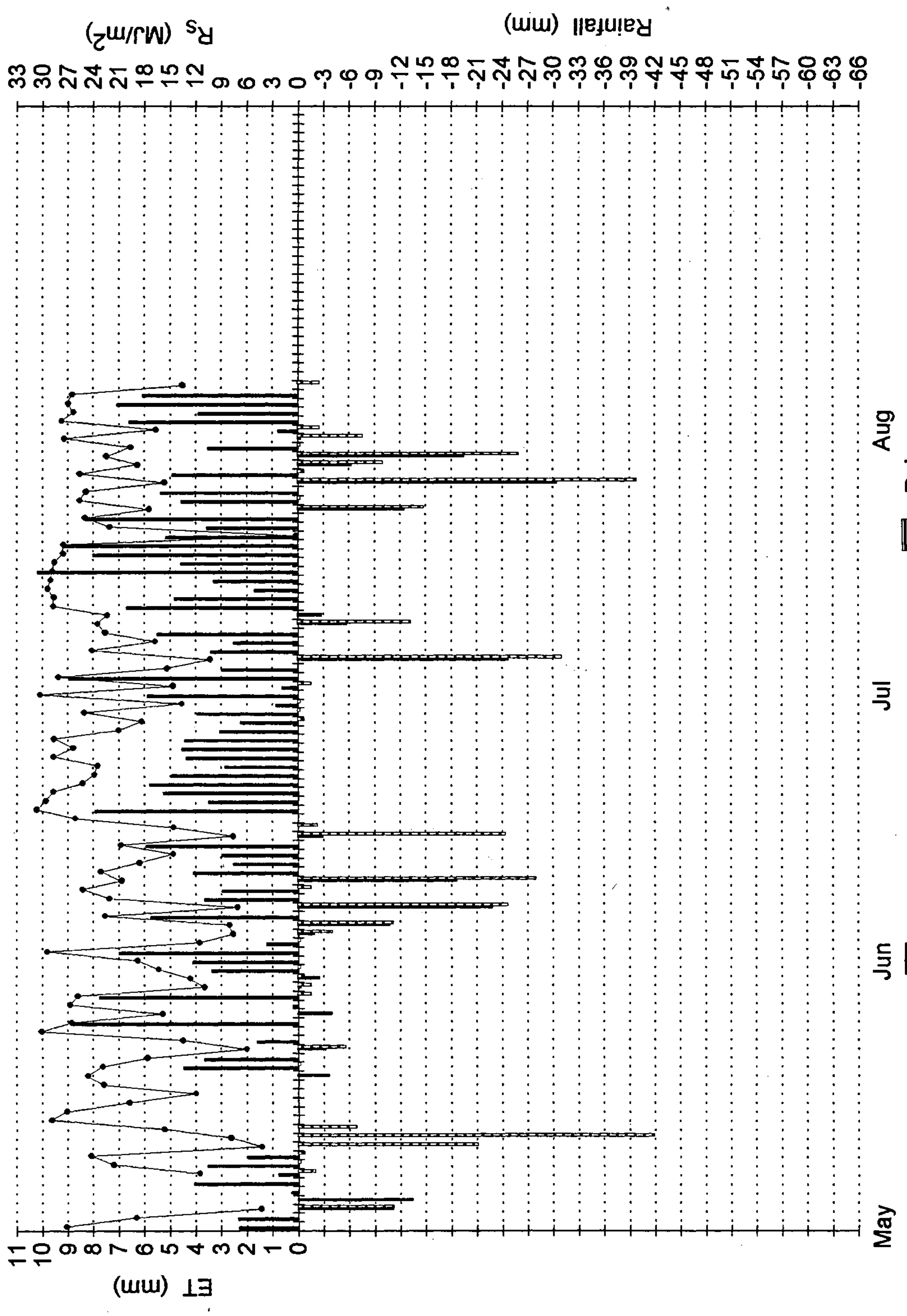

Figure 5.21. Daily ET Measurements at Wister from May through July 1995.

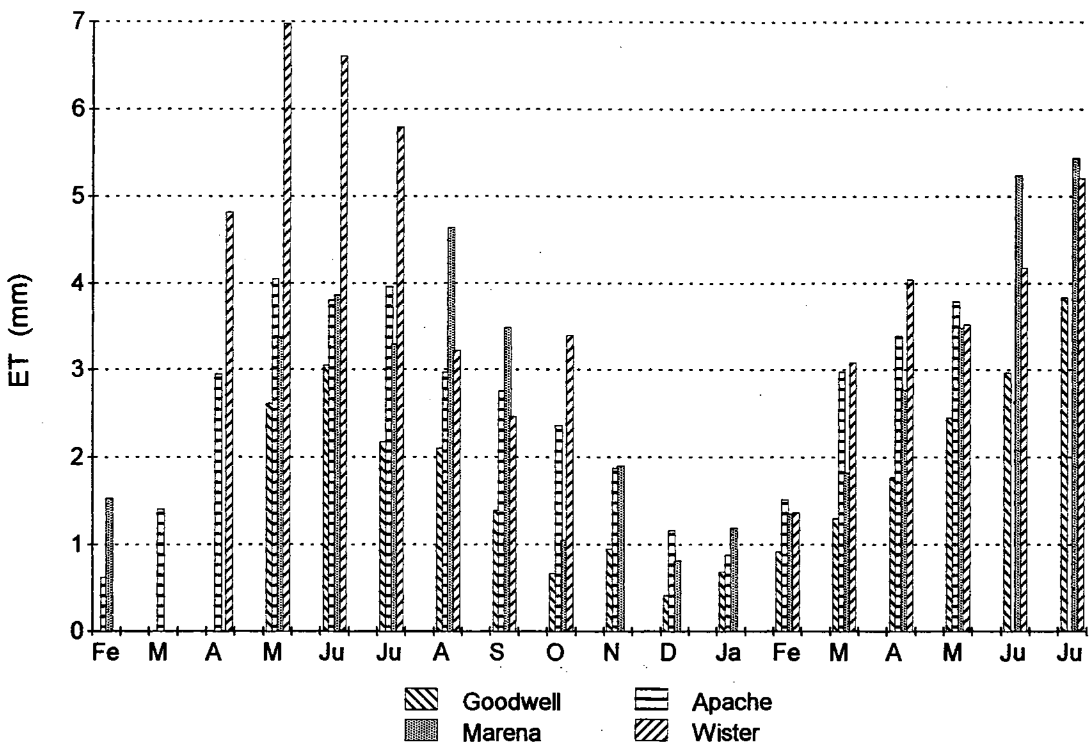

Figure 5.22. Average Daily ET by Month for February 1994 Through July 1995.

Table 5.2. Summary of Lysimeter ET Measurements at Goodwell.

		Daily avg. ET mm	Std. dev. of daily ET mm	Max. daily ET mm	Min. daily ET mm	Days of data (no rain)	Days with rain	Days of data missing
1994	May	2.6	1.4	5.1	1.1	12	3	16
	Jun	3.0	1.6	6.8	0.5	24	5	1
	Jul	2.2	1.0	4.2	0.1	22	9	0
	Aug	2.1	1.0	4.3	0.5	23	8	0
	Sep	1.4	0.9	3.2	0.0	28	2	0
	Oct	0.7	0.5	1.8	0.1	20	11	0
	Nov	0.9	0.6	2.3	0.0	19	12	0
	Dec	0.4	0.3	1.1	0.0	23	8	0
1995	Jan	0.7	0.5	2.1	0.0	22	9	0
	Feb	0.9	0.5	2.4	0.2	16	12	0
	Mar	1.3	0.8	3.0	0.0	22	9	0
	Apr	1.8	0.7	3.0	0.3	21	9	0
	May	2.4	1.0	3.8	0.2	22	9	0
	Jun	3.0	1.6	6.5	0.3	23	7	0
	Jul	3.8	1.1	5.2	1.2	25	6	0

Table 5.3. Summary of Lysimeter ET Measurements at Apache.

		Daily avg. ET mm	Std. dev. of daily ET mm	Max. daily ET mm	Min. daily ET mm	Days of data (no rain)	Days with rain	Days of data missing
1994	Feb	0.6	0.4	1.6	0.0	18	6	4
	Mar	1.4	0.5	2.1	0.3	20	6	5
	Apr	3.0	1.2	6.1	0.9	23	7	0
	May	4.0	2.2	9.0	0.1	14	17	0
	Jun	3.8	1.4	6.3	1.1	25	5	0
	Jul	4.0	2.0	8.3	0.0	19	12	0
	Aug	3.0	1.3	5.4	1.1	16	5	13
	Sep	2.8	1.2	6.6	1.8	12	4	16
	Oct	2.4	1.0	4.2	0.3	17	14	0
	Nov	1.9	1.7	6.3	0.3	9	9	16
	Dec	1.2	0.6	2.5	0.2	10	12	16
1995	Jan	0.9	0.6	2.0	0.1	9	10	18
	Feb	1.5	0.9	2.7	0.2	7	3	20
	Mar	3.0	1.6	6.1	0.1	12	9	17
	Apr	3.4	1.5	6.2	0.4	21	8	3
	May	3.8	2.3	9.2	0.1	23	8	0
	Jun	3.6	1.1	5.0	2.2	4	6	26
	Jul	2.7	1.5	4.2	1.2	2	7	29

Table 5.4. Summary of Lysimeter ET Measurements at Marena.

		Daily avg. ET mm	Std. dev. of daily ET mm	Max. daily ET mm	Min. daily ET mm	Days of data (no rain)	Days with rain	Days of data missing
1994	Feb	1.5	1.2	4.3	0.0	22	6	0
	Mar	---	---	---	---	1	8	25
	Apr	---	---	---	---	0	8	30
	May	3.4	0.7	4.3	2.6	3	11	25
	Jun	3.9	2.5	8.5	0.2	15	6	11
	Jul	3.3	1.6	6.8	0.5	17	8	11
	Aug	4.6	2.7	9.7	2.4	5	6	26
	Sep	3.5	2.2	7.4	0.2	8	8	15
	Oct	1.0	0.8	3.0	0.1	18	12	3
	Nov	1.9	1.2	4.4	0.2	16	11	3
	Dec	0.8	0.6	2.6	0.1	18	13	0
1995	Jan	1.2	0.8	2.8	0.4	18	13	0
	Feb	1.4	0.8	3.0	0.3	17	11	0
	Mar	1.8	1.2	4.1	0.0	13	8	13
	Apr	2.8	1.4	4.6	0.0	16	11	10
	May	3.5	1.7	5.9	0.0	14	12	11
	Jun	5.2	2.1	8.5	0.8	17	10	11
	Jul	5.4	3.0	13.9	0.6	23	8	0

Table 5.5. Summary of Lysimeter ET Measurements at Wister.

		Daily avg. ET mm	Std. dev. of daily ET mm	Max. daily ET mm	Min. daily ET mm	Days of data (no rain)	Days with rain	Days of data missing
1994	Feb	---	---	---	---	0	7	28
	Mar	---	---	---	---	0	9	31
	Apr	4.8	2.1	8.4	0.8	9	12	19
	May	7.0	3.5	11.2	2.7	3	8	28
	Jun	6.6	2.3	13.4	3.7	19	11	3
	Jul	5.8	2.2	11.6	2.9	16	12	6
	Aug	3.2	1.9	6.8	0.3	17	10	10
	Sep	2.5	1.7	8.0	0.4	23	6	1
	Oct	3.4	2.1	7.4	0.4	9	13	11
	Nov	---	---	---	---	0	12	23
	Dec	---	---	---	---	0	15	31
1995	Jan	---	---	---	---	0	13	31
	Feb	1.4	0.8	2.6	0.4	7	5	19
	Mar	3.1	1.4	5.9	0.5	12	7	14
	Apr	4.0	1.6	8.4	1.2	18	12	0
	May	3.5	2.6	8.8	0.2	12	15	9
	Jun	4.2	1.9	9.0	0.6	20	10	2
	Jul	5.2	2.3	10.2	0.8	20	11	0

The two measurements agreed fairly well at Apache and Wister, with more scatter in the data from Marena. At Goodwell, however, the measurements did not agree, as can be seen in Figure 5.23. The raingage appeared to report about 50% less rainfall than that estimated with the lysimeter.

To account for uncertainties in weight measurements due to possible thermal effects or to random error associated with the electronic components of the measurement system, variations in weight measurements were examined. The variance of the four weight measurements used to determine the average weight for each day at sunrise was calculated. The four weight measurements, two immediately before and two after sunrise, were averages of 30 measurements taken at 30-

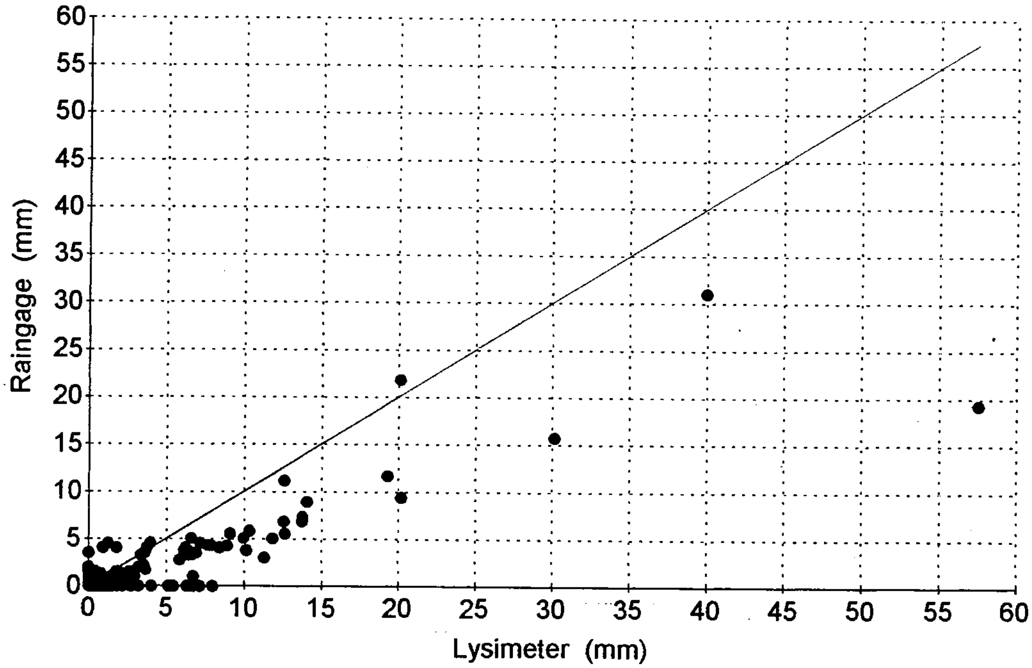

Figure 5.23. Raingage versus Lysimeter Precipitation Measurements at Goodwell.

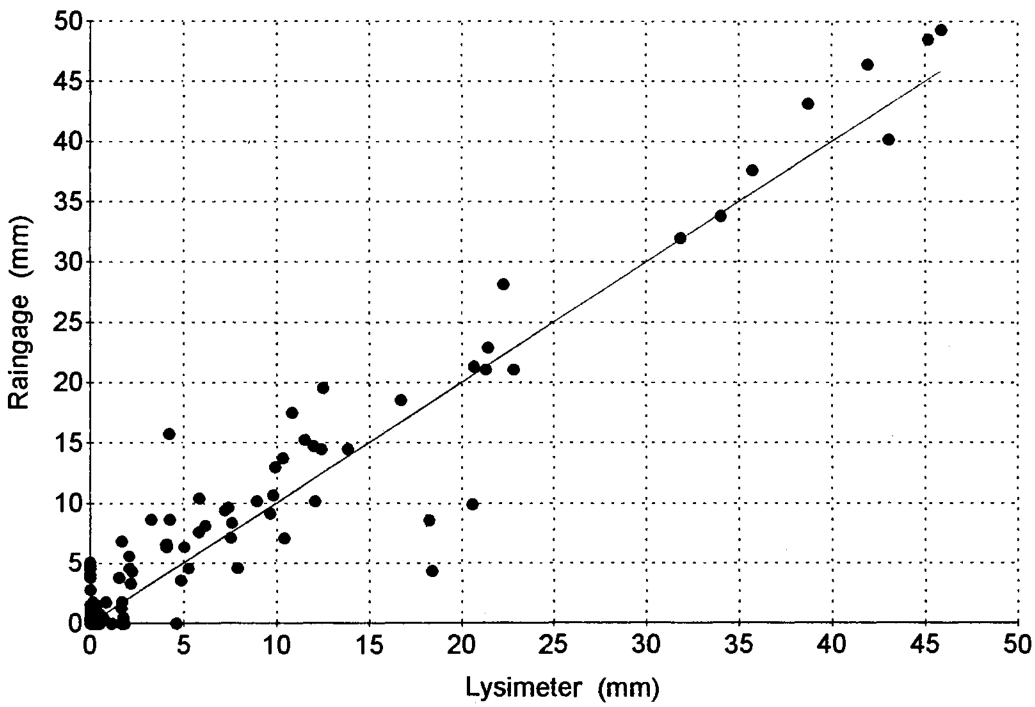

Figure 5.24. Raingage versus Lysimeter Precipitation Measurements at Apache.

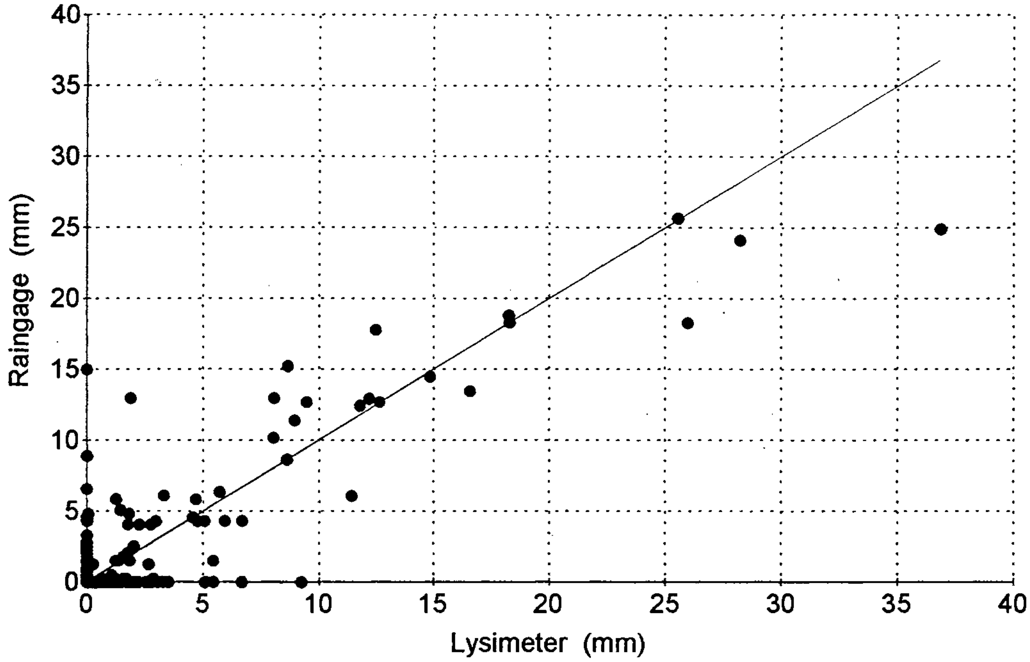

Figure 5.25. Raingage versus Lysimeter Precipitation Measurements at Marena.

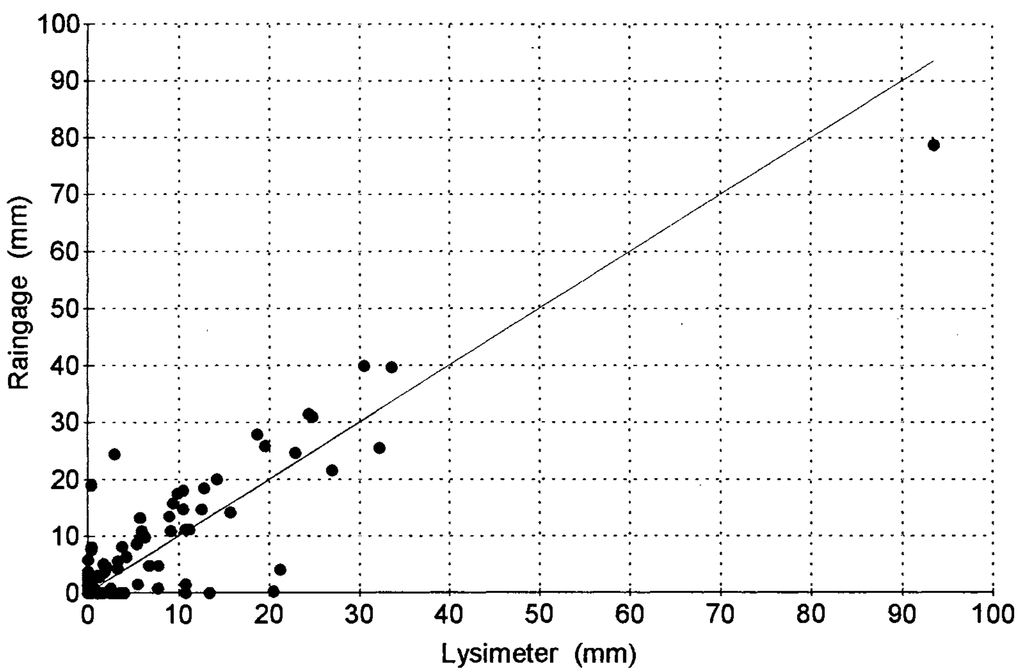

Figure 5.26. Raingage versus Lysimeter Precipitation Measurements at Wister.

second intervals and reported at 15-minute intervals. The variance in the four weight measurements was calculated as

$$\mathrm{Var}(W_i) = \frac{\Sigma_i (W_i - W_m)^2}{n - 1} \tag{5.2}$$

where

$\mathrm{Var}(W_i)$ = variance of weight measurements, kg^2

W_i = individual weight measurements, kg

W_m = mean of weight measurements, kg

n = number of measurements.

Variances in weight measurements were then used to estimate the variance in ET estimates, calculated as changes in weight from one sunrise period to the next. The variance of a difference in two independent, random variables is calculated as the sum of the variances of each variable (Haan, 1977). If the weight of the lysimeter at any sunrise period is assumed to be independent of the weight at any other sunrise period, the variance in weight changes or ET can be estimated as

$$\mathrm{Var}(ET) = \mathrm{Var}(W_i) + \mathrm{Var}(W_{i+1}) \tag{5.3}$$

where

$\mathrm{Var}(ET)$ = variance in ET estimates, kg^2

$\mathrm{Var}(W_i)$ = variance in weight measurement on day i, kg^2

$\mathrm{Var}(W_{i+1})$ = variance in weight measurement on day i+1, kg^2.

For the lysimeters with a surface area of 1 m^2, a 1-kg weight of water is equivalent to a 1-mm depth of water. Variability in ET values can then be expressed, as an equivalent depth of water, in terms of standard deviations from

$$s_{ET} = \sqrt{\mathrm{Var}(ET)} \tag{5.4}$$

where

s_{ET} = standard deviation of ET estimates, mm.

Standard deviations are useful as indicators of the stability of the lysimeter measurements used in estimating daily ET amounts. A small variability indicates that lysimeter measurements are stable and consistent from one 15-minute interval to the next during the one-hour time period around sunrise on both days used in making the ET estimate. This would suggest that the timing of the lysimeter measurements was not absolutely critical, and that averaging the lysimeter weights was not necessary since similar ET estimates would be obtained using weight measurements at times other than exactly at sunrise. A large variability indicates that lysimeter measurements are not stable during one or both of the sunrise periods due to unstable weather conditions affecting lysimeter weights or to electrical problems in the measurement system. With lysimeter weights changing within the one-hour periods, different ET estimates could be obtained depending on which time interval was chosen, resulting in less confidence in the ET estimate.

While a large variability could indicate unstable measurements and possible measurement problems, it could also indicate that rainfall was occurring during the sunrise period. Days with large standard deviations in ET estimates had to be examined in order to determine if rain had been falling during the sunrise period.

Standard deviations of daily lysimeter ET estimates are listed with the ET estimates in Appendix D, and are shown for a range of 0 to 2.0 mm in Figures 5.27 through 5.30. Standard deviations larger than 2.0 mm were reported, but occurred either when rainfall had occurred during the sunrise measurement period or on days when the lysimeters were experiencing electrical problems. The data shown in the figures indicate that standard deviations of ET estimates were usually within the range of 0.1 to 0.2 mm/d when the lysimeters were not experiencing electrical problems. Large standard deviations, such as those at Marena and Wister during the summer of

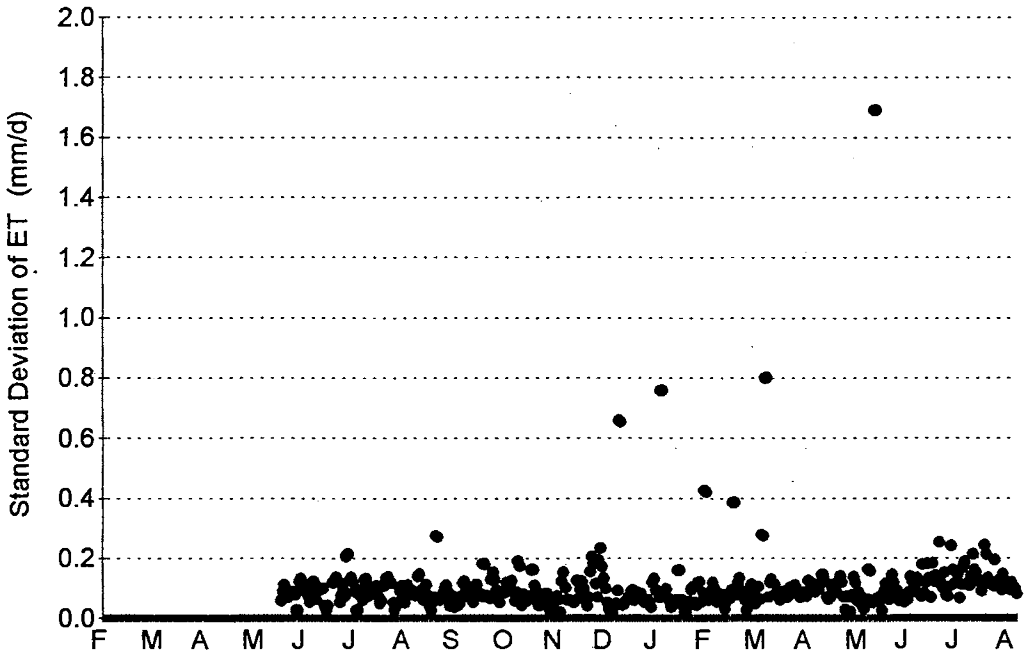

Figure 5.27. Standard Deviations of Lysimeter ET Estimates at Goodwell.

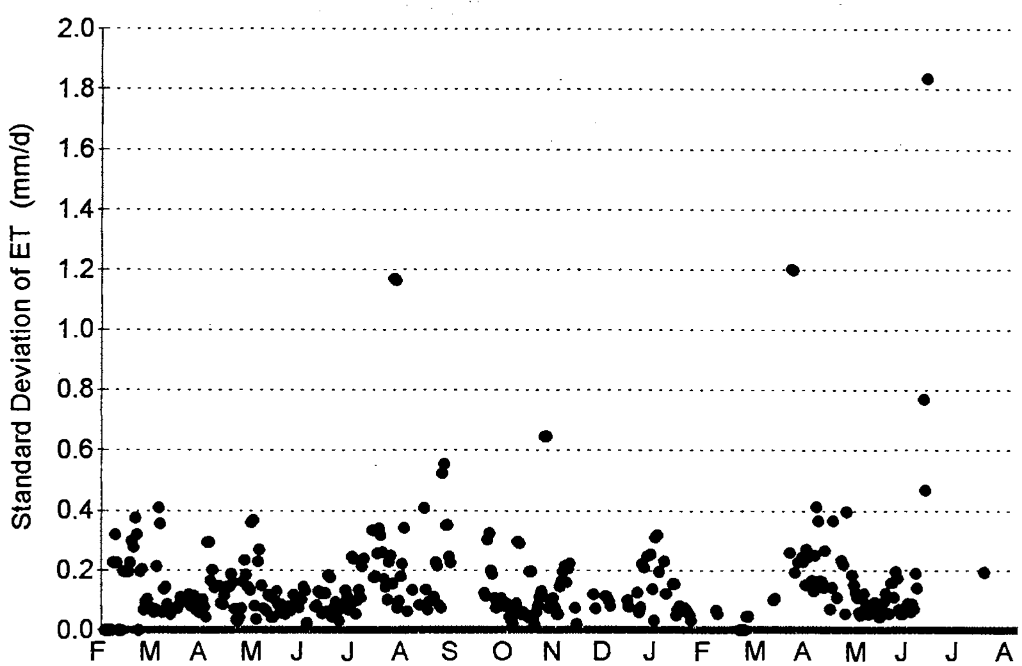

Figure 5.28. Standard Deviations of Lysimeter ET Estimates at Apache.

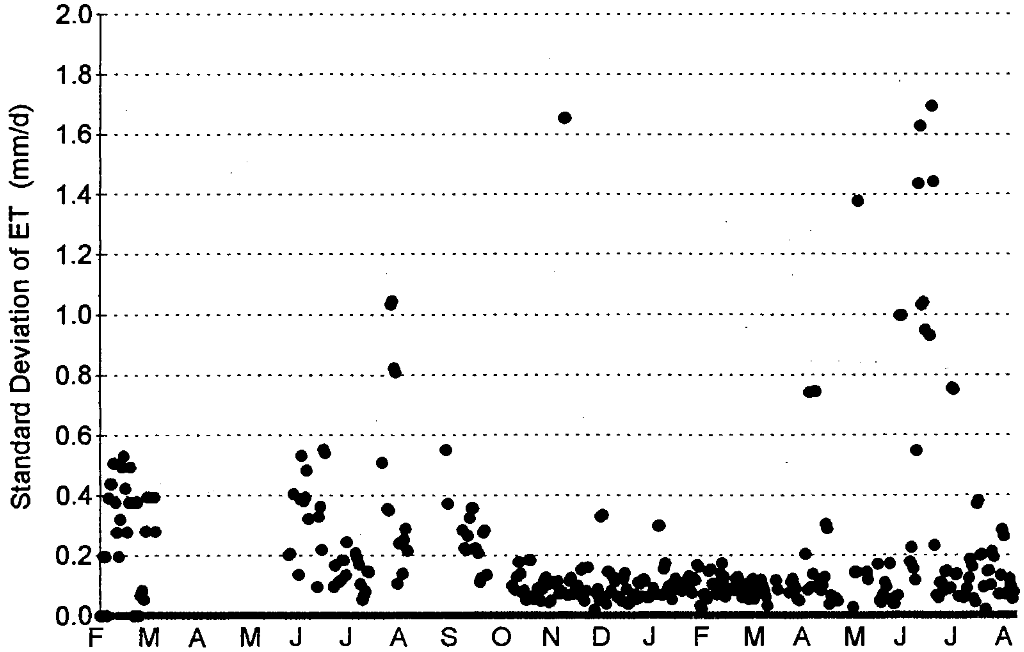

Figure 5.29. Standard Deviations of Lysimeter ET Estimates at Marena.

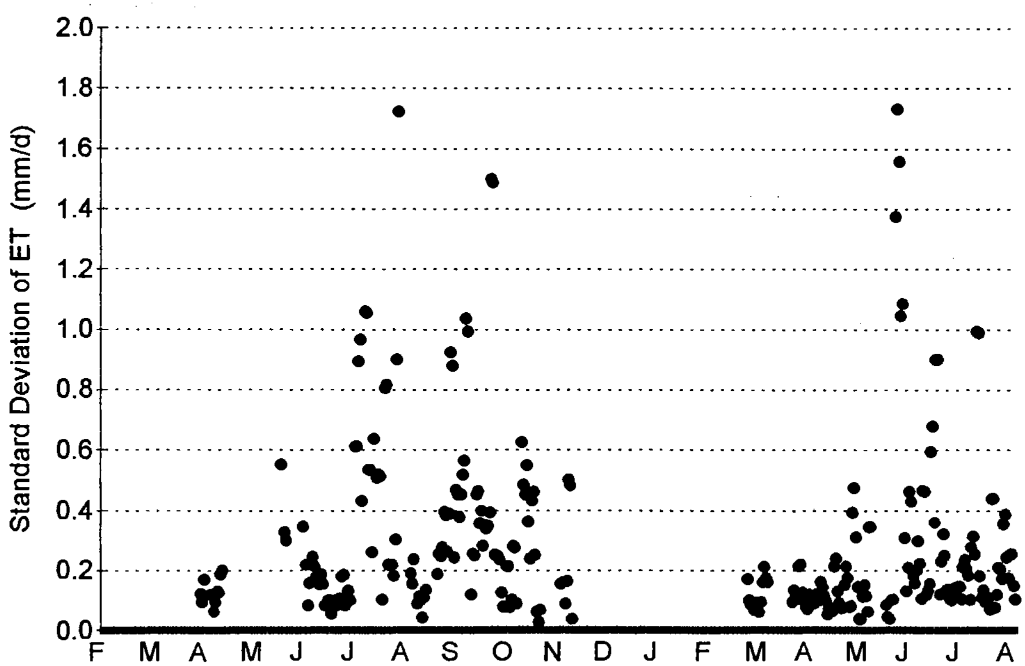

Figure 5.30. Standard Deviations of Lysimeter ET Estimates at Wister.

1994 (Figures 5.29 and 5.30), were due to wiring problems discussed previously. Other, isolated instances of large standard deviations were due to rainfall occurring during the sunrise period.

WEATHER DATA

Weather data were collected and reported at 15-minute intervals by the Mesonet station at each lysimeter site. During the period of lysimeter data collection from January 1994 through July 1995, there were very few instances of missing observations. Occasionally, a single parameter value from a 15-minute observation was missing. On some occasions, all the parameter values for a single 15-minute observation were missing. In a few instances, several hours of observations were missing, and on one occasion, two entire days of data were missing. Given the number of observations at each 15-minute interval and the number of 15-minute intervals in the one and a half year period, the amount of missing data is very small. Periods of missing data for the four lysimeter sites are listed in Appendix E.

The weather data were summarized to provide daily values of several weather parameters for the 24-hour period from sunrise on one day to sunrise on the following day. Parameter values were determined on either a daily, sunrise-to-sunrise time scale, or a daytime, sunrise-to-sunset period. A list of the daily weather parameter values summarized is shown in Table 3.3.

The daily summaries were intended to provide parameter values that described the weather conditions at each site during each day. Important information concerning interactions between weather parameters and the timing at which events occurred, however, are lost in expressing each parameter in terms of one or a few daily values. By expressing solar radiation as a daily total, for example, information about the actual radiative conditions throughout the day, which have a great impact on photosynthesis and evapotranspiration, is lost. The total solar radiation during a cloudy, overcast day may be the same as that during a day which is sunny in the morning and has a heavy, dense cloud cover in the afternoon. The vegetation at the site may respond differently under the two atmospheric conditions, but the daily radiation summary would not indicate a difference in weather conditions.

Important information is lost by reporting rainfall as a daily total. The timing of the rainfall is important in determining when and how much water becomes available for evapotranspiration. Rainfall occurring in the morning is available for evaporation during the entire day, while rainfall occurring after sunset will not be subject to appreciable evaporation until after the following sunrise when evaporative energy becomes available. A light, steady rain falling all day, with all water infiltrating into the soil, may total to the same amount as a brief, intense shower which exceeds the infiltration rate of the soil and causes surface runoff. In both cases, the actual conditions to which the soil and vegetation are exposed are different, but the total daily rainfall amounts would not indicate a difference.

A complete listing of the daily values of the weather variables summarized at each site is found in Appendix D. To qualitatively compare weather conditions at each site, daily values of solar radiation, precipitation, air temperature, wind speed, and vapor-pressure deficit are discussed briefly, and are shown in Figures 5.31 through 5.50. The data are also summarized on a monthly time scale in Tables 5.6 through 5.9.

Total solar radiation, shown in Figures 5.31 through 5.34, is a measure of the radiant energy available at the surface which can be used in the evapotranspiration process. At each site, the available energy can be seen to vary greatly throughout the year, as well as from day to day. Goodwell appeared to have fewer cloudy (low solar radiation) days throughout the year, especially during the summer and early fall months, than the other sites. Cloudy days appeared to be more frequent at Wister, and Apache and Marena were intermediate and similar to each other.

Precipitation events are shown in Figures 5.35 through 5.38, and indicate the timing and amounts of precipitation reported by the raingage at each site. Precipitation amounts reported at Goodwell were very low and infrequent throughout the year, especially during fall and winter, with daily amounts rarely exceeding 10 mm. (It must be noted, however, as discussed previously and shown in Figure 5.23, that the raingage measurements at Goodwell appeared to under-report rainfall amounts by approximately 50% on average). Apache reported more frequent rainfall, with amounts often in the range of 30 to 50 mm. Rainfall at Marena was similar in frequency to that at Apache, with amounts rarely exceeding 40 mm. Rainfall at Wister was frequent, with amounts often in the range of 20 to 40 mm, and heavy amounts reported in late fall and early winter.

Average daytime air temperatures at 1.5 m above the ground surface are shown in Figures 5.39 through 5.42. The greatest range of air temperatures was reported at Goodwell, with highest summertime and lowest wintertime temperatures and the most days with freezing temperatures. Conditions at Wister were not as extreme, with lower summertime temperatures and fewer days with freezing temperatures reported. Conditions at Apache and Marena were similar to each other and intermediate between those of Goodwell and Wister.

Average daytime wind speeds at 2 m above the ground surface are shown in Figures 5.43 through 5.46. Wind speeds at Goodwell were high and extremely variable throughout the year, with the highest speeds reported in winter. Lower and

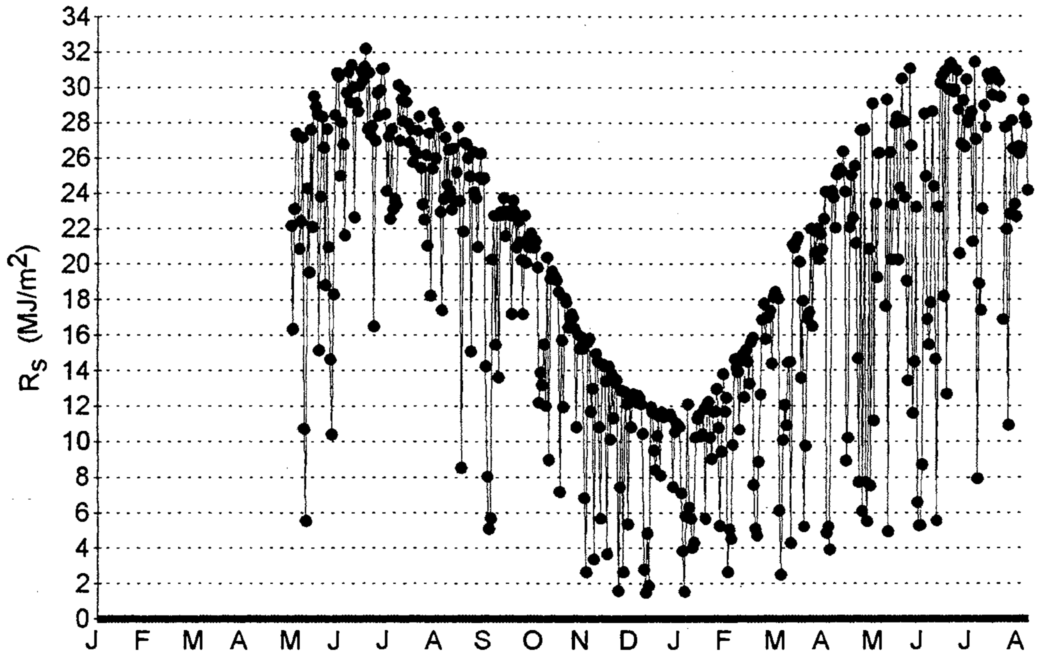

Figure 5.31. Daily Total Solar Radiation at Goodwell from May 1994 through July 1995.

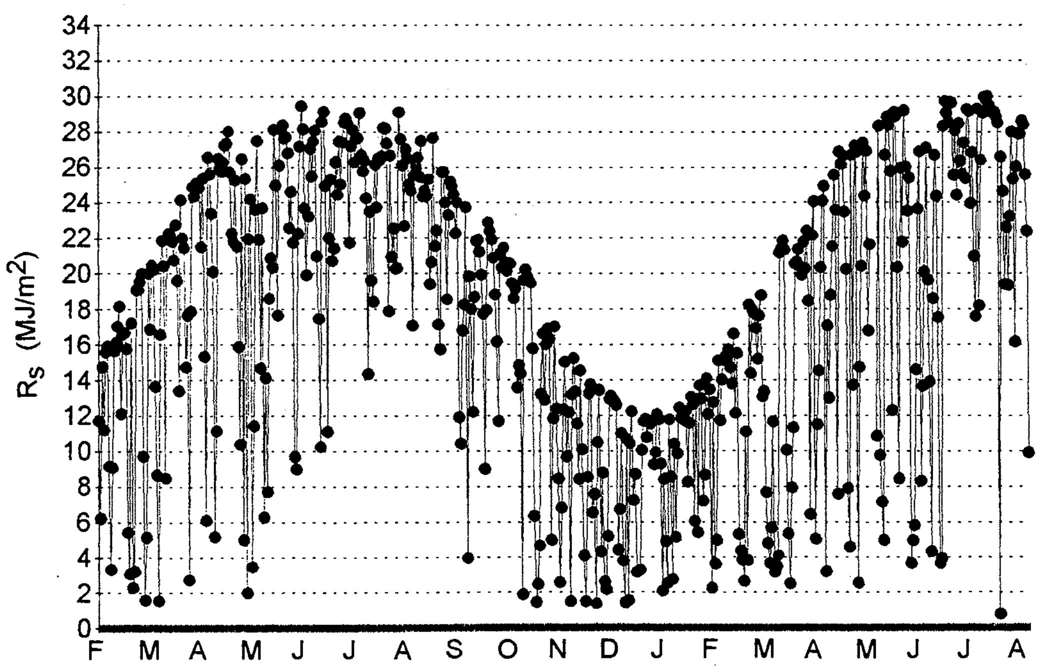

Figure 5.32. Daily Total Solar Radiation at Apache from February 1994 through July 1995.

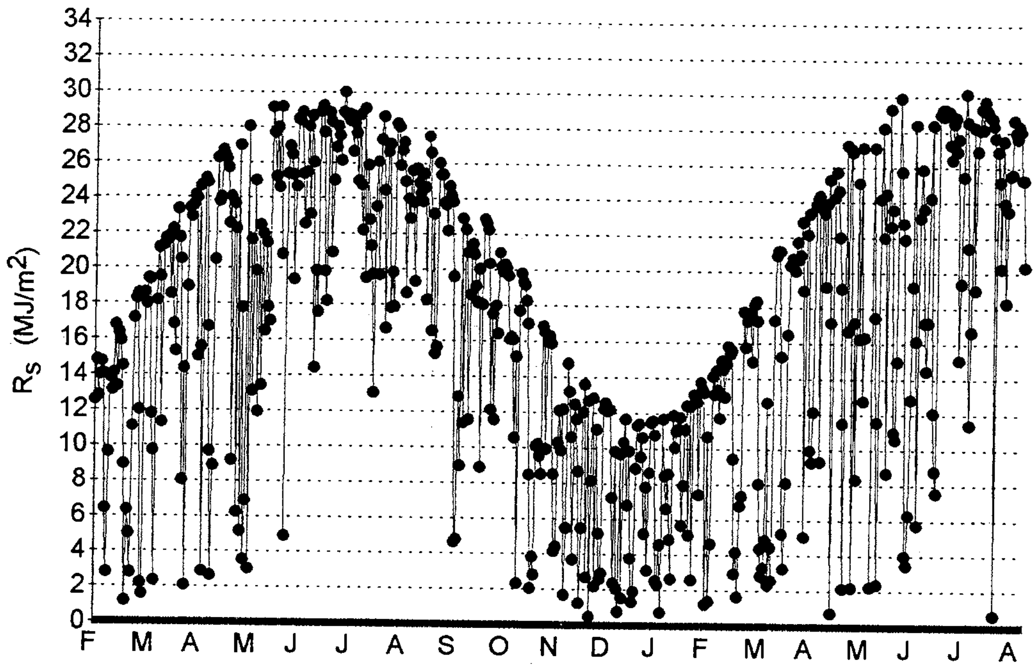

Figure 5.33. Daily Total Solar Radiation at Marena from February 1994 through July 1995.

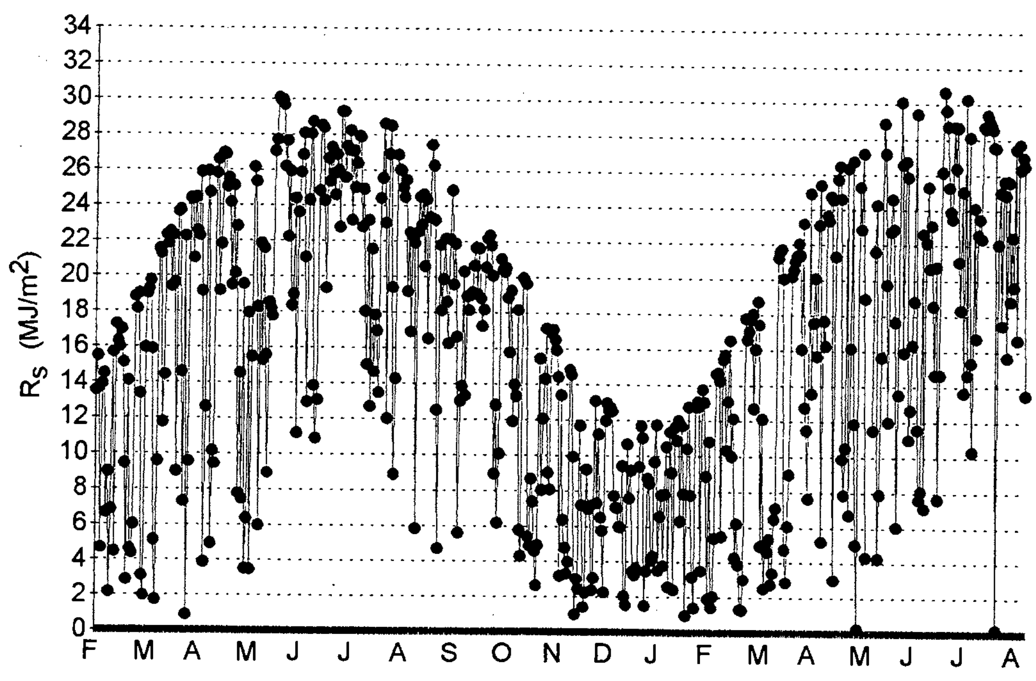

Figure 5.34. Daily Total Solar Radiation at Wister from February 1994 through July 1995.

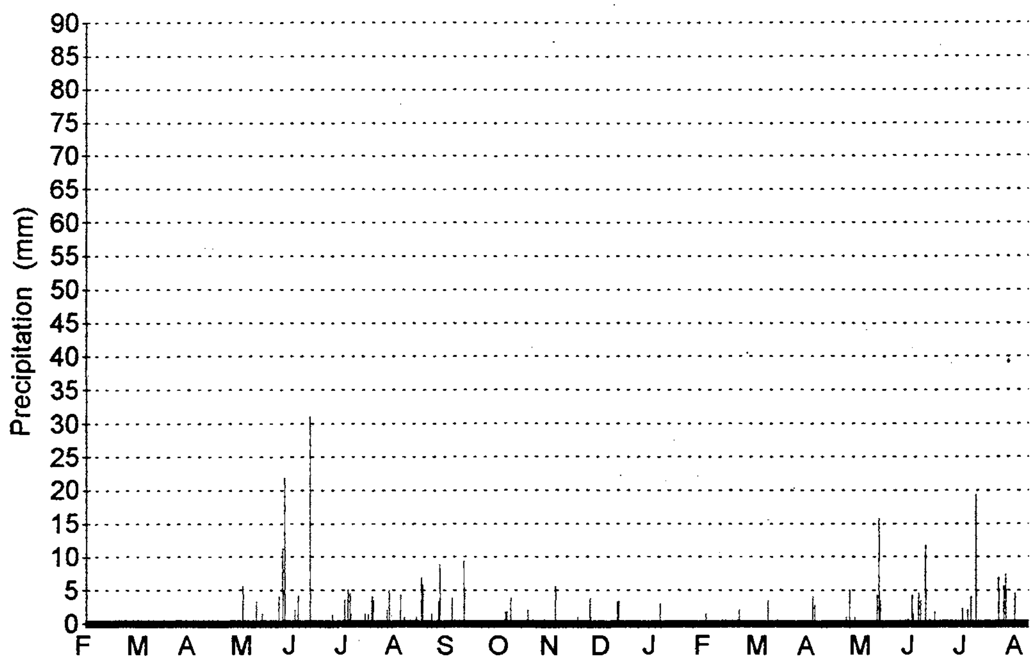

Figure 5.35. Daily Precipitation at Goodwell from May 1994 through July 1995.

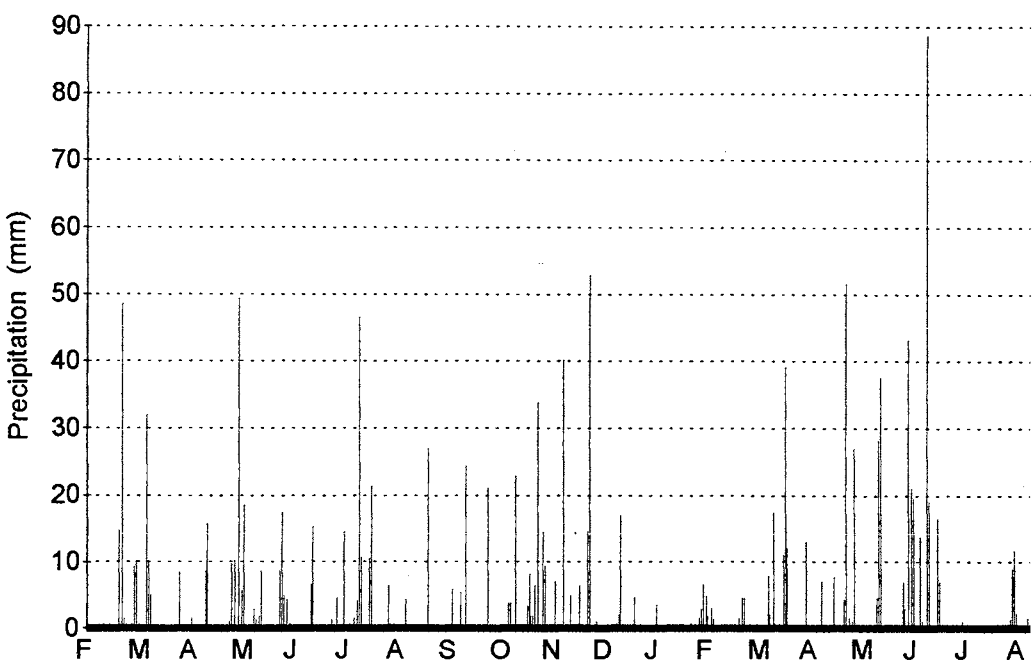

Figure 5.36. Daily Precipitation at Apache from February 1994 through July 1995.

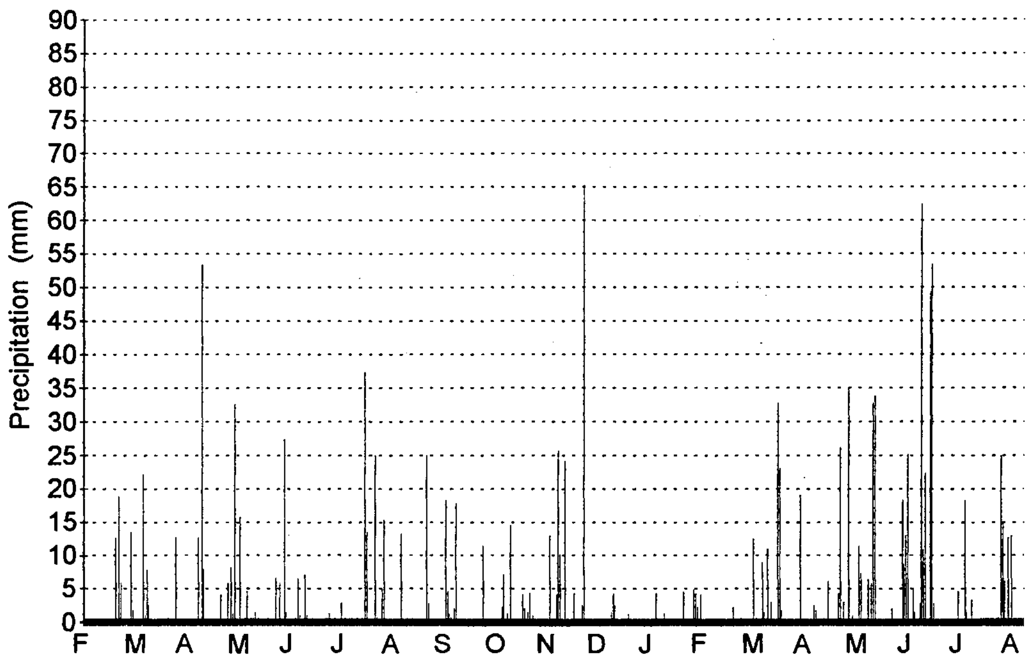

Figure 5.37. Daily Precipitation at Marena from February 1994 through July 1995.

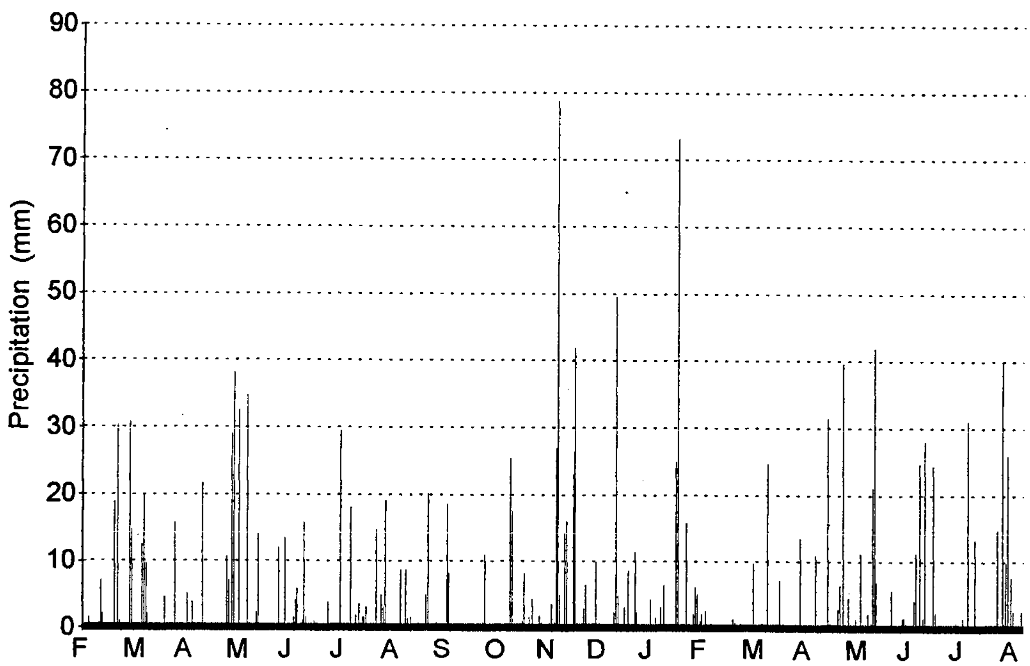

Figure 5.38. Daily Precipitation at Wister from February 1994 through July 1995.

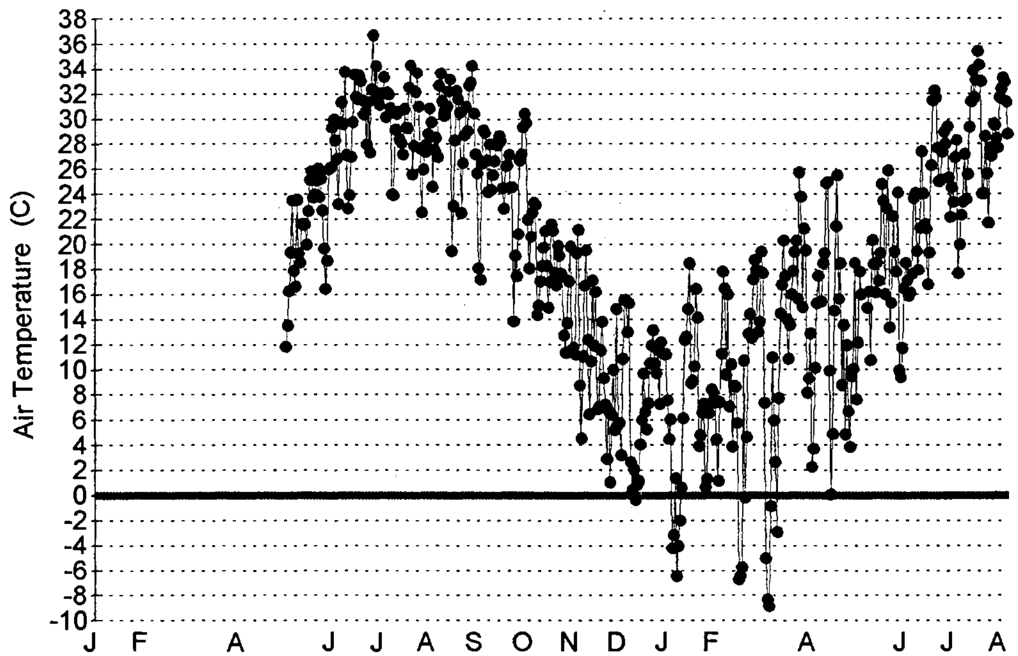

Figure 5.39. Daily Daytime Average Air Temperature at Goodwell from May 1994 through July 1995.

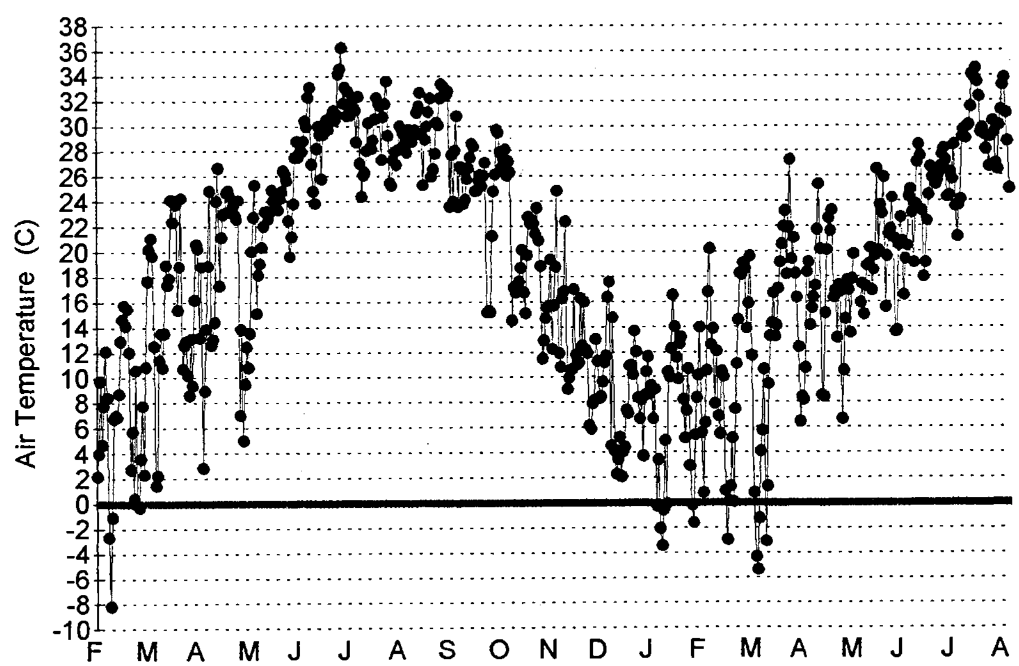

Figure 5.40. Daily Daytime Average Air Temperature at Apache from February 1994 through July 1995.

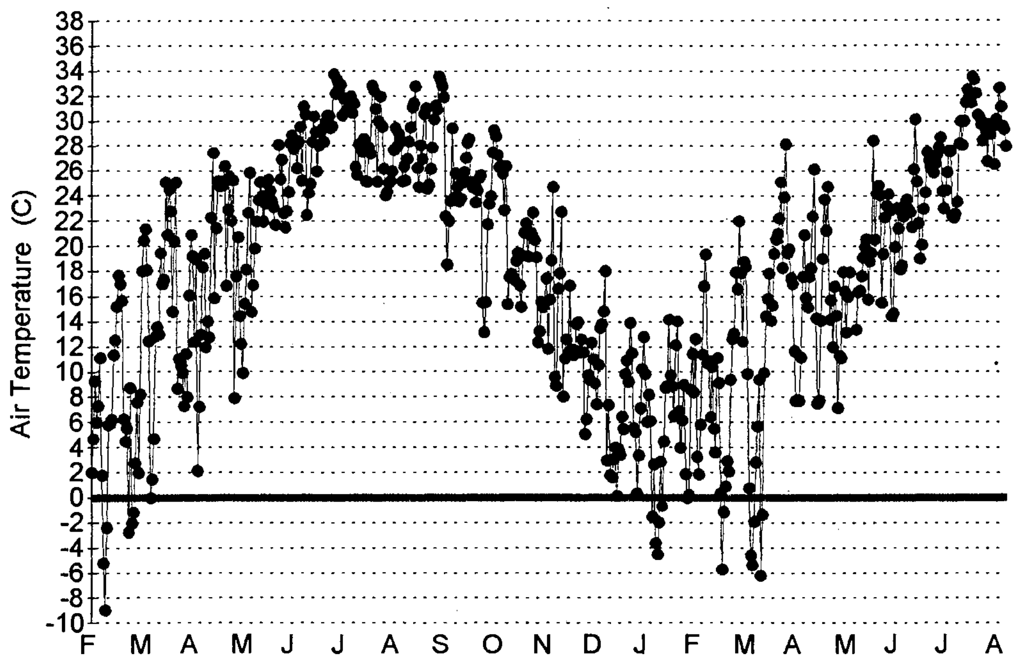

Figure 5.41. Daily Daytime Average Air Temperature at Marena from February 1994 through July 1995.

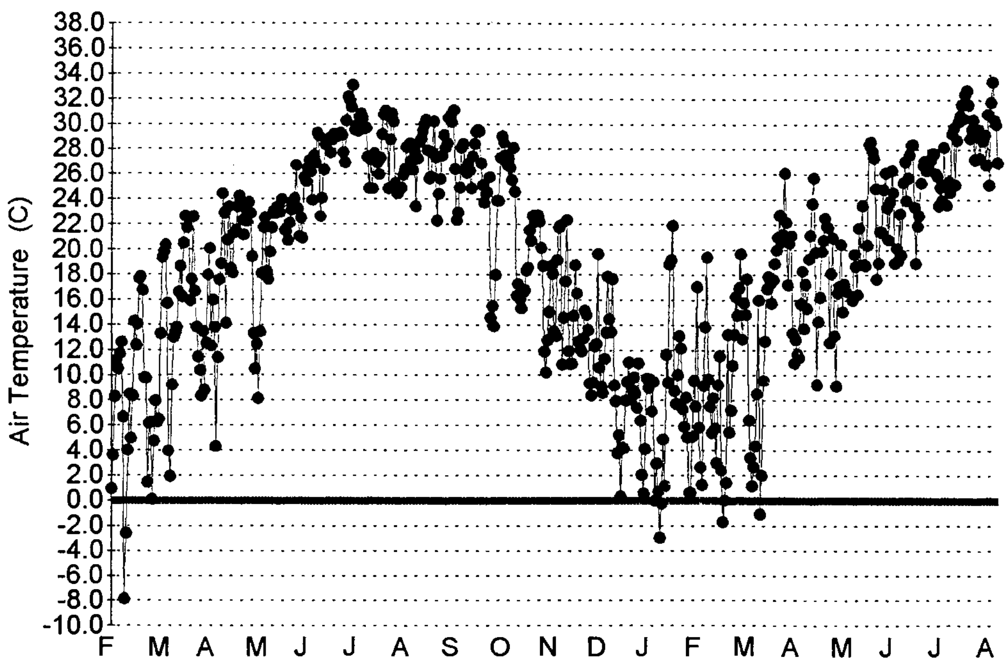

Figure 5.42. Daily Daytime Average Air Temperature at Wister from February 1994 through July 1995.

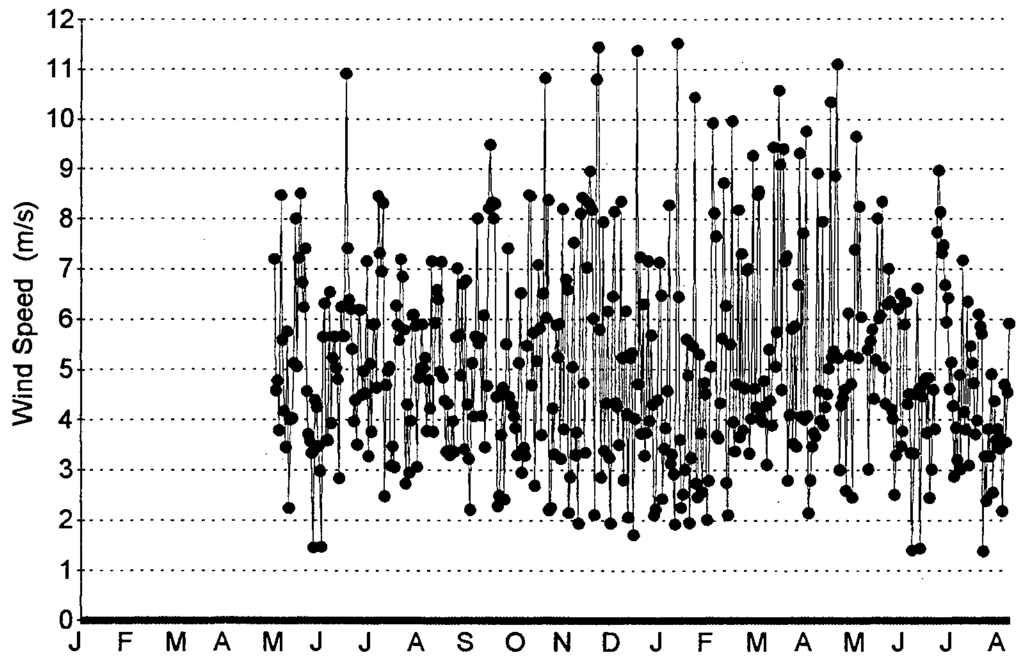

Figure 5.43. Daily Daytime Average Wind Speed at Goodwell from May 1994 through July 1995.

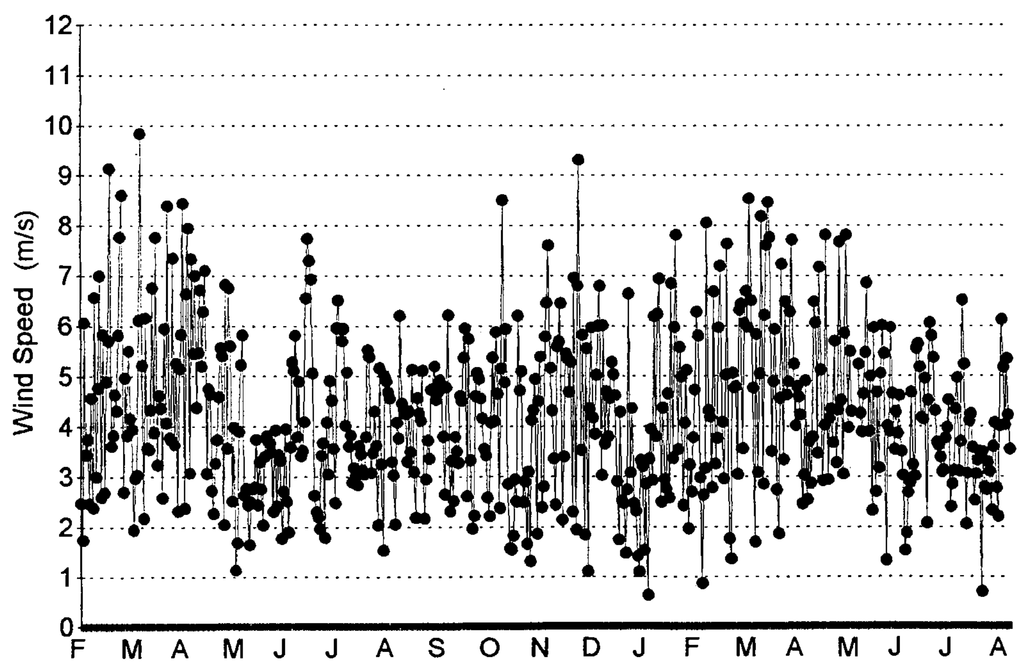

Figure 5.44. Daily Daytime Average Wind Speed at Apache from February 1994 through July 1995.

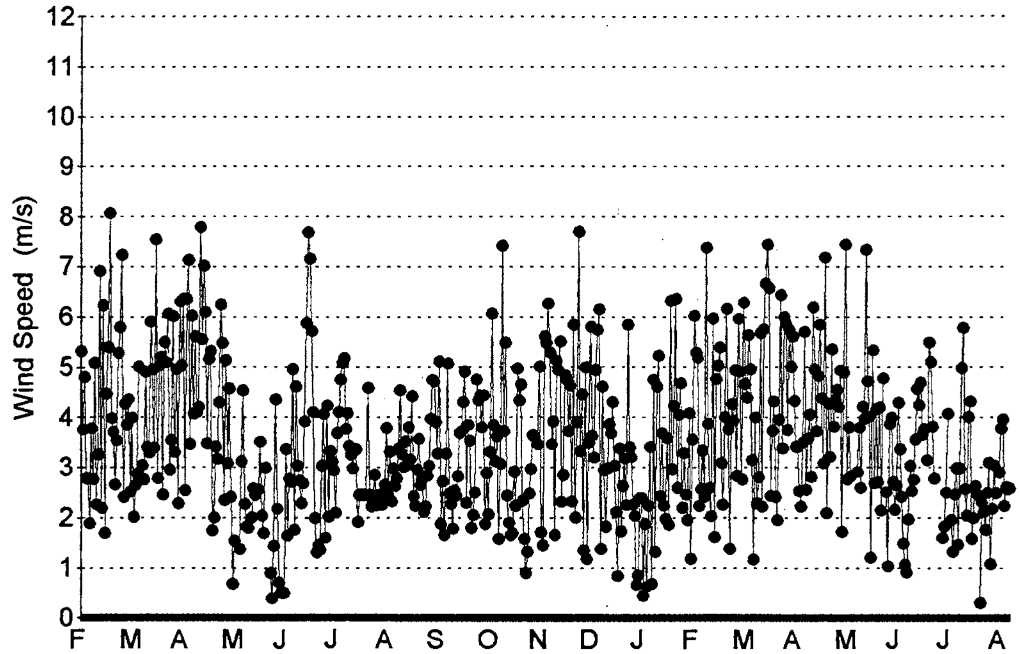

Figure 5.45. Daily Daytime Average Wind Speed at Marena from February 1994 through July 1995.

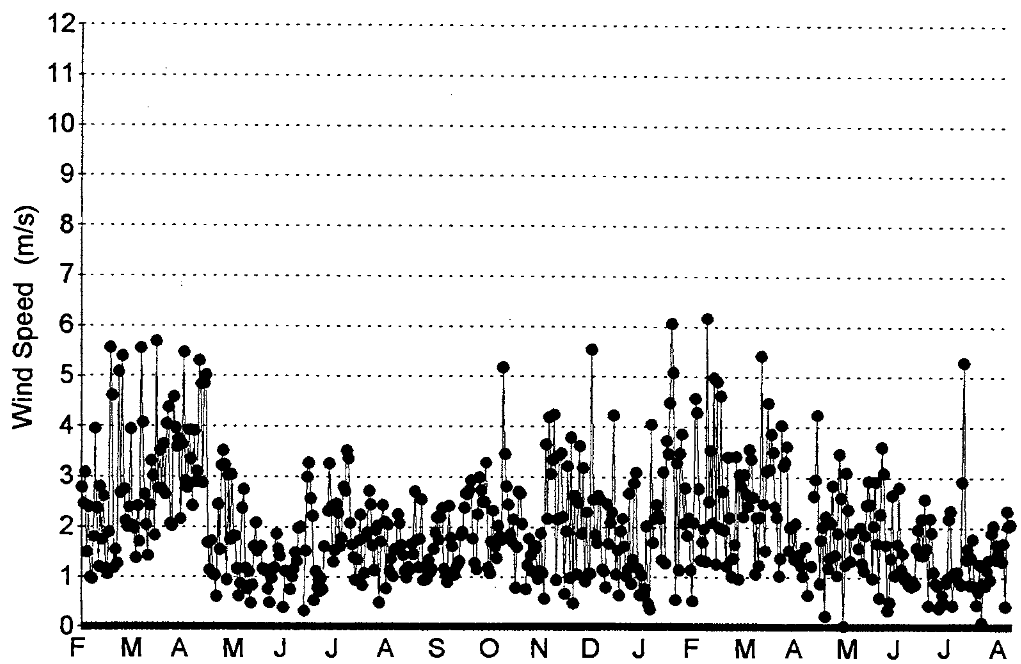

Figure 5.46. Daily Daytime Average Wind Speed at Wister from February 1994 through July 1995.

less variable wind speeds were reported at Apache and Marena. Wind speeds at Wister were very low throughout the year and much less variable than at the other sites.

Average daytime vapor-pressure deficits are shown in Figures 5.47 through 5.50. Vapor-pressure deficit is a measure of the drying power of the air or the ability of the air to take up and hold more water. A high vapor-pressure deficit indicates that the air is relatively dry and able to hold more water, while a low deficit indicates that the air is almost saturated. At Goodwell, vapor-pressure deficits were higher than at the other sites and were variable from one day to the next. Much lower and less variable deficits were observed at Wister. Apache and Marena were intermediate, with conditions similar at both sites.

Table 5.6. Summary of Selected Weather Data at Goodwell.

		Daily solar radiation MJ/m^2	Total precip mm	Daytime air temp C	Daytime wind speed m/s	Daytime vapor pres deficit kPa
1994	May	23.2	39	24.2	4.5	1.6
	Jun	28.3	41	30.2	5.3	2.9
	Jul	26.2	29	29.4	5.2	2.6
	Aug	22.2	37	28.9	4.9	2.4
	Sep	20.6	10	25.4	5.3	2.1
	Oct	15.0	15	17.6	5.2	1.2
	Nov	10.9	7	10.1	5.7	0.8
	Dec	9.0	10	7.7	4.9	0.7
1995	Jan	9.6	3	6.3	4.6	0.6
	Feb	13.5	2	9.3	5.5	0.9
	Mar	16.2	11	11.5	5.6	1.0
	Apr	19.3	8	13.8	5.8	1.2
	May	20.0	40	17.5	5.1	1.4
	Jun	25.2	23	24.6	4.9	1.8
	Jul	25.2	72	28.9	4.2	2.5

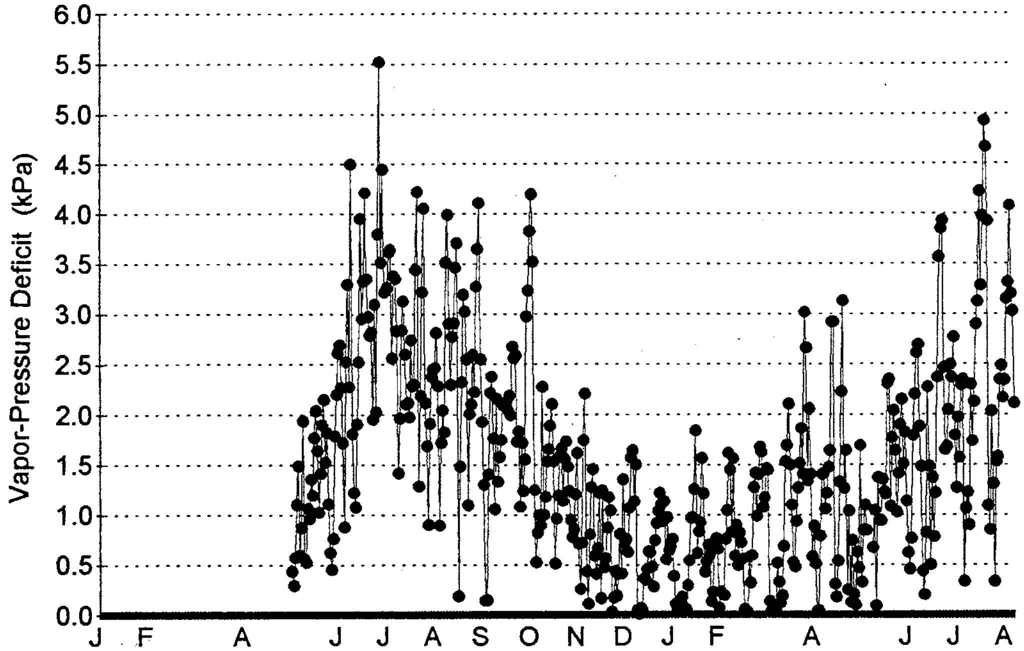

Figure 5.47. Daily Daytime Average Vapor-Pressure Deficit at Goodwell from May 1994 through July 1994.

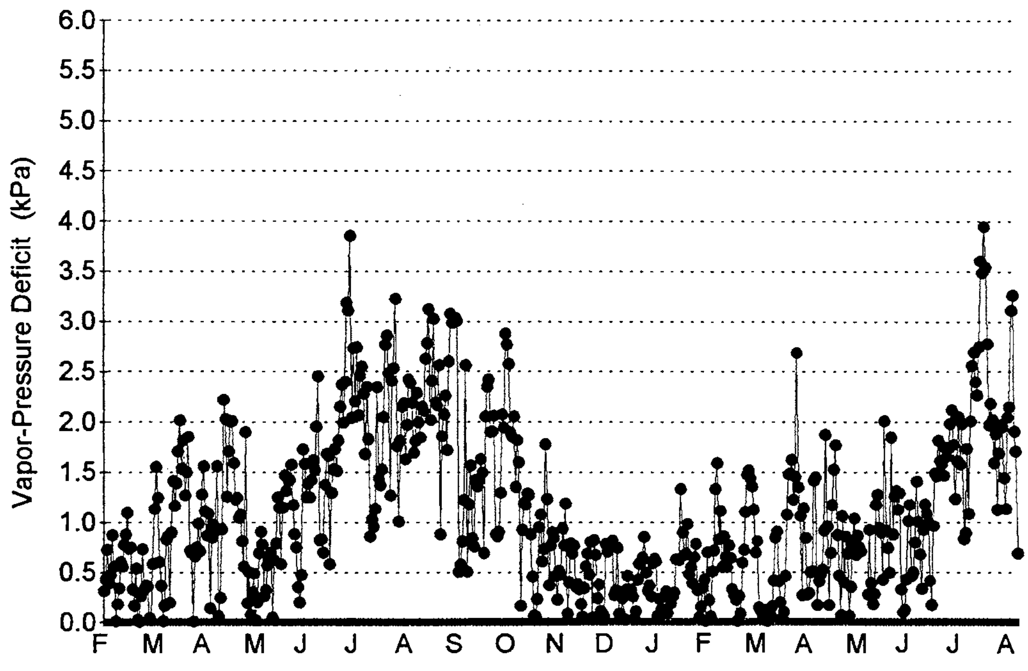

Figure 5.48. Daily Daytime Average Vapor-Pressure Deficit at Apache from February 1994 through July 1995.

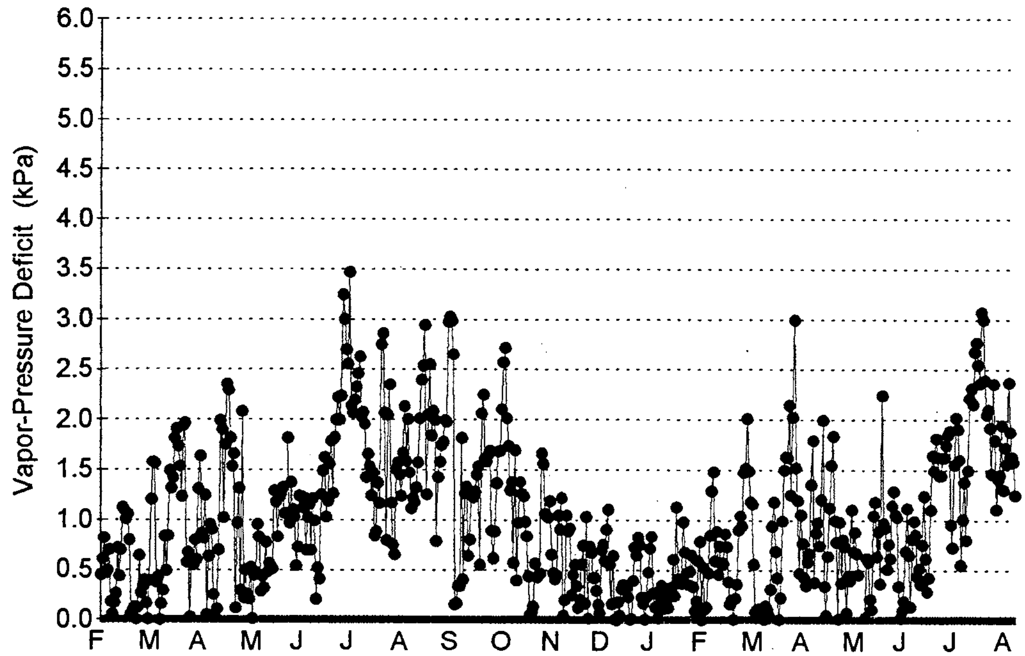

Figure 5.49. Daily Daytime Average Vapor-Pressure Deficit at Marena from February 1994 through July 1995.

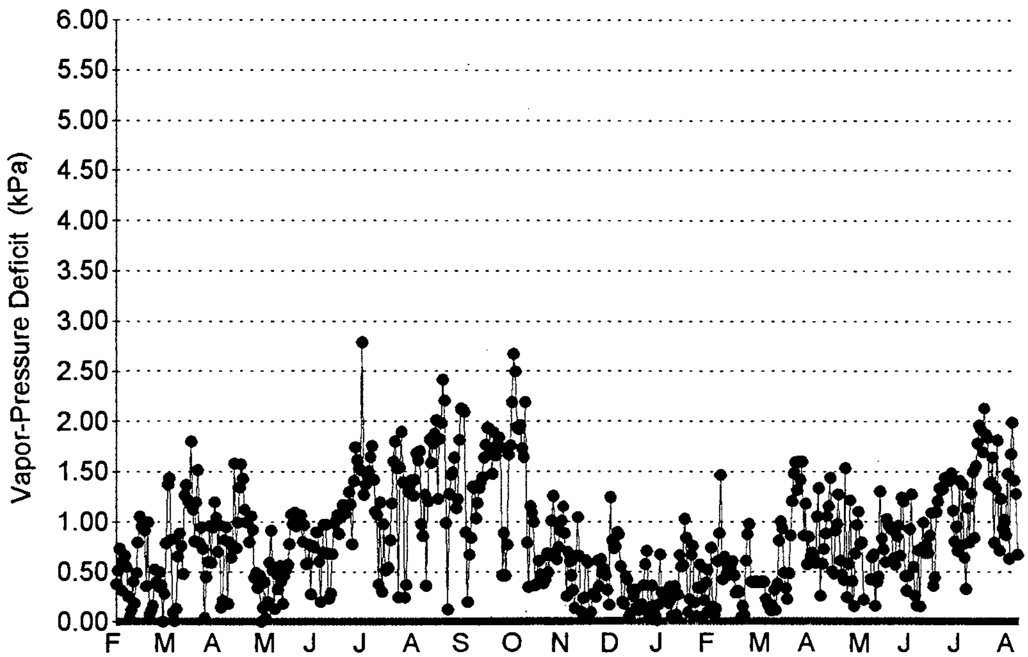

Figure 5.50. Daily Daytime Average Vapor-Pressure Deficit at Wister from February 1994 through July 1995.

Table 5.7. Summary of Selected Weather Data at Apache.

		Daily solar radiation MJ/m2	Total precip mm	Daytime air temp C	Daytime wind speed m/s	Daytime vapor pres deficit kPa
1994	Feb	12.3	75	6.5	4.6	0.5
	Mar	18.0	66	14.8	4.7	1.0
	Apr	20.5	96	18.1	5.1	1.1
	May	20.7	76	22.1	3.0	0.8
	Jun	24.3	42	30.1	4.1	1.8
	Jul	24.6	103	29.3	4.1	2.0
	Aug	23.2	38	29.9	4.0	2.3
	Sep	18.4	51	25.2	3.9	1.6
	Oct	12.9	117	19.7	3.8	0.9
	Nov	9.3	121	12.6	4.7	0.5
	Dec	8.1	30	8.6	3.5	0.4
1995	Jan	10.0	24	6.7	4.3	0.5
	Feb	12.7	11	10.4	4.9	0.8
	Mar	14.4	103	12.2	5.1	0.7
	Apr	19.5	100	16.8	4.7	0.8
	May	18.8	180	19.6	4.2	0.8
	Jun	23.1	132	24.8	4.0	1.3
	Jul	24.8	26	29.8	3.6	2.2

Table 5.8. Summary of Selected Weather Data at Marena.

		Daily solar radiation MJ/m2	Total precip mm	Daytime air temp C	Daytime wind speed m/s	Daytime vapor pres deficit kPa
1994	Feb	11.6	51	5.8	4.2	0.5
	Mar	17.22	49	14.1	4.1	1.0
	Apr	17.9	126	18.6	4.6	1.0
	May	21.6	64	22.3	1.9	0.8
	Jun	25.7	20	29.1	3.3	1.6
	Jul	24.1	97	28.5	3.1	1.7
	Aug	22.4	64	28.7	3.2	1.9
	Sep	17.6	34	24.1	3.3	1.3
	Oct	12.3	52	19.3	3.2	0.9
	Nov	8.6	137	12.5	4.1	0.6
	Dec	6.8	15	7.4	2.7	0.4
1995	Jan	9.3	23	5.6	3.4	0.4
	Feb	12.4	15	9.7	4.1	0.8
	Mar	14.6	101	12.4	4.2	0.8
	Apr	18.8	99	16.2	4.2	0.8
	May	17.2	153	20.0	3.3	0.7
	Jun	22.9	228	24.8	3.1	1.2
	Jul	25.5	76	29.6	2.7	1.9

Table 5.9. Summary of Selected Weather Data at Wister.

		Daily solar radiation MJ/m^2	Total precip mm	Daytime air temp C	Daytime wind speed m/s	Daytime vapor pres deficit kPa
1994	Feb	11.3	91	7.9	2.5	0.5
	Mar	16.5	80	14.4	3.0	0.8
	Apr	18.4	117	18.9	2.9	0.8
	May	21.0	109	21.3	1.3	0.6
	Jun	24.3	65	28.3	1.6	1.1
	Jul	21.8	72	27.8	1.9	1.1
	Aug	20.3	65	27.8	1.6	1.5
	Sep	17.5	21	24.9	1.9	1.4
	Oct	11.9	65	19.8	1.9	0.9
	Nov	7.5	226	13.9	2.4	0.5
	Dec	6.7	89	8.5	1.6	0.3
1995	Jan	8.2	142	7.3	2.7	0.4
	Feb	11.4	12	10.0	2.7	0.5
	Mar	13.9	47	14.1	2.4	0.7
	Apr	17.4	110	17.7	1.9	0.8
	May	18.0	98	22.0	1.7	0.7
	Jun	21.5	115	25.3	1.2	1.0
	Jul	23.2	118	29.3	1.5	1.4

VEGETATION MEASUREMENTS

During periodic visits to each lysimeter site, information was gathered to qualitatively and quantitatively describe the vegetation at the site. The vegetation was observed to determine when the vegetation was actively growing or in a state of dormancy. Measurements were made of canopy height, vegetative ground cover, and leaf-area index.

Active and Dormant Periods

Determining the time periods when the vegetation is actively growing and when it is dormant is important in modeling the canopy resistance for use in estimating evapotranspiration. Wright and Harding (1993) found significant differences in annual water use estimates made with the Penman-Monteith equation compared to lysimeter measurements in a grass-covered catchment which they attributed to periods of dormant vegetation. They developed a method in which estimates during dormant vegetation periods were made using the Penman-Montieth equation assuming active vegetation conditions. Two empirical functions were tested which adjusted the ET estimates based either on the day of the year or on air temperature. While Wright and Harding (1993) used an empirical relationship to adjust ET estimates, the information could be used to develop a more realistic stomatal and canopy resistance model.

From field observations and examination of weather data such as air temperature, periods of active and dormant vegetation were estimated at Goodwell, Apache, and Marena. Spring growth was assumed to begin after extended periods during which below-freezing minimum temperatures ceased to occur. Vegetation then remained active until fall when minimum temperatures fell below freezing. Vegetation at Wister remained active throughout the year, with no dormant periods. Periods of active and dormant vegetation are shown in terms of leaf-area index and vegetative ground cover in Figures 5.51 to 5.54. LAI and ground cover values of 0 indicate that there was no green-leafed, active vegetation present.

Leaf-Area Index

Several parameters used in estimating ET are determined based on the structure and density of the canopy, which is often represented by the leaf-area index (LAI). In order to develop parameter estimates, daily values of leaf-area index are needed. Daily estimates of LAI are often determined from periodic measurements of LAI and linear or non-linear relationships used to interpolate between measurements.

At each of the lysimeter sites, measurements of LAI were made at several times during periods of active vegetation. Measurements were made on the lysimeter itself, outside the lysimeter but inside the fence surrounding the lysimeter, and outside the fence in the larger field where the Mesonet weather station and lysimeter were located. Multiple measurements were made in each of these areas so that average values could be estimated and spatial variability taken into account. Each day LAI measurements were made, two measurements were made on the lysimeter, two to three measurements were made in the area inside the lysimeter fences, and six to ten measurements were made outside the lysimeter fence.

To obtain daily estimates of LAI for days when LAI was not measured, linear interpolation, field observations, and estimates of plant growth stages were used. After establishing the beginning of plant growth in the spring, field observations allowed other important phases of plant growth to be estimated. Times to reach maximum LAI and to begin die-off in the fall, and the effects of occasional clipping of the grass inside the lysimeter fence were estimated. Linear relationships were then used to interpolate and estimate LAI for each day of the year. Periodic measurements and daily estimates of LAI are shown for the four sites in Figures 5.51 to 5.54.

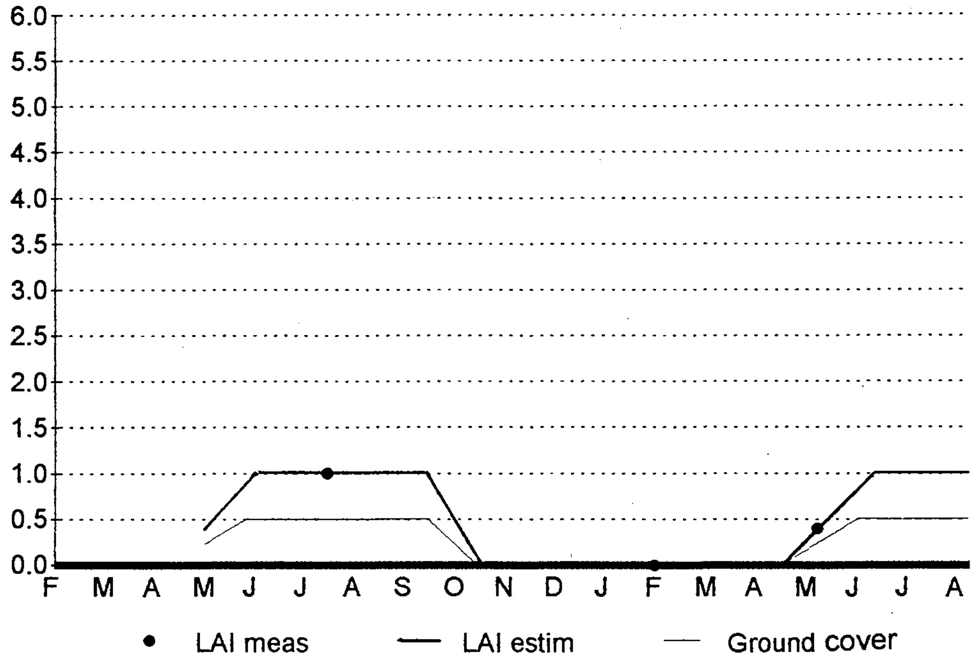

Figure 5.51. Leaf-Area Index and Ground Cover at Goodwell.

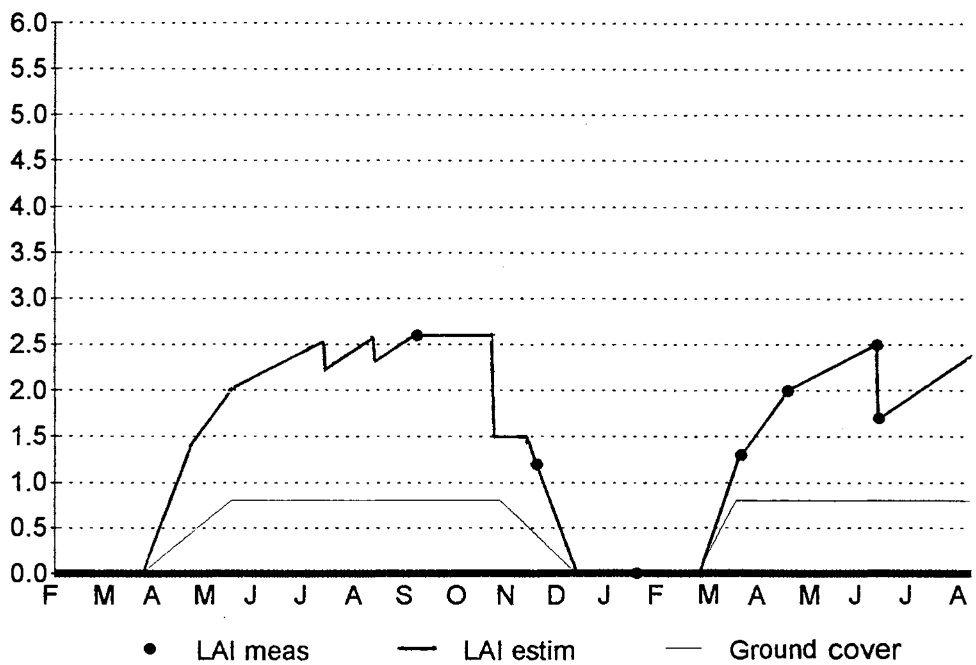

Figure 5.52. Leaf-Area Index and Ground Cover at Apache.

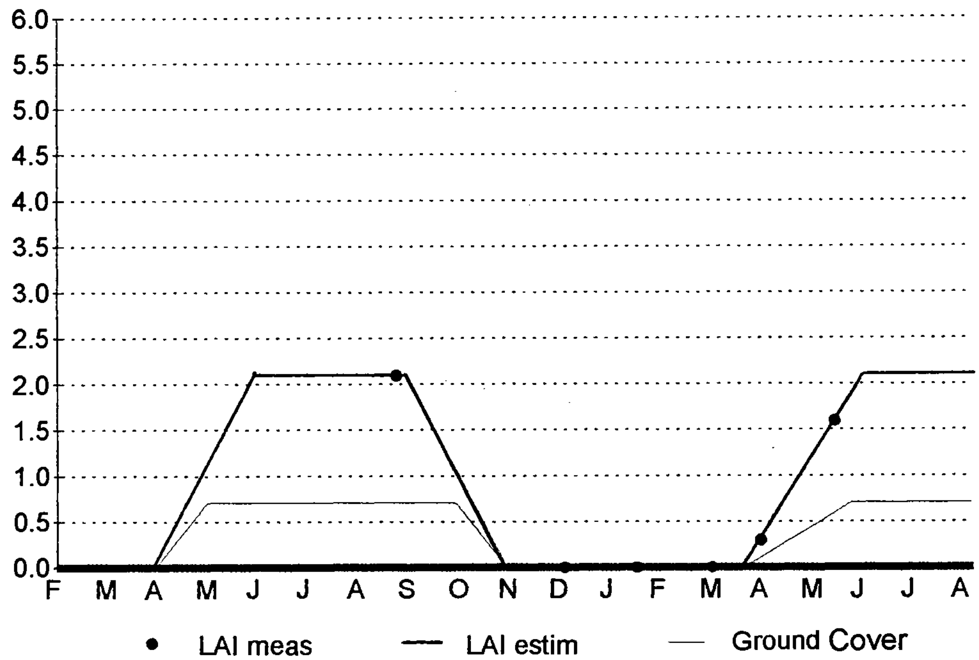

Figure 5.53. Leaf-Area Index and Ground Cover at Marena.

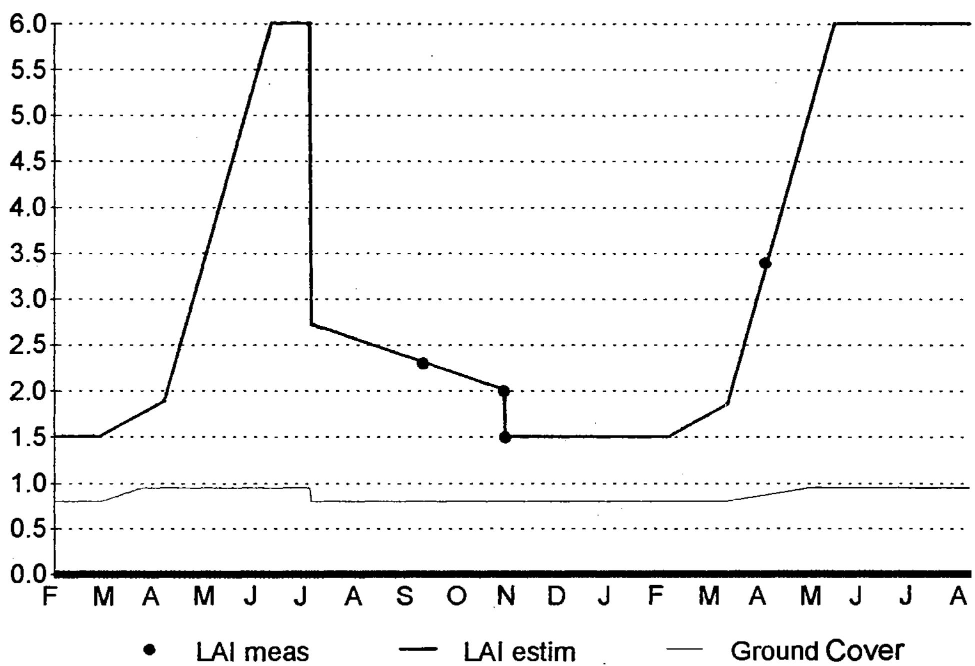

Figure 5.54. Leaf-Area Index and Ground Cover at Wister

LAI estimates for the native range sites, Goodwell and Marena, are shown in Figures 5.51 and 5.53, respectively. The vegetation at these sites became active in early spring, reached and maintained a maximum LAI during the summer, and began to die off in early fall. The vegetation was then dormant until the next spring. While cattle grazed at these sites, the stocking rate was very low and conditions inside and outside the lysimeter fence were similar.

At the pasture sites, Apache and Wister, shown in Figures 5.52 and 5.54, the fields were more intensively managed and stocking rates were higher. This required more frequent site visits in order to maintain conditions inside the lysimeter fence similar to those outside. On several occasions, grazing in the field outside the fence caused the vegetation to be shorter and sparser than that inside the fence, and the vegetation inside the fence and on the lysimeter had to be clipped. This can be seen as a sharp drop in LAI. At Wister, the cattle were removed and the field was let go to hay in the spring. After cutting for hay, the field was grazed for the remainder of the year.

Vegetative cover for days when there were no measurements was estimated in the same manner as leaf-area index, with linear relationships used to obtain daily estimates. Measurements and daily estimates of vegetative cover are shown along with LAI in Figures 5.51 to 5.54.

Canopy Height

The height of the canopy is important in estimating the aerodynamic resistance of the vegetated surface. Canopy height is necessary in determining the zero-plane displacement height and the roughness lengths, and can also be used to estimate wind speed at heights other than the reference height at which wind speed measurements were taken using the logarithmic wind profile relationship.

Canopy height measurements were made during periodic site visits. Measurement of canopy height was accomplished by averaging height measurements made at several randomly chosen locations on the lysimeter, outside the lysimeter but inside the lysimeter fence, and in the field outside the lysimeter fence. A meter stick was used to measure the height of the vegetation at each sample location. The meter stick was placed on the soil surface and the approximate height of the bulk of the vegetation near the meter stick was estimated and recorded. The vegetation was not manipulated in any way prior to measurement, i.e. leaves extended, dormant vegetation or litter removed, but rather was measured as found in order to quantify actual field conditions.

Measuring the height of the vegetation was usually not a simple, objective measurement made by reading a height from a meter stick. Due to the sparse and spatially variable nature of the vegetation at the sites, a broad range of vegetation heights were often found at each sample location. An estimation of the representative height at each location was made by visual observation. Average heights inside and outside the lysimeter fence were estimated and recorded. Occasionally, vegetation heights inside the lysimeter fence were greater than those outside due to cattle grazing, and the grass inside the fence was clipped.

As with leaf-area index and vegetative ground cover, periodic measurements were used to estimate daily canopy heights. Linear relationships were used to estimate daily heights based on measurements made inside the lysimeter fence. Measurements made inside the fence were used to better quantify the actual conditions existing on and around the lysimeter to which the lysimeter was subjected and responded. Canopy height measurements and daily height estimates are shown in Figures 5.55 to 5.59.

The canopy height information shown in Figures 5.55 to 5.59 differs slightly from the leaf-area index and ground cover information shown in Figures 5.51 to 5.54. Height measurements were made based on all vegetation existing at each sample location, whether the vegetation was active or dormant. Dormant vegetation and litter were not excluded from measurement because height measurements were intended to quantify the extent to which the vegetation interacted with and contributed to the turbulence of the flow of air above the canopy. Dormant vegetation fulfilled these roles as well as active vegetation. This must be kept in mind when viewing Figures 5.55 through 5.58 so that the apparent contradiction of having a plant canopy in winter with some height but zero leaf-area index is avoided.

SOIL WATER MEASUREMENTS

Periodic measurements of soil moisture were made both inside and outside the lysimeters using a neutron soil-moisture meter. Neutron meter measurements were made at various depths in the soil profile, and converted to soil water contents using calibration equations.

Bulk Densities and Neutron Meter Calibrations

Bulk density profiles inside and outside the lysimeter were constructed for each site in order to compare the density of the reconstructed profile inside the lysimeter to the undisturbed soil outside the lysimeter. The profile for the soil outside

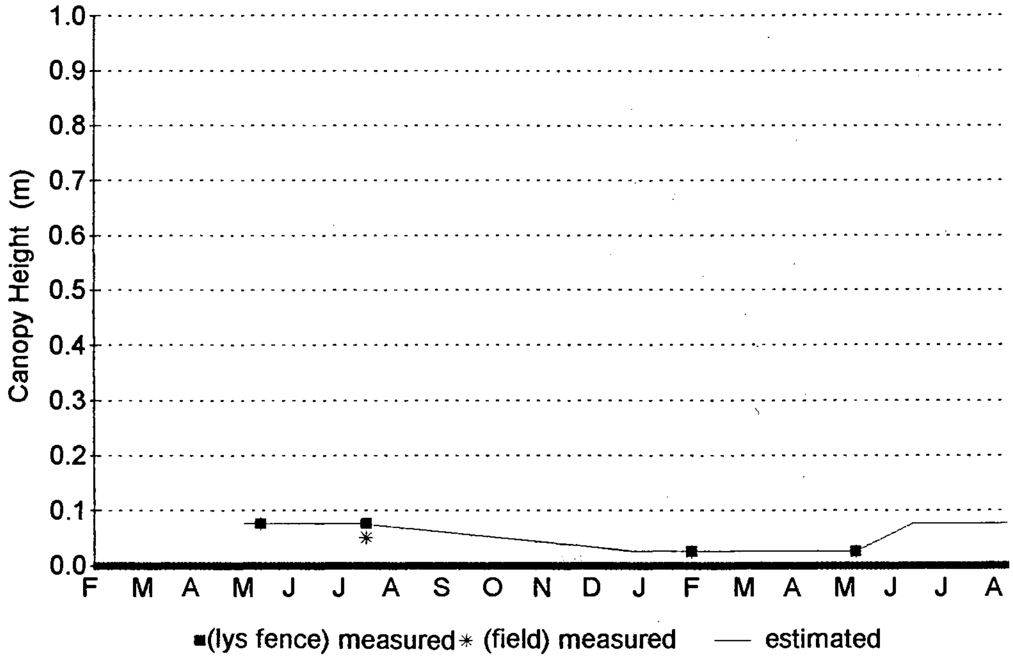

Figure 5.55. Canopy Height at Goodwell.

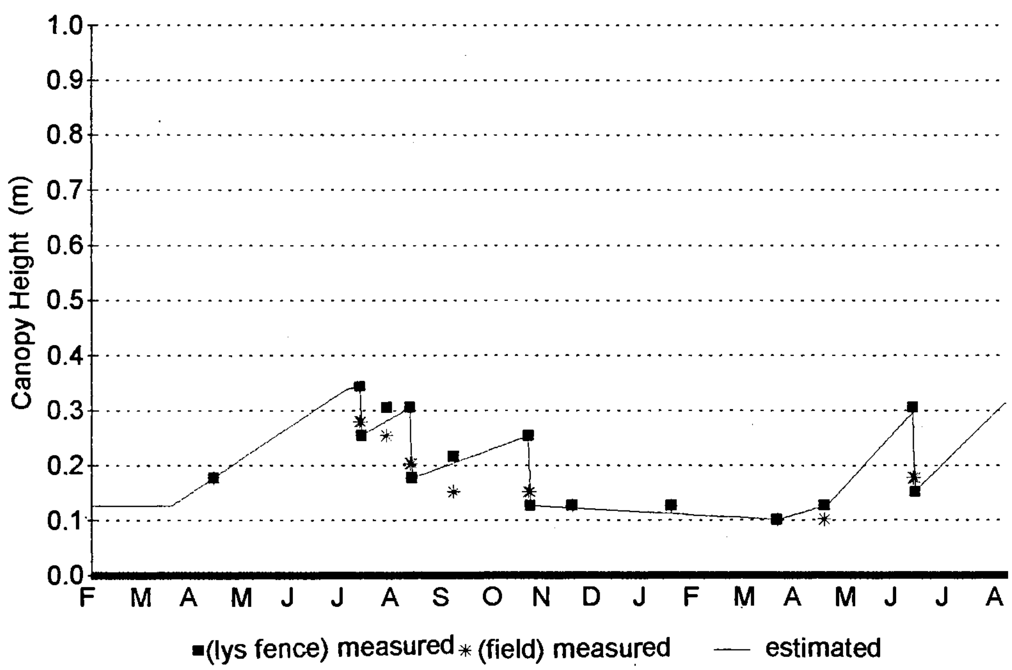

Figure 5.56. Canopy Height at Apache.

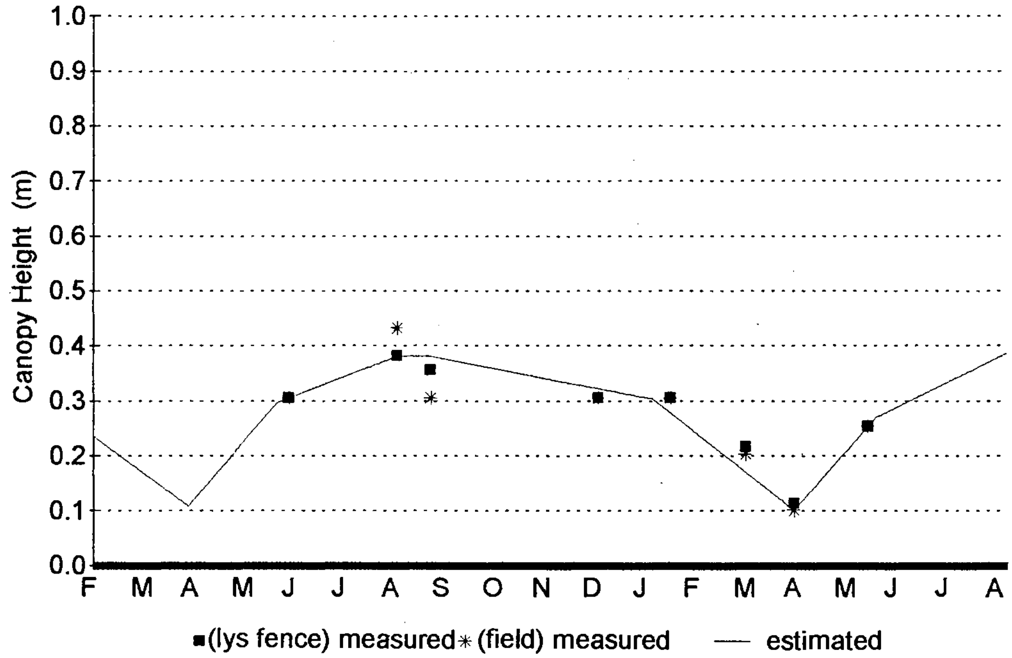

Figure 5.57. Canopy Height at Marena.

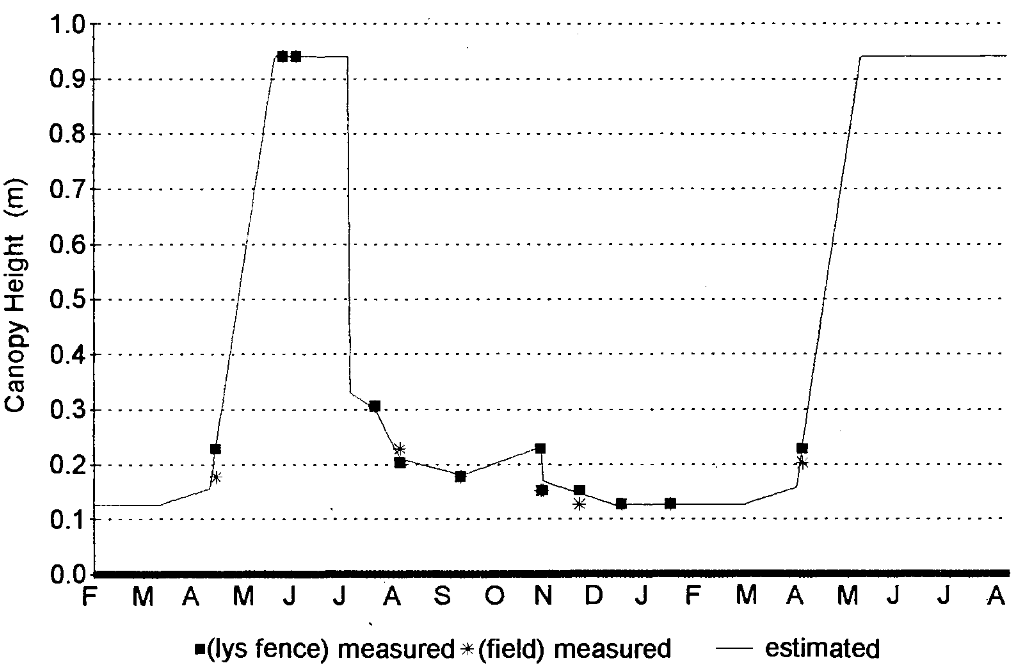

Figure 5.58. Canopy Height at Wister.

the lysimeter was estimated by averaging the bulk densities at each depth from the three access tubes outside the lysimeter.

During access tube installation at Marena and Wister, soil samples at the 1.05 m and 1.20 m depths inside the lysimeter were damaged, and bulk densities at these depths could not be determined. Bulk densities at these depths were estimated by assuming that the soil had been repacked in the same manner as that in the Goodwell and Apache lysimeters. The ratios of the bulk densities at the 1.05 m and 1.20 m depths relative to the average bulk density of the soil in the 0.15 m to 0.90 m layers was calculated for the Goodwell and Apache lysimeters. The average ratio at each depth was then calculated, and the missing bulk densities in the Marena and Wister lysimeters were estimated using these ratios.

Bulk density profiles inside and outside the lysimeter at each site are shown in Figures 5.59 through 5.62, and are summarized in Table 5.10. At all sites, the bulk density of the disturbed and repacked soil inside the lysimeters was less than that of the undisturbed soil outside the lysimeter. Ratios of the bulk density inside the lysimeter to that outside the lysimeter for individual 0.15-m interval measurements ranged from 0.70 to 0.99 for the entire profile. The ratios of the average bulk densities of the profiles ranged from 0.84 to 0.89. Bulk densities were determined during access-tube installation, between March and May 1994, approximately six months after lysimeters were installed. With time, as the soil inside the lysimeter settles, bulk densities are expected to increase.

Volumetric water contents of the soil samples were determined from water contents on a mass basis and sample bulk densities using Equation 3.3. Linear regression was then used to determine a calibration equation relating volumetric water contents and neutron-meter measurements of the form shown in Equation 3.4.

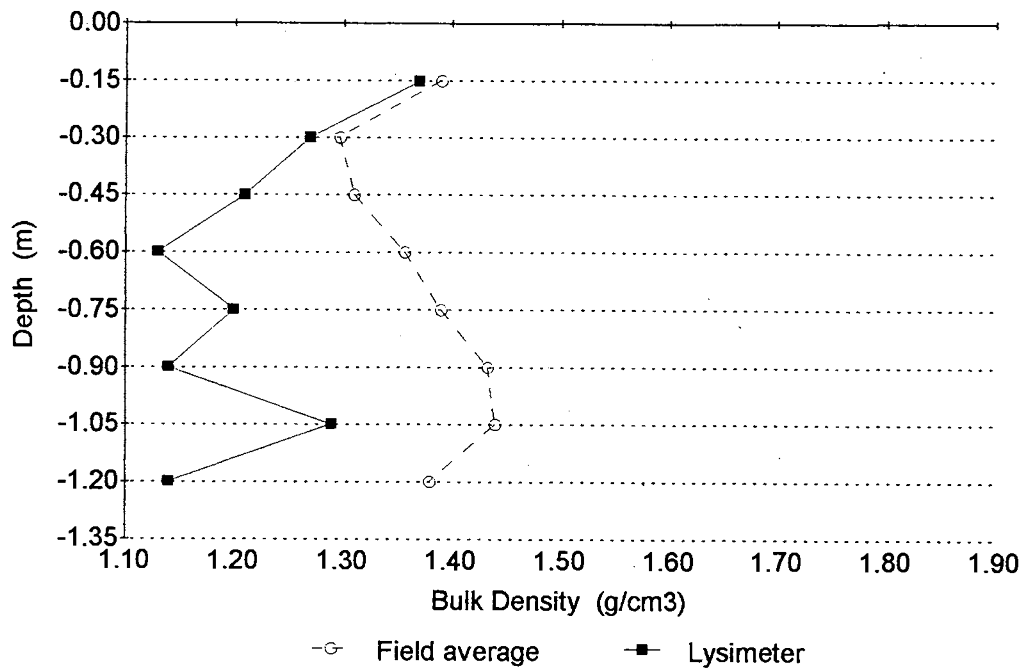

Figure 5.59. Soil Bulk Density Profiles at Goodwell.

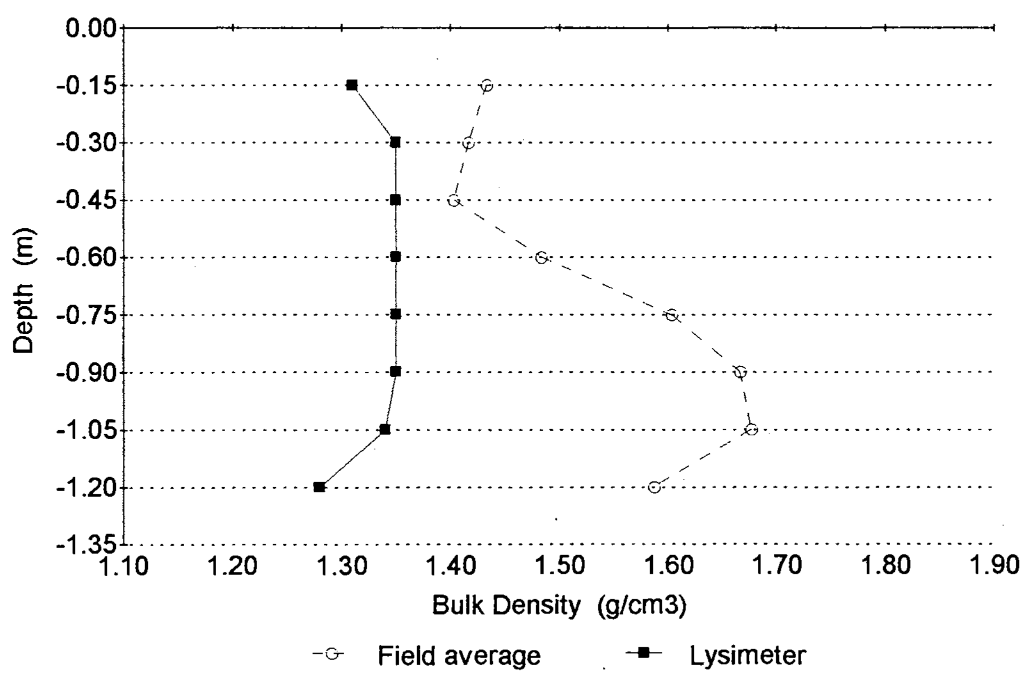

Figure 5.60. Soil Bulk Density Profiles at Apache.

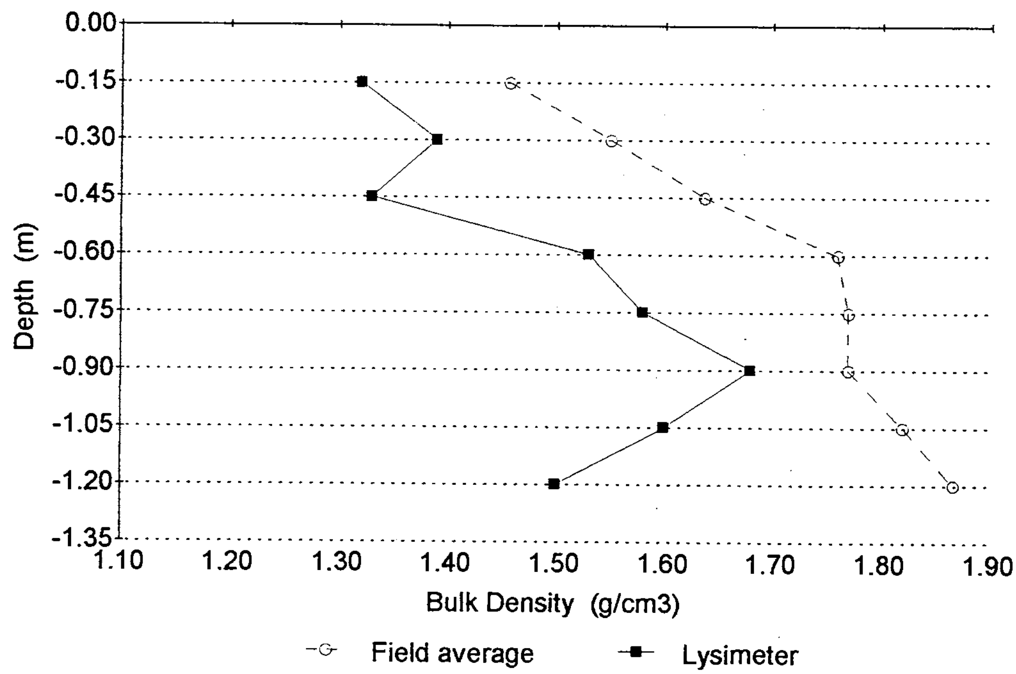

Figure 5.61. Soil Bulk Density Profiles at Marena.

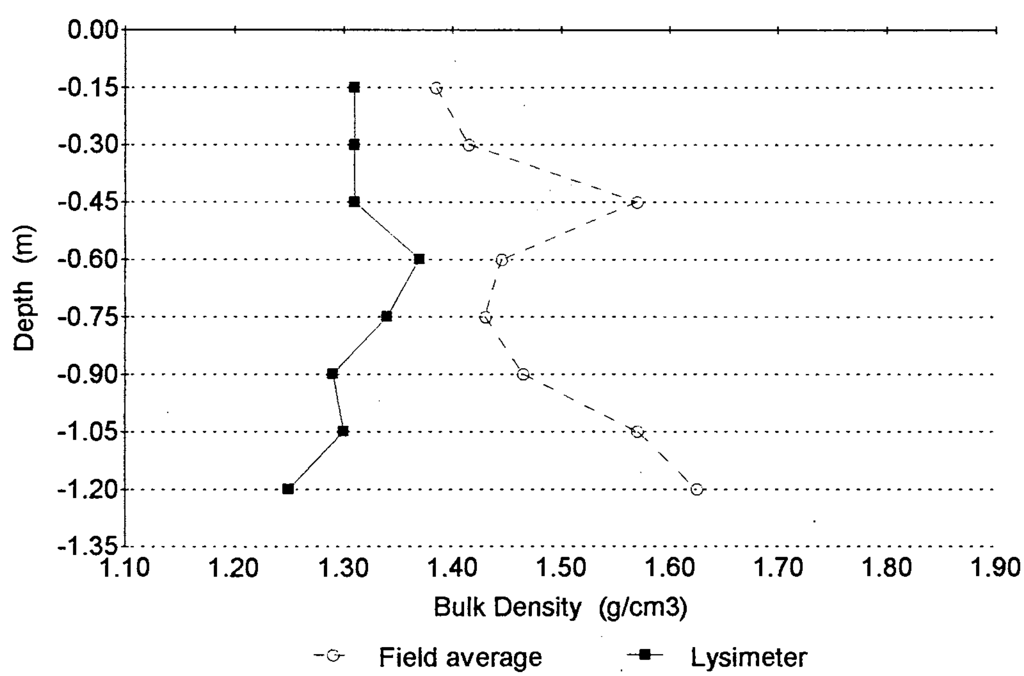

Figure 5.62. Soil Bulk Density Profiles at Wister.

Table 5.10. Soil Bulk Density Profiles.

depth	Goodwell		Apache		Marena		Wister	
	field	lysim	field	lysim	field	lysim	field	lysim
m	g/cm^3	g/cm^3	g/cm^3	g/cm^3	g/cm^3	g/cm^3	g/cm^3	g/cm^3
0.15	1.39	1.37	1.43	1.31	1.46	1.32	1.39	1.31
0.30	1.30	1.27	1.42	1.35	1.55	1.39	1.42	1.31
0.45	1.31	1.21	1.40	1.35	1.64	1.33	1.57	1.31
0.60	1.36	1.13	1.48	1.35	1.76	1.53	1.45	1.37
0.75	1.39	1.20	1.60	1.35	1.77	1.58	1.43	1.34
0.90	1.43	1.14	1.67	1.35	1.77	1.68	1.47	1.29
1.05	1.44	1.29	1.68	1.34	1.82	1.52*	1.57	1.36*
1.20	1.38	1.14	1.59	1.28	1.87	1.38*	1.63	1.24*
average	1.37	1.22	1.53	1.34	1.70	1.47	1.49	1.32

* Soil samples at these depths were damaged during removal and bulk density measurements could not be made. Bulk density values at these depths are estimates.

Parameters determined for each calibration equation, and the correlation coefficients for each linear regression, are shown in Table 5.11. Water contents measured with the neutron meter are compared to estimates made with the the calibration equations in Figures 5.63 through 5.66.

Table 5.11. Neutron-Meter Calibration-Equation Parameters.

	Inside Lysimeter			Outside Lysimeter		
	a	b	r^2	a	b	r^2
Goodwell	0.700	-0.0437	0.95	0.560	-0.0134	0.84
Apache	0.403	0.0846	0.66	0.531	0.0232	0.95
Marena	0.471	0.00307	0.70	0.366	0.0680	0.53
Wister	0.458	0.104	0.76	0.645	-0.0391	0.75

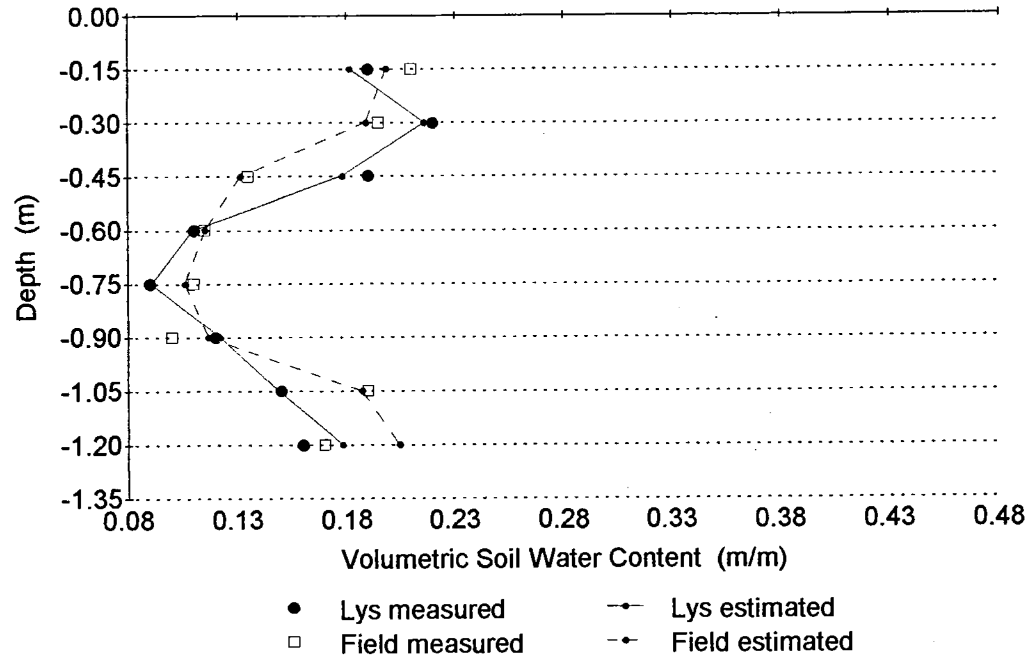

Figure 5.63. Neutron Probe Calibrations at Goodwell.

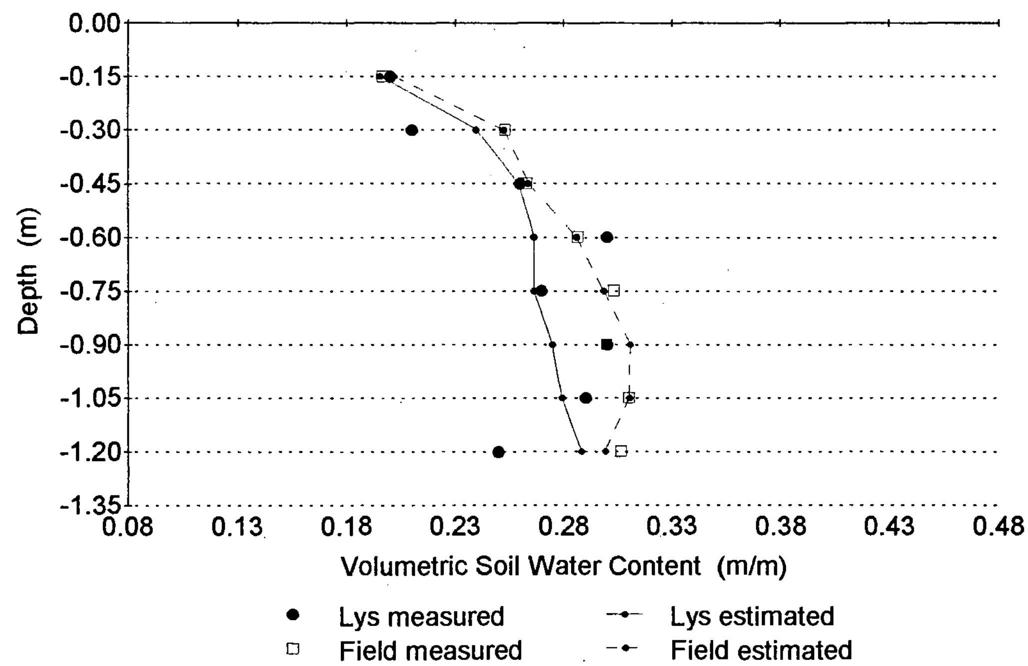

Figure 5.64. Neutron Probe Calibrations at Apache.

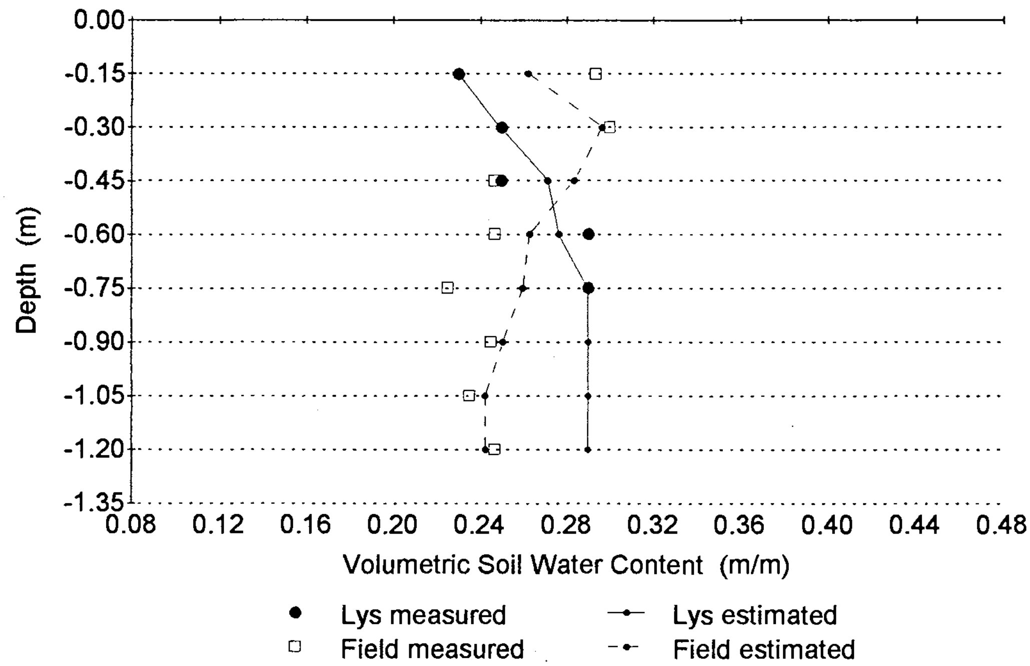

Figure 5.65. Neutron Probe Calibrations at Marena.

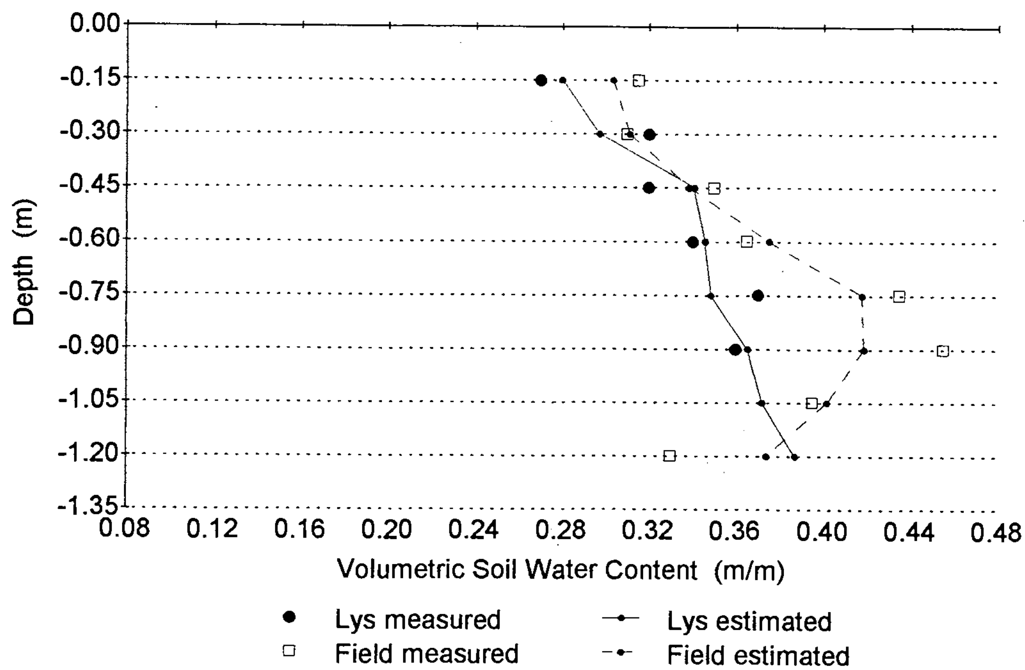

Figure 5.66. Neutron Probe Calibrations at Wister.

Neutron-Meter Measurements

During periodic visits to the lysimeter sites, soil-water measurements were made inside and outside the lysimeter using the neutron meter. Neutron-meter count measurements were converted to volumetric soil moisture contents using the calibration equations for each site. Soil-moisture profiles were then generated from the volumetric water-content estimates at each depth, and estimates of the total water content in the profile were made. Water contents, estimated on a volume basis as m^3 of water per m^3 of soil, were then expressed as an equivalent depth of water, in mm, per unit surface area, m^2.

Estimates of the total water contents, expressed as equivalent soil-water depths, in the top 1 m of the soil profile are shown in Figure 5.67 and are listed in Tables 5.12 to 5.15. The water contents indicate that, in general, the total water in

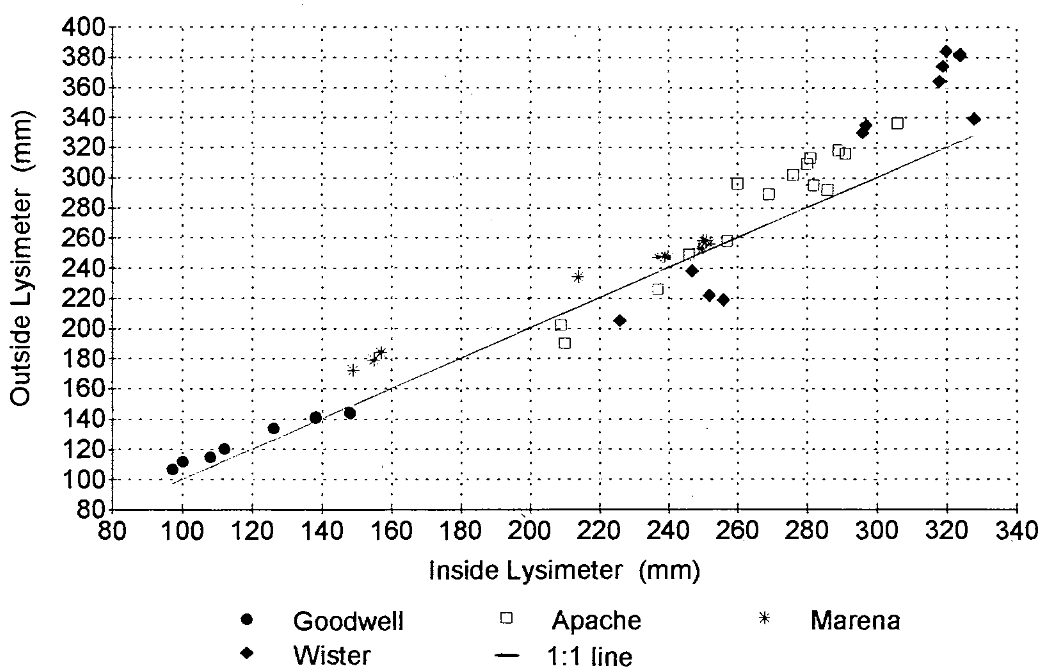

Figure 5.67. Equivalent Soil-Water Depths in Top 1 m of Soil Inside and Outside the Lysimeters.

Table 5.12. Equivalent Soil-Water Depth in Top 1 m of Soil at Goodwell.

Date	Inside Lysimeter mm	Outside Lysimeter mm
21 April 1994	148	144
11 May 1994	138	141
16 May 1994	126	134
13 July 1994	97	107
26 August 1994	100	112
24 January 1995	108	115
2 May 1995	112	120

Table 5.13. Equivalent Soil-Water Depth in Top 1 m of Soil at Apache.

Date	Inside Lysimeter mm	Outside Lysimeter mm
29 March 1994	282	295
6 April 1994	276	302
15 April 1994	281	313
9 May 1994	289	318
30 May 1994	260	296
11 July 1994	246	249
18 July 1994	257	258
27 July 1994	237	226
10 August 1994	210	190
20 October 1994	209	202
15 November 1994	269	289
13 January 1995	280	309
17 March 1995	306	336
24 March 1995	291	316
14 April 1995	286	292

Table 5.14. Equivalent Soil-Water Depth in Top 1 m of Soil at Marena.

Date	Inside Lysimeter mm	Outside Lysimeter mm
20 March 1994	252	256
3 April 1994	250	253
20 April 1994	249	253
29 April 1994	239	248
12 May 1994	250	258
26 May 1994	214	234
28 June 1994	157	184
22 August 1994	155	179
13 October 1994	149	172
30 November 1994	239	248
12 January 1995	237	247
26 February 1995	240	247
24 March 1995	251	258

Table 5.15. Equivalent Soil-Water Depth in Top 1 m of Soil at Wister.

Date	Inside Lysimeter mm	Outside Lysimeter mm
18 May 1994	318	364
25 May 1994	297	335
2 June 1994	296	330
19 July 1994	256	219
3 August 1994	252	222
8 September 1994	226	205
26 October 1994	247	238
18 November 1994	320	384
29 November 1994	319	374
13 December 1994	324	382
11 January 1995	324	381
31 March 1995	328	339

the soil inside the lysimeter was similar to that in the soil outside the lysimeter. The ratio of the soil-water content inside the lysimeter to that outside ranged from 0.89 to 1.03 at Goodwell, 0.88 to 1.11 at Apache, 0.85 to 0.99 at Marena, and 0.83 to 1.17 at Wister.

Soil-moisture measurements made inside and outside the lysimeter at each site are shown in Appendix C. At Goodwell, the soil water content inside the lysimeter was consistently lower throughout the profile, though only slightly, than that outside the lysimeter. At Apache, the soil-water content was usually lower inside the lysimeter throughout most of the year. During the warmest months, however, from July through October, the soil-water content was higher in the upper soil layers inside the lysimeter. At Marena, the soil-water content was consistently higher in the upper soil layers inside the lysimeter, and lower in the lower layers inside the lysimeter. Conditions at Wister were similar to those at Apache: water contents usually lower inside the lysimeter, but higher in the upper layers during the summer.

Chapter 6

MODELING RESULTS

The ET estimation model presented by Shuttleworth and Wallace (1985) was tested at the four lysimeter sites. Meteorological parameters were either measured directly by the Mesonet weather station at the site, or estimated based on measured parameters. Resistance terms were modeled based on meteorological parameters, plant, canopy, and soil characteristics, and available soil-water supplies at each site. ET estimates from the model were compared to lysimeter measurements.

ESTIMATION OF RESISTANCE PARAMETERS

In order to objectively model and evaluate the resistance parameters used in the evapotranspiration model, weather and lysimeter data were divided into two data sets. One data set was used to develop models for the resistances, and the second set was used to evaluate the performance of the models. The two data sets consisted of alternate months of data: one set contained odd-numbered months (January, March, May, July, September, and November), and the other set contained even-numbered months (February, April, June, August, October, and December).

The intent of dividing the data was to have two independent sets of data: one set for model development, and one for model verification. In modeling the canopy resistance and the soil surface resistance, however, it was necessary to monitor daily soil-water contents throughout the year in order to account for soil moisture depletion and effects of drying soil. This required that all the data be present and available during modeling in order to calculate daily water balances and cumulative evapotranspiration amounts throughout the year. During the model development phase, resistance models were developed using one data set but run on both data sets in order to maintain the required water balances through time. Adjustments to the model were made based only on the results from the one data set. During the model verification phase, the models were run on both data sets and water balances were maintained, but only the model results from the second data set were evaluated.

Process Followed in Modeling Resistances

An iterative process was used to develop models for the resistance terms and to adjust model parameters. Five resistances had to be modeled and were expected to vary at each site and throughout the year, and assumptions were made to try to simplify the modeling process. The forms of the resistance models were assumed based on results reported in the literature in order to have functional forms with which to begin, which could later be modified as needed. Individual resistance values were assumed under specific weather or vegetative conditions in order to infer or model the other resistances under those conditions. In this way, the modeling process became more a matter of inference rather than trial and error. The steps which were followed in modeling the resistances are outlined in the following paragraphs.

1. Relationships for estimating the aerodynamic resistances were first identified. The above-canopy aerodynamic resistance was modeled using the logarithmic wind profile approach followed by the majority of researchers making ET

estimates with the Penman-Monteith and Shuttleworth-Wallace methods. In-canopy resistances were less-well established, and several methods from the literature were tested.

2. A value for the plant stomatal resistance during periods of dormancy was assumed. During dormant periods, a high stomatal resistance value was chosen to represent a large resistance to evaporation when stomates were closed and inactive. During other periods when stomates were assumed to be closed, such as when soil-water stores were depleted, the large stomatal resistance represented closed stomates and little evaporation from the plant.

3. Periods during which the vegetation was dormant were examined to determine appropriate values for the soil resistance. Days soon after rainfall, when the soil was wet and soil resistance would be expected to be low, were examined in order to estimate a minimum value of soil resistance. The soil surface resistance was then estimated based on the soil resistance and amount of exposed soil at each site.

4. Periods during which the vegetation was active were then examined in order to model the stomatal resistance and estimate the canopy resistance. At each site, days after a rainfall were chosen when adequate soil water was assumed to be available and the plants were assumed to be under no water stress. Stomatal resistance under conditions of non-limiting soil-water availability was modeled based on response functions relating stomatal behavior to weather parameters such as solar radiation and vapor-pressure deficit. Canopy resistance was then estimated based on stomatal resistance and leaf-area index.

5. Effects of limited soil-water availability on soil surface resistance were modeled using a two-stage evaporation approach. Each day, the cumulative evaporation was totaled, with the cumulative amount reset to zero following a rainfall event when the soil was wetted. When the cumulative evaporation was less than a

threshold value, soil water was assumed to be available in the near-surface soil layer, and the soil resistance increased slowly each day. When the threshold value was reached, soil water in the near-surface layer was assumed to be depleted, and the soil resistance increased rapidly each day.

6. Effects of limited soil-water availability on stomatal resistance were modeled by including a water-stress function in the stomatal resistance model. At each site, soil-water content values at wilting point and field capacity were estimated from neutron-meter measurements, and the available water content of the soil was estimated. A daily soil-water balance was maintained, and the daily available water fraction was calculated. The water-stress function was then modeled based on the available soil-water fraction.

7. The performance of the resistance models was evaluated by comparing ET estimates made with the Shuttleworth-Wallace model to ET measurements reported by the lysimeters. Daily ET values were compared, as well as daily soil-water contents estimated with the model versus lysimeter and neutron-meter measurements.

8. A sensitivity analysis was later performed to identify the most important parameters involved in modeling the resistances and in obtaining ET estimates from the Shuttleworth-Wallace model.

Statistics Used to Evaluate Model Performance

Linear regression was used to objectively evaluate model performance by comparing measured ET to modeled ET. A linear relationship was developed,

$$ET_{model} = mET_{lys} + b \qquad (6.1)$$

where

ET_{model} = ET model estimate, mm/d

ET_{lys} = lysimeter ET measurement, mm/d

m = slope

b = y-intercept.

The slope and y-intercept were determined, as well as the correlation coefficient, r^2, standard error of the estimate, and average lysimeter and model ET amounts.

As resistance models were developed and tested, the linear regression statistics were examined and used in adjusting model parameters. Parameters were adjusted so that average ET estimates approximated average lysimeter measurements, standard errors of the estimate were minimized, and the correlation coefficient was maximized.

Aerodynamic Resistances

Aerodynamic Resistance of Mean Canopy Flow

The aerodynamic resistance of the mean canopy flow was estimated from the logarithmic wind profile equation, Equation 4.52, as a function of canopy height, zero-plane displacement height, roughness lengths, and average wind speed. The zero-plane displacement height was assumed to be a constant function of vegetation height and was estimated using Equation 4.53. Roughness lengths were assumed to be constant functions of vegetation height and were estimated using Equations 4.54 and 4.55.

The wind speed used in Equation 4.52 was the average wind speed calculated during the daytime hours. The daytime average wind speed was estimated for the same daytime, sunrise-to-sunset period over which estimates of other model parameters such as vapor-pressure deficit and net radiation were made.

The range of average daytime wind speeds encountered and aerodynamic resistances estimated at each site are summarized in Table 6.1, with daily resistance values shown in Figures 6.1 through 6.4. Resistance values estimated using Equation 4.52 are related logarithmically to canopy height and inversely to wind speed, and the interrelationship between vegetation height and wind speed can be seen. High wind speeds at Goodwell would suggest large amounts of turbulence being generated in the air flowing over the surface, and low resistance to water vapor transfer. The low vegetation heights, however, resulted in little vegetation exposed to the turbulent air, and a high resistance to water vapor transfer. At Apache and Marena, wind speeds were lower, resulting in less turbulence, but vegetation heights were greater, with more transpiring vegetation exposed to the air flow. Resulting aerodynamic resistances were similar in average values and ranges of values at these three sites. At Wister, much lower wind speeds contributed to higher resistances despite taller vegetation during much of the year.

Table 6.1. Aerodynamic Resistance of the Mean Flow.

	Daytime Wind Speed				Aerodynamic Resistance			
	Avg	Std dev	Min	Max	Avg	Std dev	Min	Max
	m/s	m/s	m/s	m/s	s/m	s/m	s/m	s/m
Goodwell	5.13	2.03	1.39	11.52	62	29	21	179
Apache	4.23	1.64	0.63	9.84	48	27	17	317
Marena	3.51	1.53	0.31	8.08	53	39	17	398
Wister	2.06	1.15	0.02	6.17	88	62	12	532

Aerodynamic Resistance of the Canopy to In-Canopy Flow

The aerodynamic resistance of the canopy to in-canopy flow describes the influence on water-vapor transfer of the air flow within the plant canopy. The model

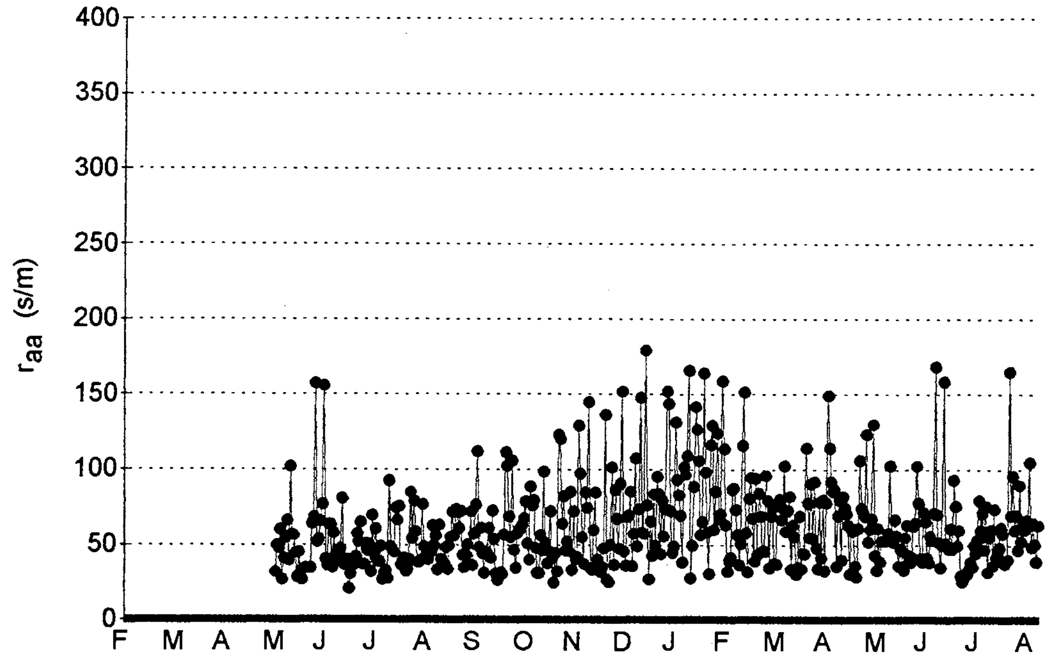

Figure 6.1. Aerodynamic Resistance of the Mean Flow for May 1994 through July 1995 at Goodwell.

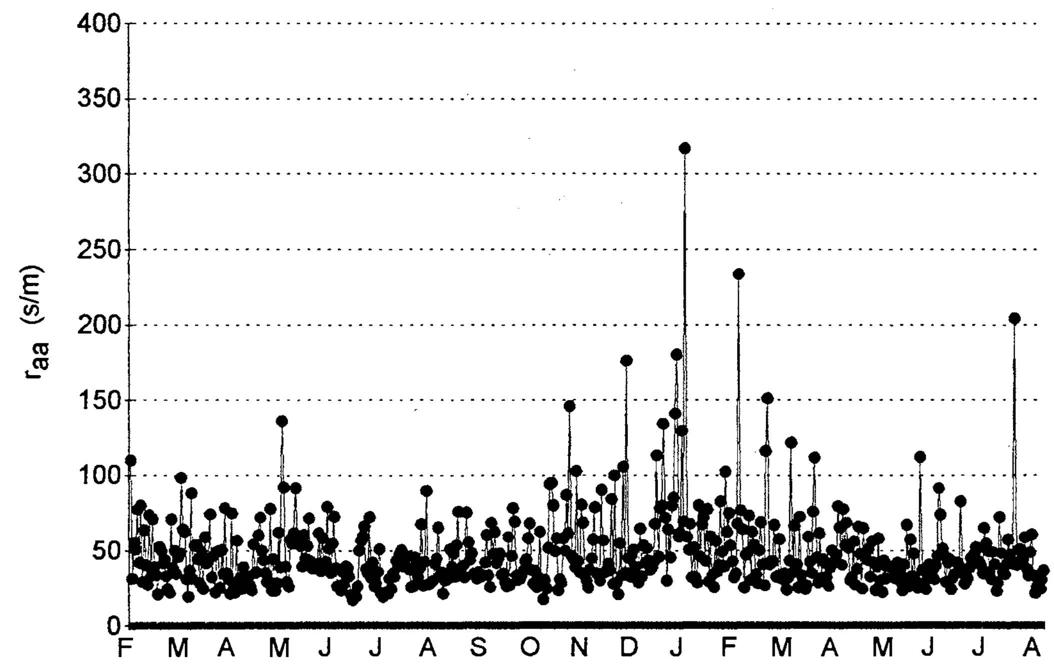

Figure 6.2. Aerodynamic Resistance of the Mean Flow for February 1994 through July 1995 at Apache.

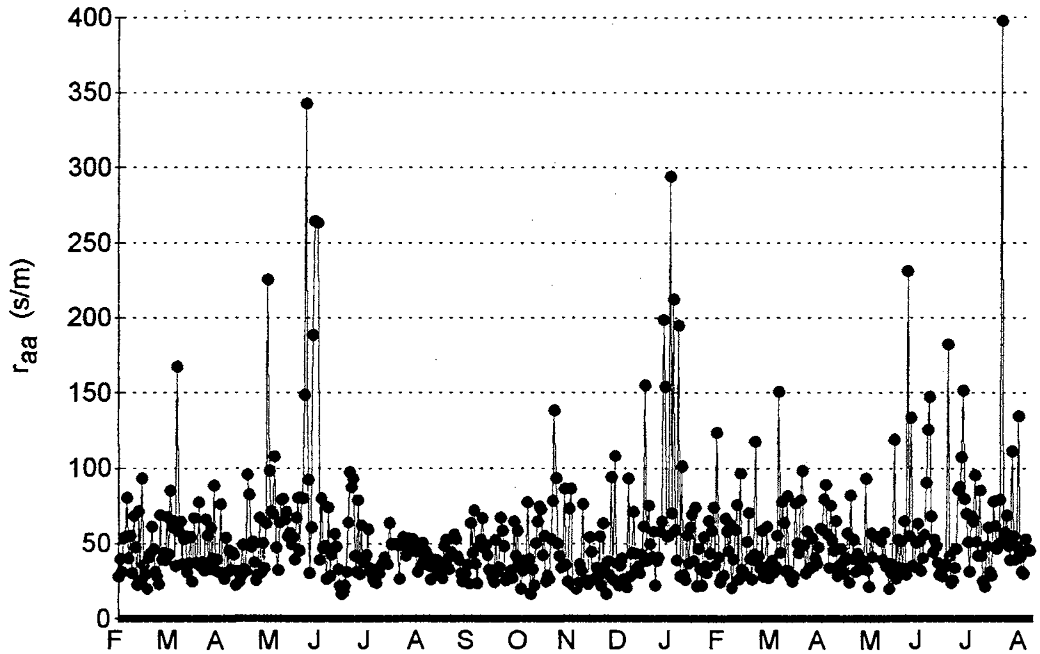

Figure 6.3. Aerodynamic Resistance of the Mean Flow for February 1994 through July 1995 at Marena.

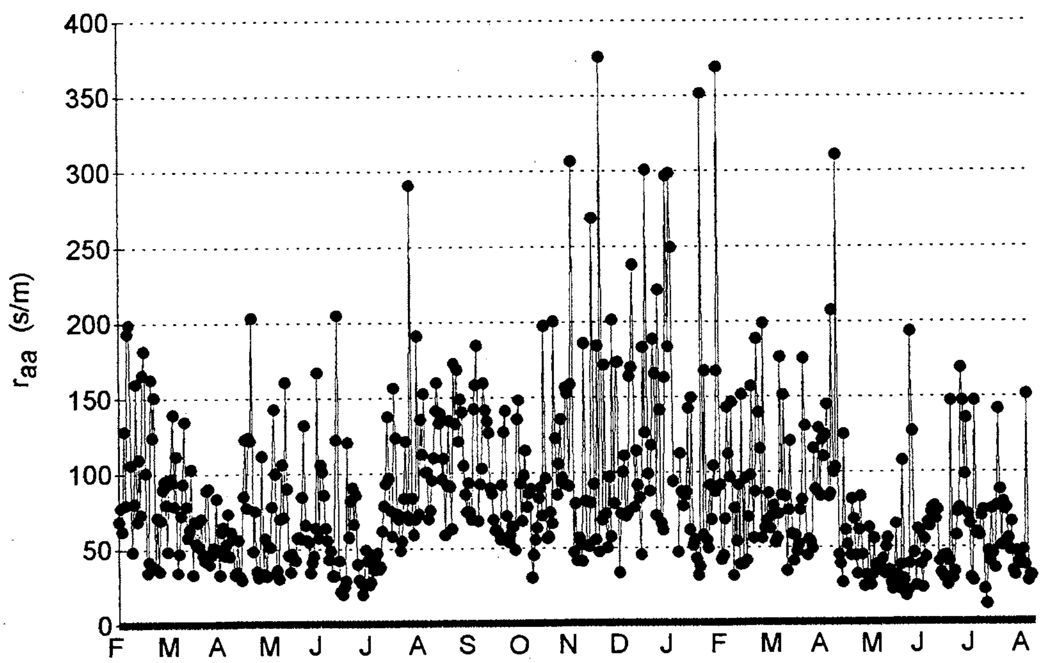

Figure 6.4. Aerodynamic Resistance of the Mean Flow for February 1994 through July 1995 at Wister.

proposed by Shuttleworth and Gurney (1990), as well as modified versions proposed by others, estimates resistance based on leaf width, wind speed at the top of the plant canopy, and an extinction coefficient which describes the decrease in turbulence with depth inside the canopy. Shuttleworth and Wallace (1985), Ham and Heilman (1991), and Massman (1992), however, reported that a relationship to adequately describe the resistance could not be determined, and that a constant resistance value could be used instead.

The model proposed by Shuttleworth and Gurney (1990), shown as Equations 4.56, 4.57, and 4.58, was tested with a range of leaf widths and extinction coefficients to determine the effects of these parameters on resistance values. Leaf widths of the vegetation at the four sites were estimated to vary between 2 and 10 mm throughout the year. Extinction coefficients reported for a wetland meadow were in the range of 2.0 to 3.7 (Lafleur and Rouse, 1990), and for corn, in the range of 2.5 to 3 (Farahani and Bausch, 1994). Appropriate values for pasture or native grass were not known, and values in the range of 1.0 to 5.0 were tested.

Daily resistance values were calculated over the range of leaf widths and extinction coefficients, and the average value and standard deviation were determined. Average values were found to vary more than an order of magnitude, with standard deviations being approximately 50% of the average value. The largest average resistance values resulted from using an extinction coefficient of 1.0 and a leaf width of 10 mm, and the smallest average values were obtained with an extinction coefficient of 5.0 and a 2-mm leaf width.

Based on uncertainties in leaf width and changes in leaf width throughout the year, and uncertainty in choosing an extinction coefficient for each site and changes in the coefficient with canopy structure and density, a constant resistance value was chosen. Shuttleworth and Wallace (1985) used a value of 25 s/m, while Massman

(1992) reported using a value of 40 s/m. The value reported by Massman (1992), obtained from measurements made over a semiarid grassland region, was chosen.

Aerodynamic Resistance of the Soil Surface to In-Canopy Flow

The aerodynamic resistance of the soil surface to in-canopy flow describes the influence of the soil surface within the canopy on water-vapor transfer. Relationships proposed for estimating the resistance have varied depending on assumptions made about the wind speed profile within the canopy. The model proposed by Shuttleworth and Wallace (1985) assumed that the wind speed profile was logarithmic above the canopy and varied linearly within the canopy, and included an extinction coefficient. The relationship developed by Stannard (1993) was derived assuming that the logarithmic wind profile under sparse-canopy conditions extended into the canopy and down to the soil surface. Others, including Ham and Heilman (1991) and Massman (1992), concluded that adequate relationships could not be reliably determined due to variability and uncertainty in in-canopy measurements, and suggested using constant values for the resistance.

Based on a lack of information regarding in-canopy wind profiles and extinction coefficients, a constant value for the resistance was chosen. A value of 40 s/m, reported by Massman (1992) working in a grassland region, was chosen.

Canopy Resistance

Canopy resistance was estimated by modeling the stomatal resistance of individual leaves to several environmental factors, and adjusting the resistance of individual leaves to account for canopy density. The canopy resistance model, Equation 4.63, is of the form

$$r_{cc} = \frac{r_{st}}{2LAI} \tag{4.63}$$

where

r_{cc} = canopy resistance, s/m

r_{st} = stomatal resistance, s/m

LAI = leaf-area index.

Stomatal resistance was estimated by modeling the response of stomatal conductance, the inverse of resistance, to several environmental variables. Following the method of Stewart (1988), stomatal conductance was modeled as a maximum, unstressed value modified by response functions which decreased the conductance due to atmospheric stresses and soil-water availability. The stomatal resistance model, Equations 4.64 and 4.65, is of the form

$$r_{st} = \frac{1}{g_c} \tag{4.64}$$

where

r_{st} = stomatal resistance, s/m

g_c = stomatal conductance, m/s

and

$$g_c = g_{max}\, g(R_s) g(D) g(T_a) g(\theta) \tag{4.65}$$

where

g_{max} = maximum conductance, m/s

$g(R_s)$ = function for stomatal response to solar radiation

$g(D)$ = function for stomatal response to vapor-pressure deficit

$g(T_a)$ = function for stomatal response to air temperature

$g(\theta)$ = function for stomatal response to soil water availability.

Stomatal resistance was modeled in a two-step process. First, weather and ET data were obtained for days during which soil water was assumed to be non-limiting and the vegetation was assumed to be under no moisture stress. Data were used from time periods during which the vegetation at the site was actively growing. Days were chosen following rainfall events which deposited enough water to meet atmospheric ET demand for several days. The effects of limited water availability and possible moisture stress were then modeled using data from other days when soil water was in various stages of depletion.

Modeling Canopy Resistance Under Conditions of Non-Limiting Water Availability

Under conditions of non-limiting water availability, the function describing stomatal response to soil water availability, $g(\theta)$, assumed a value of 1, indicating that there was no water stress affecting the stomatal conductance value. For time periods soon after a rainfall, when water was assumed to be available and the plants were assumed to be under no water stress, weather and ET data were used to determine expressions for the remaining response functions in the stomatal conductance model.

Response functions were determined by choosing a functional form for each response, estimating parameter values in the function, and calculating stomatal conductances and the subsequent canopy resistances. Canopy resistance values, as well as the other resistance values, meteorological variables, and canopy information were then input to the evapotranspiration model and ET estimates were obtained.

In order to develop a model for estimating canopy resistance, therefore, estimates of the other four resistances were needed. Aerodynamic resistances were estimated first, as described above. Estimates of soil surface resistance were then needed for the periods immediately following rainfall events. Resistance values during these periods, when the soil surface was wet, represented minimum values of soil surface resistance. Farahani and Bausch (1994) cited reported values of soil surface resistance in the range of 50 to 1500 s/m. Values ranging from 50 to 500 s/m were tested at each site to determine a suitable value for each soil.

ET estimates from the model were then compared to lysimeter ET values, and statistics including average measured and estimated ET, standard error of the estimate, and slope of the linear relationship between estimated and measured ET were examined in order to evaluate the ET estimate based on the canopy resistance model. Response function parameters and functional forms were then adjusted as needed to improve ET estimates.

The stomatal resistance model was developed by beginning with the stomatal conductance model of Equation 4.65 but with only one stress function. Different functional relationships for that stress function were tested, and parameters were chosen which, when the canopy and other resistances were input to the ET model, provided the best ET estimates. A second stress function based on a different weather variable was then added, and the parameters were again adjusted. This continued until no further improvements in the model were gained.

The atmospheric parameters found to most influence stomatal behavior were solar radiation and vapor-pressure deficit. Air temperature was found to have little influence and was dropped from the model.

The function for the stomatal response to solar radiation, $g(R_S)$, proposed by Stewart (1988), Equation 4.66, was used and is of the form

$$g(R_s)=\frac{R_s(R_{s\,max}+c_1)}{R_{s\,max}(R_s+c_1)} \tag{4.66}$$

where

R_{smax} = maximum daily solar radiation received during the year, MJ/m^2

c_1 = fitting constant.

The value of R_{smax} was set to the maximum clear-sky radiation occurring at the four sites during the year, calculated using the method outlined in Jensen et al. (1990) to be 32 MJ/m^2. Values of c_1 in the range of 10 to 50 did not have a significant effect on the solar radiation response function, and a mid-range value of 30 was chosen.

Response functions describing stomatal response to atmospheric vapor-pressure deficit were then examined, and a relationship proposed by Massman and Kaufmann (1991) was found to provide the best results. The function, Equation 4.67, is of the form

$$g(D) = \frac{1}{1+bD} \tag{4.67}$$

where

D = vapor pressure deficit, kPa

b = fitting constant.

A range of values for the parameter b were tested, with a value of b = 1.0 chosen for use at all sites.

Values of the maximum stomatal conductance, g_{max}, were estimated and adjusted during modeling as each response function was tested. Final values determined for each site, as well as the parameters chosen for each response function, are listed in Table 6.2.

Results from the comparison of lysimeter ET measurements and ET estimates under conditions of non-limiting soil-water are shown in Figures 6.5 through 6.8, and summarized in Table 6.3. The canopy resistance model was developed, using the model development data set, from periods of active vegetation throughout the year to include a wide range of vegetative growth conditions.

Table 6.2. Parameter Values for Stomatal Resistance Model.

Response function	Parameter	Goodwell	Apache	Marena	Wister
	g_{max}	0.006	0.004	0.006	0.003
$g(R_s)$	R_{smax}	32	32	32	32
	c_1	30	30	30	30
g(D)	b	1	1	1	1

The best results, based on the magnitude of the standard errors and correlation coefficients, were achieved at Goodwell and Apache. This may be attributed to vegetative conditions at these sites, which were not as variable as those at the other sites. The vegetation at Goodwell varied very little in terms of canopy height and leaf-area index, being very short and sparse throughout the year. The vegetation at Apache was fairly dense and was grazed regularly, resulting in relatively small variations in canopy height and density.

At Marena and Wister, errors were higher and correlation coefficients were slightly lower than at the other sites. The vegetation at these sites varied more throughout the year, in terms of plant species at Marena, and canopy height and

Table 6.3. Performance of Canopy Resistance Model Using Model Development Data Set Under Conditions of Non-Limiting Water Availability.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	3.7	3.1	4.2	4.5
Average model ET, mm/d:	3.5	2.8	4.0	4.2
Regression standard error, mm/d:	0.6	0.7	0.9	1.0
Correlation coefficient, r^2:	0.69	0.83	0.63	0.59
Slope of regression line:	0.79	0.79	0.56	0.68
Intercept of regression line:	0.55	0.34	1.67	1.14
Number of days of data:	19	31	21	25

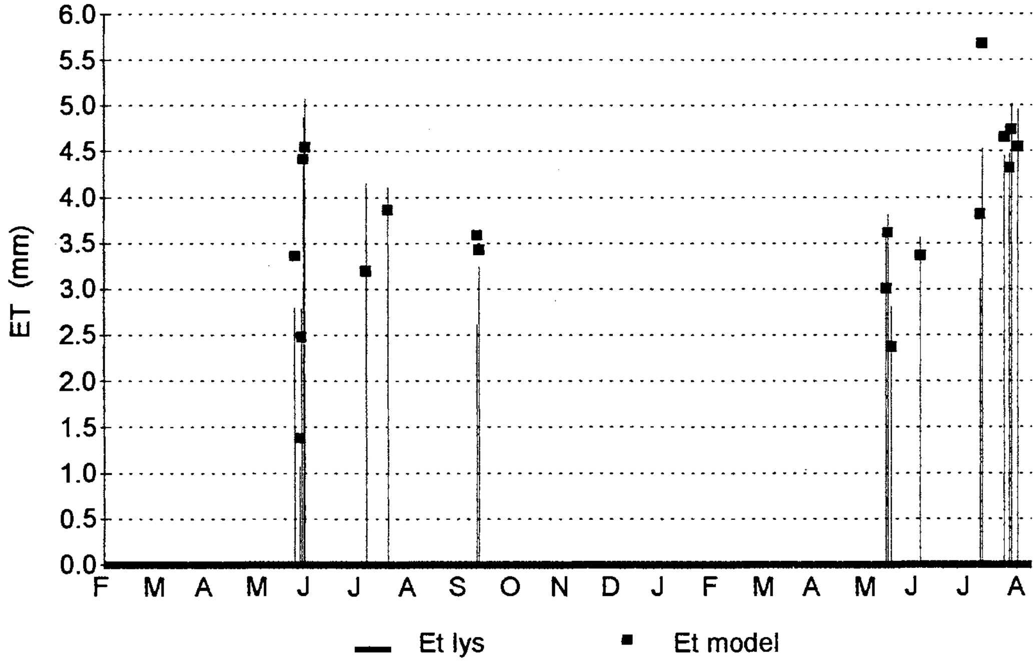

Figure 6.5. Lysimeter Measurements and Model Estimates During Canopy Resistance Model Development at Goodwell.

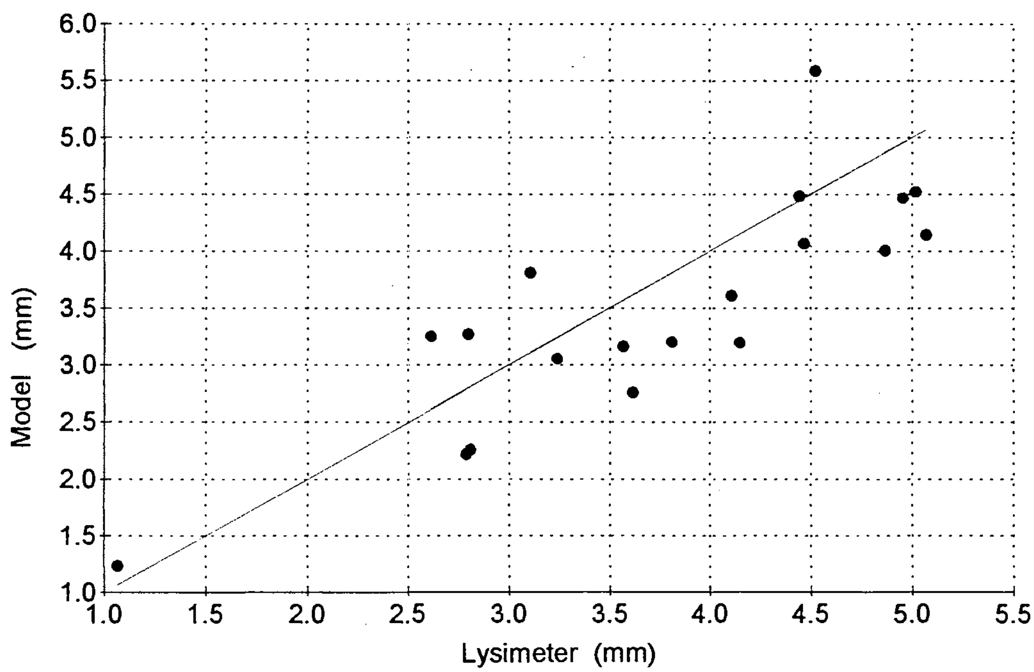

Figure 6.6. Comparison of Lysimeter ET and ET Model Estimates Obtained During Canopy Resistance Model Development at Goodwell.

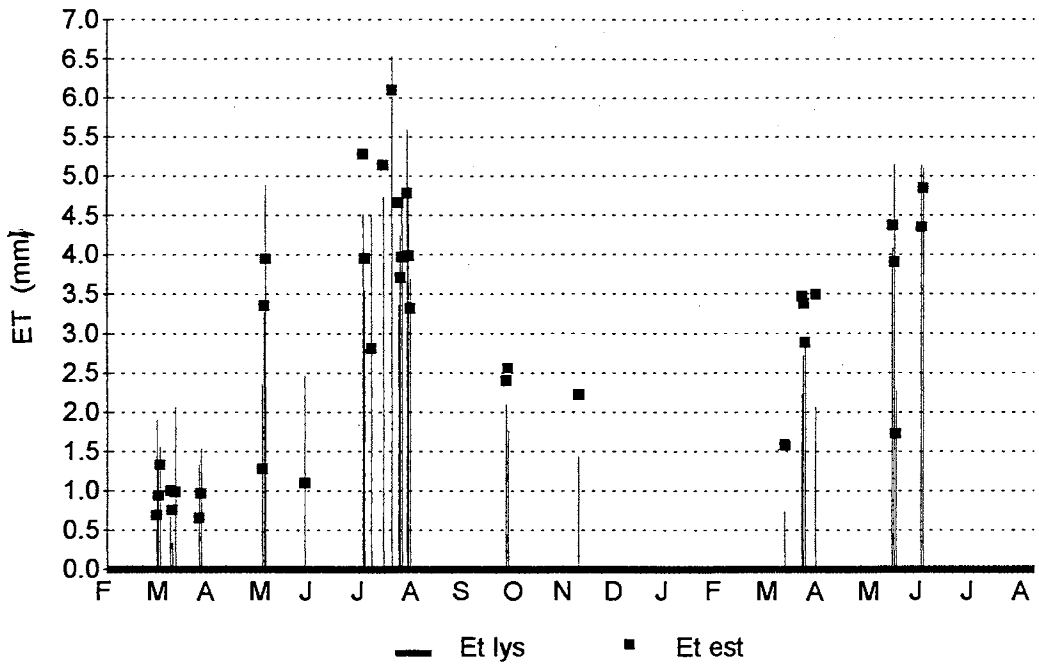

Figure 6.7. Lysimeter Measurements and Model Estimates During Canopy Resistance Model Development at Apache.

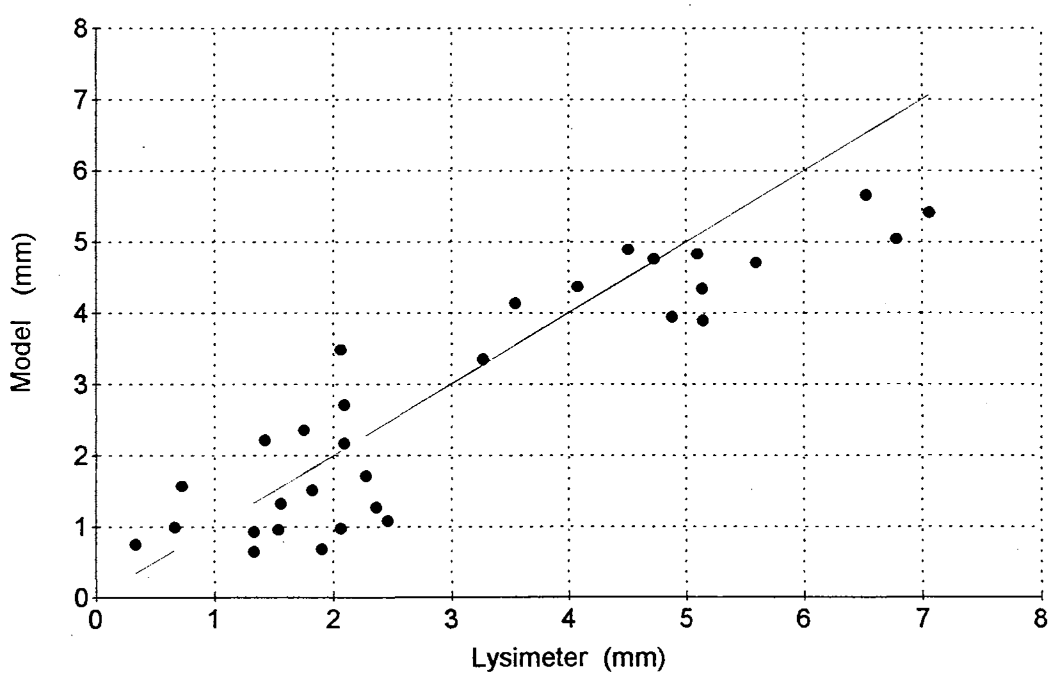

Figure 6.8. Comparison of Lysimeter ET and ET Model Estimates Obtained During Canopy Resistance Model Development at Apache.

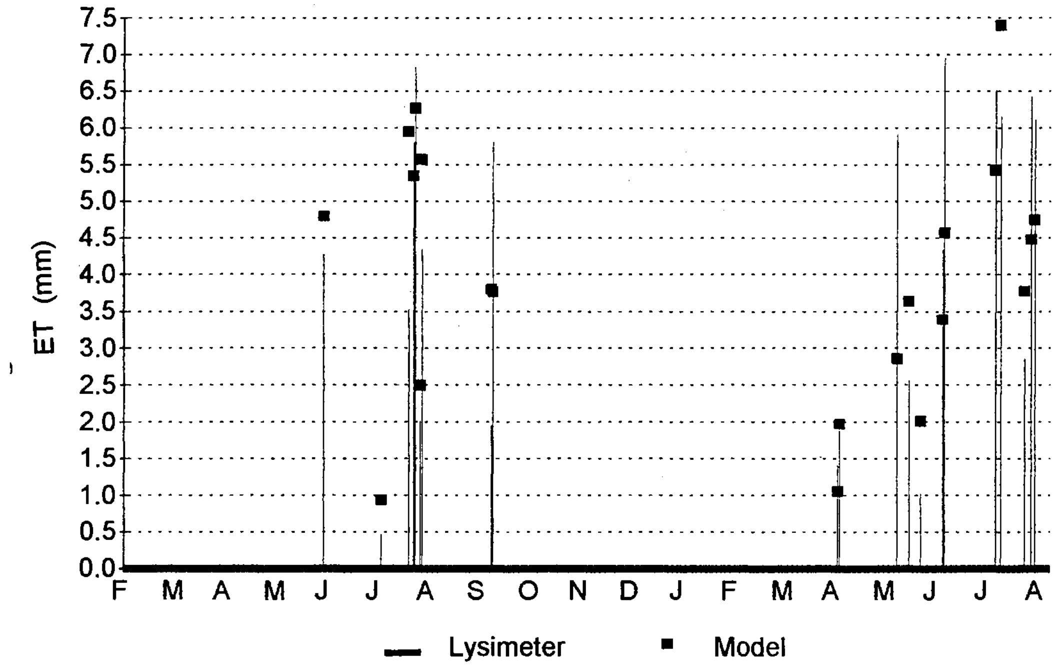

Figure 6.9. Lysimeter Measurements and Model Estimates During Canopy Resistance Model Development at Marena.

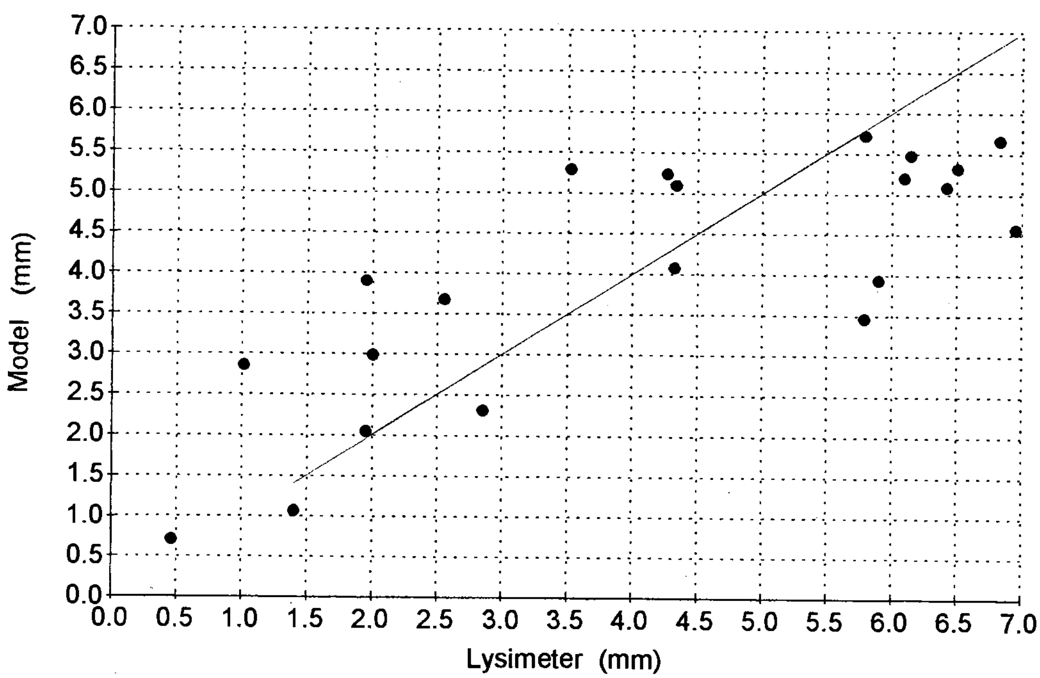

Figure 6.10. Comparison of Lysimeter ET and ET Model Estimates Obtained During Canopy Resistance Model Development at Marena.

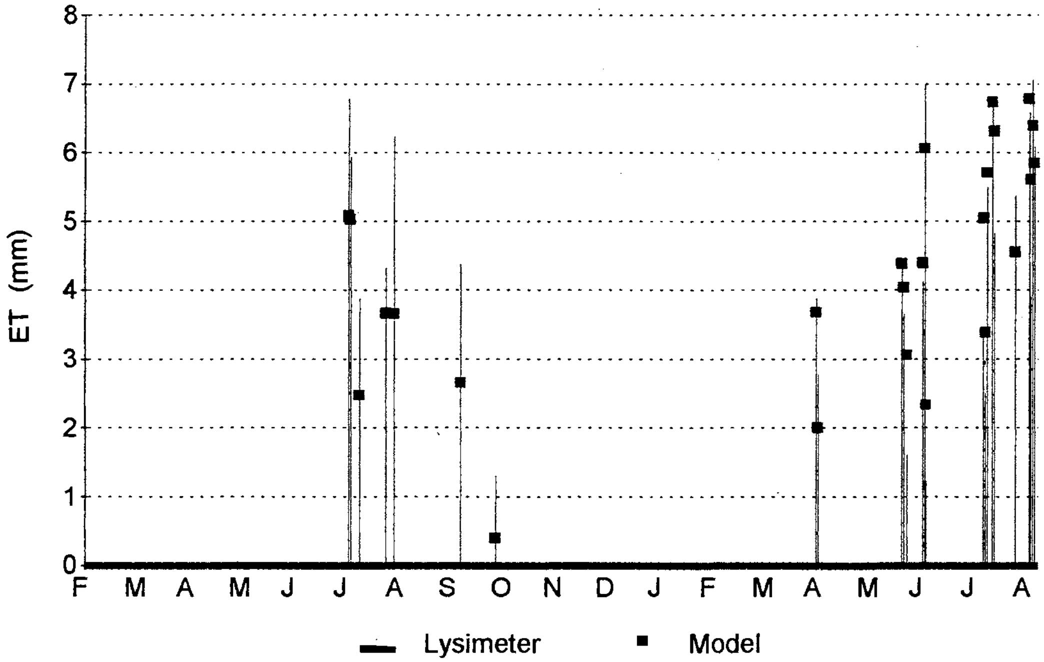

Figure 6.11. Lysimeter Measurements and Model Estimates During Canopy Resistance Model Development at Wister.

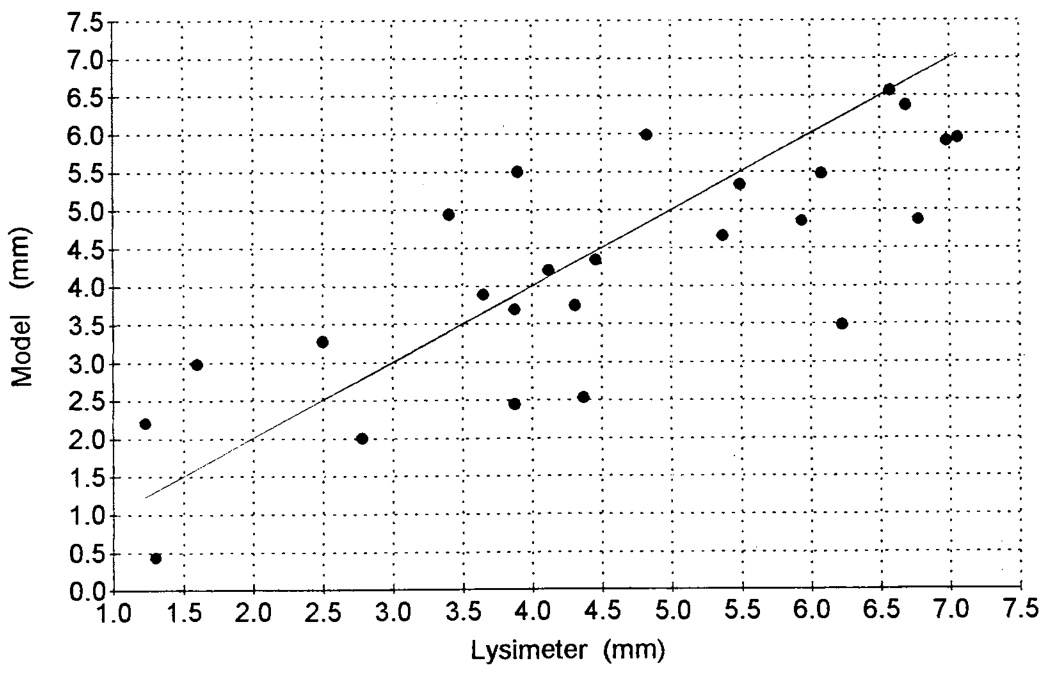

Figure 6.12. Comparison of Lysimeter ET and ET Model Estimates Obtained During Canopy Resistance Model Development at Wister.

density at Wister. While the vegetation at the other three sites was dominated by one species, the vegetation at Marena consisted of a wide variety of warm-season and cool-season species whose composition changed throughout the year. Model parameter values appropriate during one time of the year may not have been appropriate during other time periods due to differences in the distribution of plant species. Conditions at Wister ranged from short vegetation due to grazing to very dense vegetation almost 1 m tall before being cut for hay.

Modeling Canopy Resistance Under Conditions of Limited Water Availability

A stress function was required to describe the influence of limited soil water availability on plant stomatal behavior. Increasing levels of water stress have been reported by many researchers (see for example Allaway and Milthorpe, 1976; Davies et al., 1981; Grace, 1983) to result in reductions in stomatal opening, and in stomatal closure. The stress function was used to increase canopy resistance, thereby reducing ET, when soil water depletion resulted in a lack of water available to support plant growth.

The water availability stress function required a daily accounting of the water content in the soil profile. Estimates of the maximum amount of available water in the soil at each site were made, and the actual water content on a given day was compared to the maximum amount to determine the extent of the water stress. The water stress function was then used in Equation 4.65 in estimating canopy resistance.

In modeling the water availability stress function, data were used during time periods when soil water contents were in various stages of depletion. Available soil water conditions ranged from fully replenished at all sites except Goodwell to fully depleted at all sites. During these time periods, however, changes in soil water content which affected canopy resistance also affected the soil surface resistance.

This required modeling the water availability stress function concurrently with the soil surface resistance model, described below.

The water availability stress function was modeled by first estimating the available water capacity of the soil at each site. Available water capacities were calculated as the difference between water contents at field capacity and at wilting point. The field capacity represents the maximum amount of water which the soil can hold against gravity, and the wilting point represents the minimum amount of water extractable by the plants. The field capacities and wilting points of each soil were estimated from neutron moisture meter measurements taken at each site at different times throughout the year. The highest neutron meter measurements were used as an estimate of field capacity, and generally occurred in spring after fall and winter precipitation had replenished depleted soil water stores. Neutron-meter measurements taken during the summer, after spring and summer growth and low rainfall amounts had depleted soil water stores, were used as estimates of the wilting point. Field capacities, wilting points, and maximum available water contents estimated for each site are listed in Table 6.4.

Table 6.4. Soil Water Properties Estimated for the Top 1-m Depth of Soil at Each Site.

	Wilting point mm	Field capacity mm	Maximum available water content θ_{max} mm
Goodwell	90	240	150
Apache	170	340	170
Marena	120	270	150
Wister	200	360	160

The water availability stress function was modeled by comparing the available water content on a given day to the maximum available water content of the soil. The available water fraction was calculated as the ratio of the daily water content to the maximum content,

$$awf_i = \frac{\theta_i}{\theta_{max}} \qquad (6.2)$$

where

awf_i = available water fraction on day i, mm

θ_i = available water content in the soil on day i, mm

θ_{max} = maximum available water content of the soil, mm.

An available water fraction of 0 meant that there was no available water in the profile, while a value of 1 meant that the water content was at field capacity throughout the soil profile. On a few occasions, rainfall events occurred after the soil water had been replenished, and the available water fraction could have exceeded the value of 1.0. This was interpreted to mean that the soil would have been saturated and that surface runoff would have occurred. Available water fraction was modeled to constrain values to the range of 0 to 1, with rainfall amounts causing the available water fraction to exceed a value of 1 assumed to be lost to surface runoff.

A critical value of the water fraction was established to determine when water stress began to occur. If the available water fraction was greater than the critical value, adequate soil water was assumed to be available and no moisture stress occurred. The water availability stress function, $g(\theta)$, was then written as

$$g(\theta) = 1 \qquad \text{if } awf_i > awf_c \qquad (6.3)$$

where

awf_i = available water fraction on day i

awf_c = critical value of available water fraction.

If the available water fraction was less than the critical value, a linear relationship was used to determine a value for the stress function,

$$g(\theta)=\frac{awf_i}{awf_c} \qquad \text{if } awf_i < awf_c \qquad (6.4)$$

A value of 0.6 for the critical available water fraction was found to provide good results at all sites.

The water availability stress function was used in Equation 4.65 in estimating canopy resistance under any conditions of soil-water availability. Canopy resistance was estimated and input, along with the other four resistances, to the ET model and ET estimates were generated.

At the end of each day, after ET estimates were made, the available water content in the soil was updated. A water balance was maintained to account for water movement into and out of the soil. The ET amount was subtracted from the water content from the previous day, and any precipitation occurring during the day was added;

$$\theta_i = \theta_{i-1} - ET_i + Prec_i \qquad (6.5)$$

where

θ_i = soil-water content on day i, mm

θ_{i-1} = soil-water content on day i-1, mm

ET_i = evapotranspiration on day i, mm

$Prec_i$ = precipitation on day i, mm.

The performance of the ET model under varying conditions of water availability was examined using canopy resistance values estimated with the water availability response function included. Data were used only during time periods when the vegetation was active, and included varying phases of vegetative growth.

Comparisons of ET model estimates and lysimeter ET measurements are summarized in Table 6.5.

ET model estimates, on average, underestimated ET at all sites, and did not fit lysimeter measurements as well during periods when water stress may have occurred (compare Tables 6.3 and 6.5). Standard errors increased at all sites, and lower correlation coefficients were reported for all sites except Goodwell.

The increase in model error suggests that the relatively simple water availability response function used in the canopy resistance model and/or the soil surface resistance model did not completely account for effects of limited water on plant response and soil surface behavior. Estimates of the maximum available water contents of the soils obtained based on infrequent neutron-meter measurements and the simple linear function used to decrease stomatal conductance may have caused the increase in the errors. The inherent assumption in the water availability function that plants respond immediately to changes in soil-water content, that they are able to use water immediately after a rainfall regardless of the rainfall amount, for example, may not be true and could contribute to errors.

Table 6.5. Performance of Canopy Resistance Model Under Varying Conditions of Water Availability.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	2.5	3.6	4.0	3.9
Average model ET, mm/d:	2.2	3.4	3.4	3.3
Regression standard error, mm/d:	0.7	1.1	1.4	1.4
Correlation coefficient, r^2:	0.71	0.44	0.45	0.38
Slope of regression line:	0.86	0.47	0.56	0.50
Intercept of regression line:	0.00	1.67	1.15	1.28
Number of days of data:	100	87	65	66

Modeling the effects of limited soil-water availability on canopy and soil surface resistances was difficult because the two resistances had to be modeled concurrently. As the soil-water content was depleted, less water was available to the plants and water stress may have occurred, increasing the canopy resistance. As the soil surface and near-surface layer dried, less water was available to evaporate from the surface, increasing the soil surface resistance. These events occurred concurrently and could not be separated into different time periods and modeled separately. Therefore, in adjusting model parameters during these time periods, several iterations as well as trial and error were required.

Soil Surface Resistance

The soil surface resistance was modeled as a resistance to water movement exerted by the soil particles, adjusted for the actual surface area of exposed soil. Soil resistance was modeled using a two-stage bare-soil evaporation approach. During the first stage, water is available in the near-surface layer of soil and the evaporation rate is fairly constant. As water is depleted in the near-surface layer, the evaporation rate decreases. In terms of soil resistance, a fairly constant evaporation rate during the first stage would imply the resistance was fairly constant, while during the second stage, a decreasing evaporation rate would imply that the resistance was increasing. The soil resistance was then scaled by the amount of exposed soil surface area to obtain the soil surface resistance.

The soil resistance model was developed by modifying slightly the implications of resistance and evaporation rate during the two stages of evaporation from bare soil. First stage evaporation was assumed to begin after the soil was wetted during a rainfall event. The day after the rainfall, water was assumed to be available in the near-surface layer and soil resistance was at its lowest. Each day thereafter, as water evaporated, was taken up by plants, or drained out of the surface layer, less water was available for evaporation and the soil resistance increased slowly. When a certain amount of evaporation from the soil had accumulated, second stage evaporation was assumed to begin. During second-stage evaporation, soil resistance increased rapidly until a maximum value was reached and little evaporation occurred. The maximum value was then assumed to apply each day until the soil was wetted again.

In order to signal the transition from first-stage to second-stage evaporation, cumulative evaporation from the near-surface layer had to be tracked each day. During first-stage evaporation, soil surface resistance values were estimated and input to the ET model, ET estimates were made, and the cumulative ET amount was updated. When a critical value of cumulative ET was reached, second-stage evaporation was assumed to begin.

The soil water content in the near-surface layer was also tracked to determine if water was available for evaporation. If water was not available, soil surface resistance assumed its maximum value. Keeping an account of the soil water content was necessary to more realistically model evaporation, especially following a light rainfall that did not refill a depleted near-surface soil layer. If the layer was initially depleted, a light rainfall might wet the soil surface and initiate rapid, first-stage evaporation. If the water evaporated quickly without percolating deeper into the soil, the soil surface resistance could change abruptly from a low value when water was present to its maximum value after the water evaporated and no water was available in the soil after that.

The soil surface resistance model is of the form

$$r_{ss} = \frac{r_{s\,min}}{(1 - C_x)} + r_{s1}t \qquad \text{for } \Sigma ET < W_e \qquad (6.6)$$

$$r_{ss} = r_{ssstg1} + r_{s2}t \qquad \text{for } \Sigma ET > W_e \text{ and } r_{ss} < r_{ssmax} \qquad (6.7)$$

where

r_{ss} = soil surface resistance, s/m

r_{smin} = minimum soil resistance, s/m

C_x = vegetated cover fraction

r_{s1} = increase in soil resistance during first stage evaporation, s/m/day

r_{s2} = increase in soil resistance during second stage evaporation, s/m/day

r_{ssstg1} = maximum resistance reached during first stage, s/m

t = time, day

ΣET = cumulative evaporation, mm

W_e = cumulative evaporation at which second-stage evaporation begins, mm

r_{ssmax} = maximum soil surface resistance, s/m.

Equation 6.6 is used to estimate soil surface resistance during first-stage evaporation, Equation 6.7 is used during second-stage evaporation, and W_e is the cumulative evaporation amount that signals the change from first-stage to second-stage evaporation. The vegetated cover fraction, C_x, is the fraction of the surface area covered by vegetation, so the quantity (1 - C_x) represents the fraction of the surface area under bare soil conditions. The vegetated cover fraction was assumed to be constant throughout the year, and at each site was assigned the maximum value encountered during the year from leaf-area index measurements.

The model shown in Equations 6.6 and 6.7 is slightly different from that proposed earlier in Equations 4.72 and 4.73. It was proposed earlier that during the first stage of evaporation, the soil surface resistance remained at a constant, minimum value, and that during the second stage, the resistance began to increase.

This model was modified so that during the first stage, the resistance began with a minimum value right after a rainfall wetted the surface, but began to increase slowly after that. When the cumulative evaporation amount was reached, the resistance value began to increase at a much more rapid rate. Resistance increased until a maximum value, r_{ssmax} = 10000 s/m, was reached. The resistance value then remained at this maximum value until the soil was wetted again.

A number of parameter values used in the soil surface resistance model had to be estimated. A value of 25 mm was chosen for the maximum available water content in the near-surface soil layer and was assumed to apply at all sites. A range of values from 10 to 50 mm was tested and little effect on model performance was noted.

A critical value of cumulative evaporation, which signaled the end of first-stage evaporation and the beginning of second-stage evaporation, was assumed to be 9 mm. This value, reported by Ritchie (1972) to apply for a loam soil, was used at all sites. Values in the range of 6 to 12 mm were tested with little effect on model performance noted.

The minimum soil resistance, r_{smin}, and the daily rates of increase in resistance during each evaporation stage, r_{s1} and r_{s2}, were first estimated from time periods when the vegetation was dormant. Canopy resistance was assigned a very large value, r_{cc} = 10000 s/m, to represent the resistance when stomates were closed and the plants were not transpiring. Days after a rainfall were examined to estimate the minimum soil resistance, and following days were examined to estimate the increase in resistance. These parameters were then adjusted by trial and error as needed to improve model estimates. Parameter values chosen for the soil surface resistance model are listed in Table 6.6.

Table 6.6. Parameter Values for Soil Surface Resistance Model.

	r_{smin} s/m	r_{s1} s/m/d	r_{s2} s/m/d	W_e mm	C_x
Goodwell	250	150	500	9	0.5
Apache	150	150	500	9	0.8
Marena	100	150	500	9	0.7
Wister	100	150	500	9	0.9

THE EVAPOTRANSPIRATION MODEL

With resistance models and parameter values identified, the final step in the modeling effort consisted of testing the resistance models and evaluating the overall performance of the ET model under all conditions throughout the year at each site. All data in the data set created for model development (odd-numbered months) were used, and included periods of active and dormant vegetation, weather conditions from all times of the year, and different stages of vegetative growth. ET estimates were compared to lysimeter ET measurements, and model parameter values were adjusted as needed.

The resistance and ET models were then run using the data from the second, independent weather and lysimeter data set (even-numbered months) as a verification of the model and the parameter values. ET model estimates were compared to lysimeter measurements to examine the performance of the models using data independent from that used to develop the models.

A sensitivity analysis was performed to determine the impact of changes in model parameter values on model output. The most sensitive parameters, those which caused the greatest change in model output, could be identified as requiring more accurate estimates, while the least sensitive could be estimated with less accuracy.

Evaluating Model Performance

Data used in testing the models consisted of all days during which lysimeter and weather data were available, excluding days on which rainfall occurred (since lysimeter measurements could not separate rain and ET). Also excluded were days on which ET measurements reported by the lysimeters exceeded net radiation amounts (expressed as equivalent depths of evaporated water). Net radiation was estimated based on solar radiation and surface albedo (see Equation 4.49). Net radiation is a measure of the maximum amount of solar energy incident at the surface and under most conditions can be taken as a measure of the maximum amount of evapotranspiration possible. Under conditions of advection of sensible heat, however, it is possible for energy in the form of sensible heat to move from one location to another, increasing the amount of energy available, and thereby, the amount of ET possible. Under these conditions, the net radiation equation would underestimate the actual net energy available since it does not account for advection, and the ET model would provide estimates based on the underestimated net radiation. This is not to imply that the Shuttleworth-Wallace model can not be used under advective conditions, but rather that the equation used to estimate net radiation is based on solar radiation and does not account for advection. Had total energy measurements been available, the time periods excluded during suspected periods of advection would have been included in the analysis.

Soil-water accounting was a part of the modeling process at each site. An initial water content was estimated, daily ET estimates were made, and a soil-water balance was maintained throughout the data collection period. The water contents estimated from the soil-water balance were compared to the first neutron-meter measurements at the site, and the assumed initial water content was then adjusted so that the model estimate approximated the field measurement. This one-time adjustment was made only for purposes of initializing the model.

Model Performance During Model Development

The performance of the ET model was first evaluated by comparing ET model estimates and lysimeter measurements from all time periods included in the model development (odd-numbered months) data set. Conditions included those discussed previously, with limiting and non-limiting water availability, a variety of weather conditions throughout the year, and periods during which the vegetation was active, as well as dormant.

Model results are shown in Figures 6.13 through 6.20, and are summarized in Table 6.7. For this model development data set, the model tended to underestimate lysimeter ET, and standard errors were on the order of 1 mm/d. Table 6.5 presented results for periods of active vegetation only. In general, results improved slightly with

Table 6.7. Performance of ET Model Under All Conditions Using the Model-Development Data Set.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	2.0	3.0	3.4	3.9
Average model ET, mm/d:	1.8	2.6	2.6	3.3
Regression standard error, mm/d:	0.7	1.0	1.3	1.4
Correlation coefficient, r^2:	0.72	0.55	0.56	0.40
Slope of regression line:	0.78	0.53	0.65	0.51
Intercept of regression line:	0.23	0.97	0.44	1.28
Number of days of data:	156	111	89	66

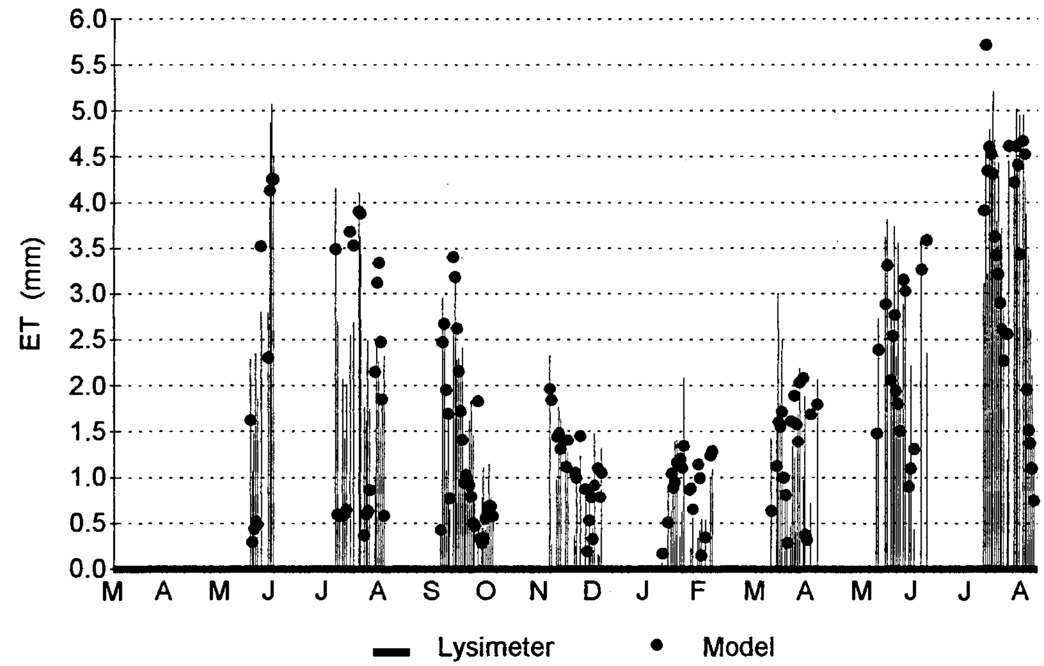

Figure 6.13. Lysimeter Measurements and Model Estimates Under All Conditions During Model Development at Goodwell.

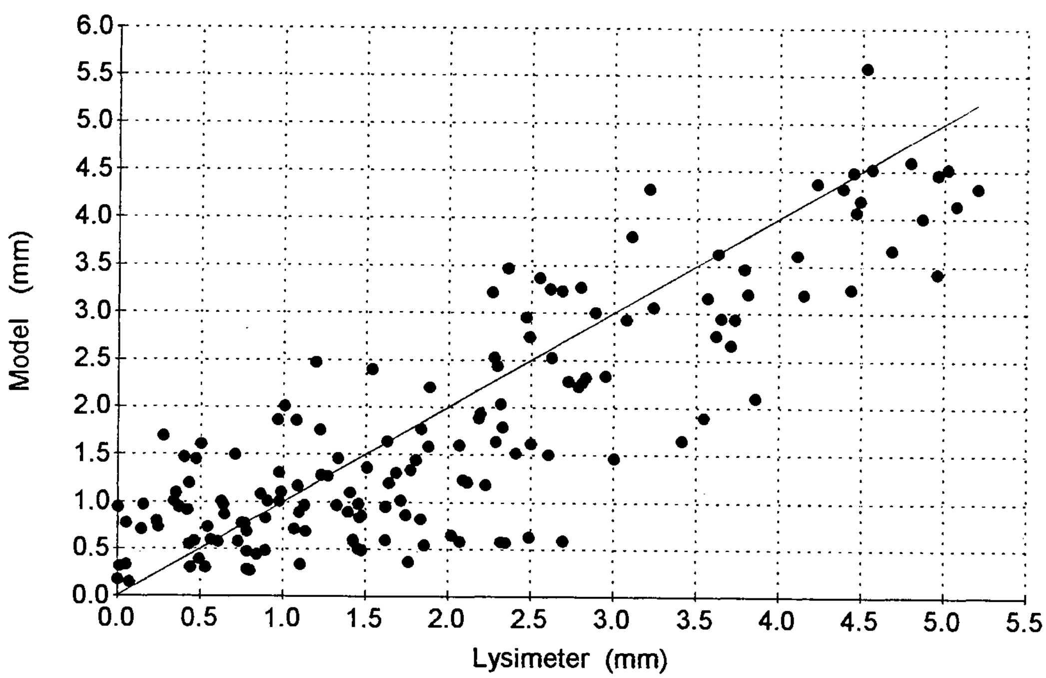

Figure 6.14. Comparison of Lysimeter ET and ET Model Estimates Under All Conditions During Model Development at Goodwell.

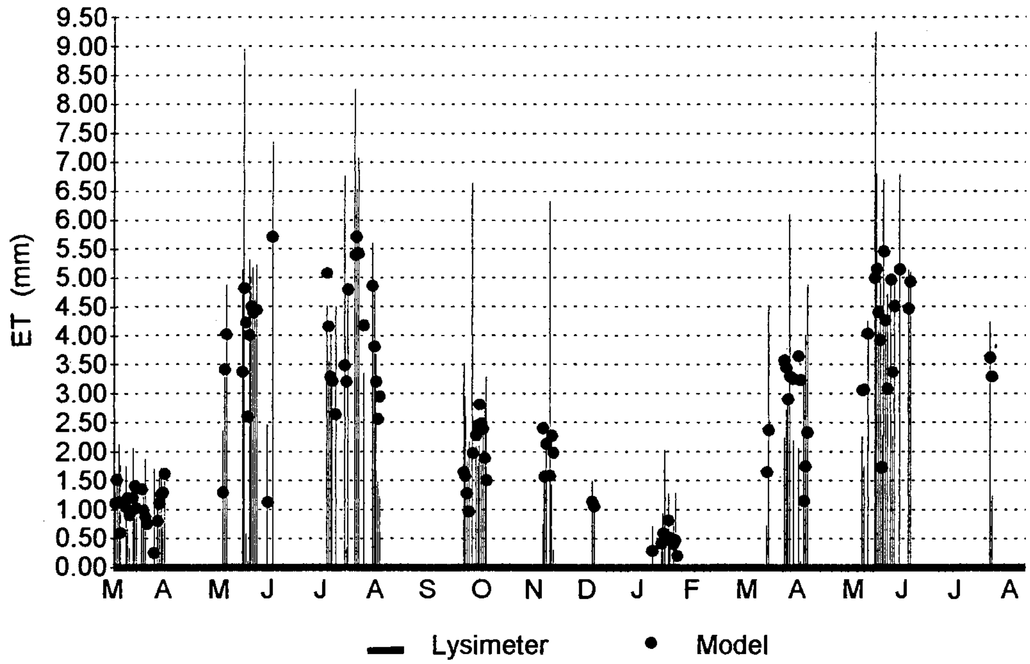

Figure 6.15. Lysimeter Measurements and Model Estimates Under All Conditions During Model Development at Apache.

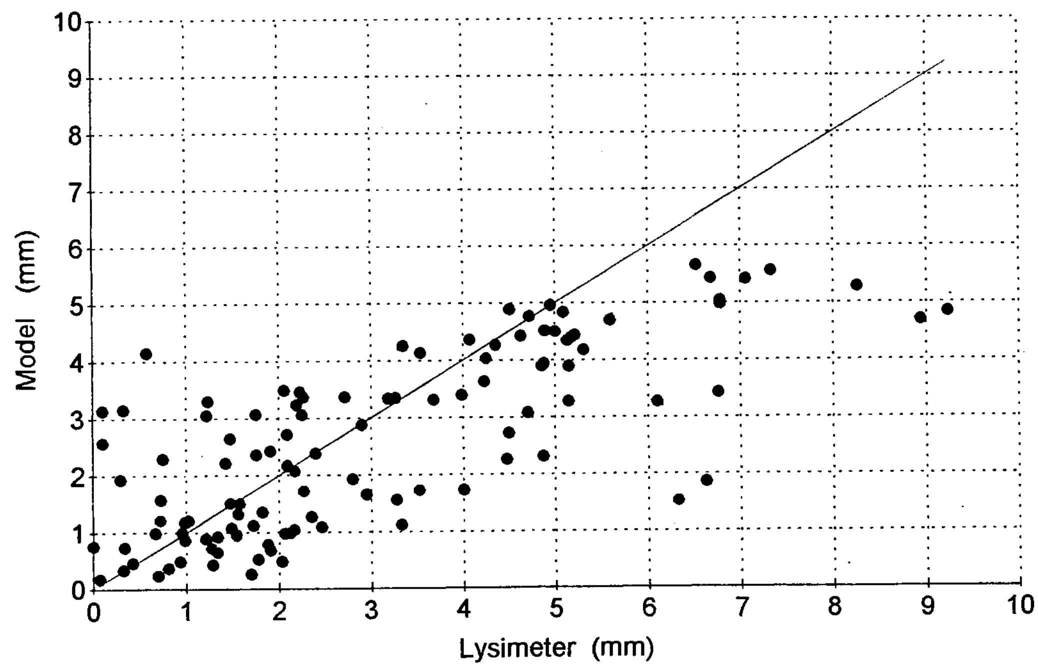

Figure 6.16. Comparison of Lysimeter ET and ET Model Estimates Under All Conditions During Model Development at Apache.

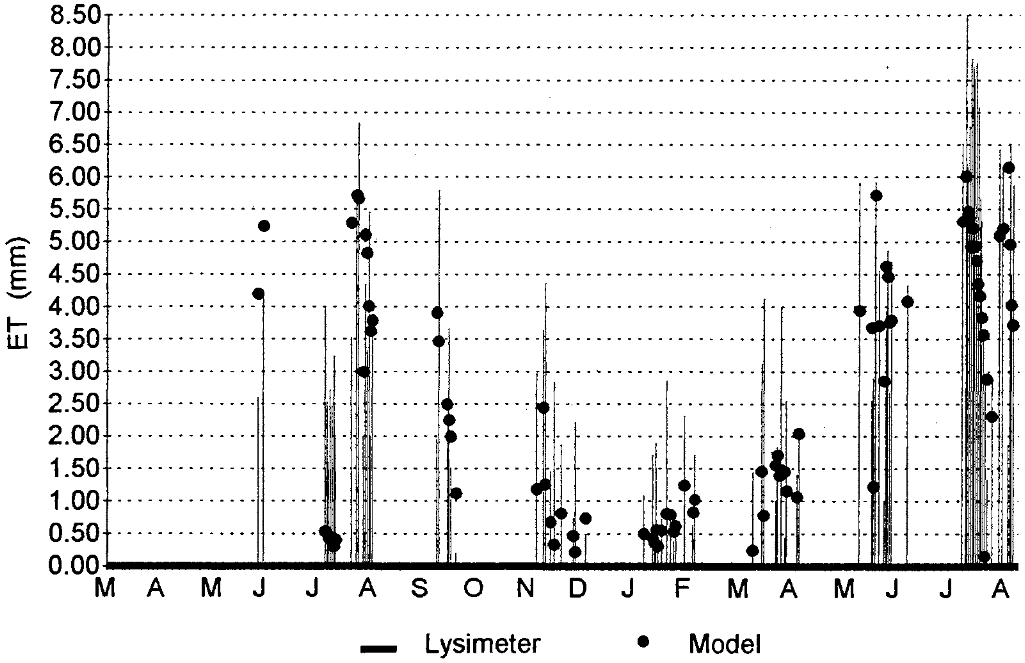

Figure 6.17. Lysimeter Measurements and Model Estimates Under All Conditions During Model Development at Marena.

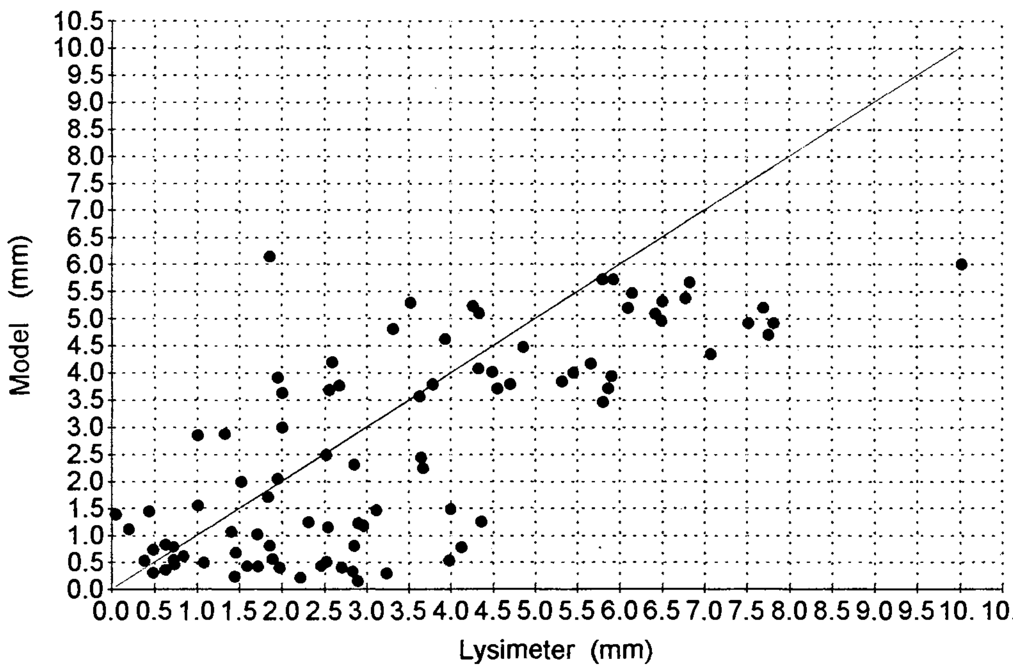

Figure 6.18. Comparison of Lysimeter ET and ET Model Estimates Under All Conditions During Model Development at Marena.

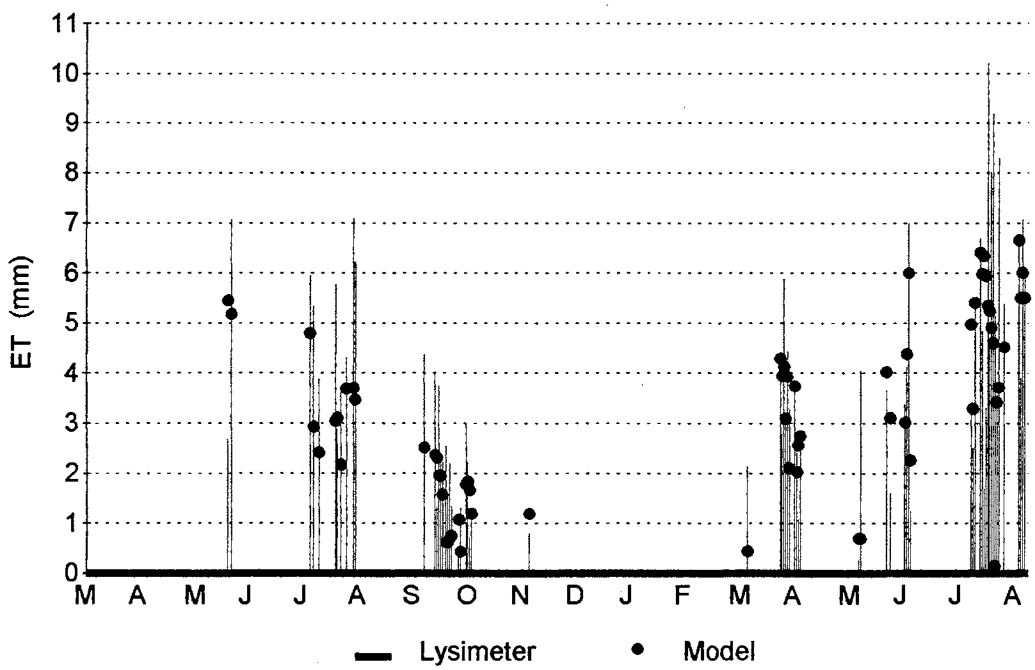

Figure 6.19. Lysimeter Measurements and Model Estimates Under All Conditions During Model Development at Wister.

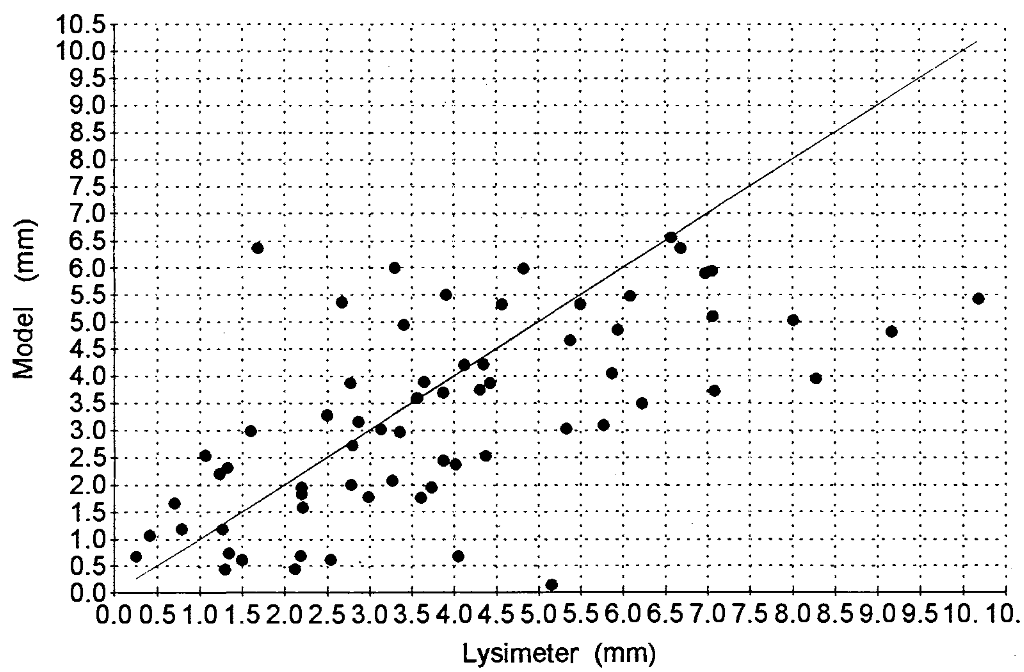

Figure 6.20. Comparison of Lysimeter ET and ET Model Estimates Under All Conditions During Model Development at Wister.

the inclusion of dormant vegetative periods, with slightly lower standard errors and higher correlation coefficients in some cases.

The slight improvement in model results may be attributable more to the magnitude of the ET estimates than the performance of the model during periods of dormancy. The performance of the ET model during periods of dormant vegetation is shown in Table 6.8. ET measurements and model estimates were very low, so even a large percent error in estimates resulted in a small magnitude of error. Averaging in the small error during these periods with the larger errors during other time periods resulted in a slightly smaller average error and the appearance of an improvement in the fit of the model.

During periods of dormant vegetation, the canopy resistance model was not used. A large canopy resistance value, r_{cc} = 10000 s/m, was used to represent closed stomates, which allowed very little evaporation from the crop component in the ET model. ET model estimates were then a result of evaporation mainly from the soil component and were dependent on the soil surface resistance estimates. Possible contributions to ET estimates of evaporation from wet plant surfaces following a rainfall event were not modeled. Model results during periods of dormant vegetation, shown in Table 6.8, indicate a need for improvement in both the canopy and soil

Table 6.8 Performance of ET Model Under Dormant Vegetation Conditions.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	1.0	1.1	1.8	--
Average model ET, mm/d:	1.0	0.7	0.8	--
Regression standard error, mm/d:	0.4	0.3	0.4	--
Correlation coefficient, r^2:	0.31	0.07	0.32	--
Slope of regression line:	0.35	0.13	0.22	--
Intercept of regression line:	0.69	0.55	0.35	--
Number of days of data:	56	24	24	--

surface resistance models to better describe evaporative surface conditions and provide more accurate ET estimates during periods of dormant vegetation.

The model did not appear to fully account for the daily variability of ET amounts observed from lysimeter measurements. Model assumptions, such as the assumption that plants responded immediately to increases in available water, may not have been valid. The simple canopy resistance model did not include all atmospheric variables which may have affected stomatal response and could not accurately describe the complex mechanisms involved in transpiration using weather data averaged on a daily time scale.

Model estimates under all conditions were averaged over longer time periods to determine whether some of the model error may have been due to variability in ET which the model could not account for. Running averages of model ET and lysimeter ET were calculated for 3-day and 5-day periods from consecutive days of data. Results of averaging over 3- and 5-day time periods are shown in Tables 6.9 and 6.10.

Model results improved, in general, by averaging ET estimates over several days, with lower standard errors and higher correlation coefficients reported. This suggests that some of the natural variability in daily ET amounts could be taken into

Table 6.9. Performance of ET Model Estimates Using a 3-day Running Average.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	2.1	3.1	4.0	4.2
Average model ET, mm/d:	1.8	2.7	3.0	3.6
Regression standard error, mm/d:	0.5	0.7	1.0	1.3
Correlation coefficient, r^2:	0.81	0.79	0.73	0.42
Slope of regression line:	0.84	0.78	0.75	0.61
Intercept of regression line:	0.06	0.31	0.00	1.06
Number of days of data:	77	46	35	27

Table 6.10. Performance of ET Model Estimates Using a 5-day Running Average.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	2.2	3.6	5.0	5.1
Average model ET, mm/d:	1.9	3.2	3.4	4.3
Regression standard error, mm/d:	0.4	0.5	1.0	1.2
Correlation coefficient, r^2:	0.89	0.80	0.74	0.27
Slope of regression line:	0.88	0.77	0.74	0.42
Intercept of regression line:	-0.02	0.50	-0.21	2.13
Number of days of data:	39	15	17	12

account with the model if time periods of several days were considered. Results of the averaging at Wister were mixed, however, with results improving slightly for the 3-day averaging, but worsening for the 5-day averaging. This may have been due to the small sample size, with only a few time periods available for the 5-day averaging.

Model Verification

Following development of the canopy and soil surface resistance models and evaluation of ET model performance using data from the odd-numbered months, model performance was verified using the second data set containing data from even-numbered months. ET model estimates were compared to lysimeter ET measurements under the same conditions as during model development: during periods of active vegetation under conditions of non-limiting and varying soil-water availability; and under all conditions of vegetative activity and water availability encountered throughout the year.

Results of the comparison of ET estimates and lysimeter measurements under conditions of active vegetation and non-limiting water availability are shown in Table 6.11. Results were mixed in comparison to those obtained using the model development data set, shown in Table 6.3. While average model ET was lower than average lysimeter measurements at all sites previously, model ET was higher at two sites and lower at the other two using the second data set. Results were worse, in terms of higher standard errors and lower correlation coefficients, at Apache and Wister using the second data set. Goodwell showed a slight improvement in terms of the correlation coefficient, but with a much higher standard error. Results at Marena were improved, with the model performing better than at any other site with either data set.

Under conditions of dormant vegetation, shown in Table 6.12, results were similar to those obtained using the model development data set. While the model fit was poor, standard errors were low due to the very low ET rates.

Under conditions of varying soil-water availability, results using the second data set, shown in Table 6.13, were again mixed compared to results using the model development data set, shown in Table 6.5. While correlation coefficients were lower at all sites using the second data set, three sites showed a slight decrease in standard errors.

Table 6.11. Model Verification Under Conditions of Active Vegetation and Non-Limiting Soil-Water Availability.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	2.8	3.4	3.0	3.8
Average model ET, mm/d:	3.0	3.2	3.4	3.4
Regression standard error, mm/d:	1.6	1.0	0.5	1.4
Correlation coefficient, r^2:	0.72	0.34	0.87	0.31
Slope of regression line:	0.89	0.69	0.64	0.43
Intercept of regression line:	0.54	0.99	1.41	1.78
Number of days of data:	21	32	12	29

Table 6.12. Model Verification Under Conditions of Dormant Vegetation.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	0.8	0.9	1.2	--
Average model ET, mm/d:	0.8	0.5	0.6	--
Regression standard error, mm/d:	0.3	0.2	0.4	--
Correlation coefficient, r^2:	0.35	0.18	0.07	--
Slope of regression line:	0.48	0.16	0.11	--
Intercept of regression line:	0.42	0.39	0.44	--
Number of days of data:	55	31	48	--

Table 6.13. Model Verification Under Conditions of Varying Soil-Water Availability.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	2.4	3.2	3.8	4.5
Average model ET, mm/d:	2.0	3.1	3.3	3.7
Regression standard error, mm/d:	0.8	1.0	1.1	1.3
Correlation coefficient, r^2:	0.31	0.28	0.43	0.34
Slope of regression line:	0.51	0.47	0.38	0.40
Intercept of regression line:	0.76	1.47	1.90	1.94
Number of days of data:	83	105	55	83

Including periods during which the vegetation was dormant had the same effect on model performance as noted for the model development data set. Results, shown in Table 6.14, improved slightly over those reported in Table 6.13 using only periods of active vegetation. Standard errors were slightly lower than those reported using the model development data set, although correlation coefficients were generally lower.

Table 6.14. Model Verification Under All Conditions Using the Model Verification Data Set.

	Goodwell	Apache	Marena	Wister
Average lysimeter ET, mm/d:	1.7	2.7	2.6	4.5
Average model ET, mm/d:	1.5	2.5	2.1	3.7
Regression standard error, mm/d:	0.6	1.1	1.2	1.3
Correlation coefficient, r^2:	0.45	0.53	0.57	0.34
Slope of regression line:	0.58	0.70	0.58	0.40
Intercept of regression line:	0.51	0.60	0.59	1.94
Number of days of data:	138	138	102	83

Sensitivity Analysis of Model Parameters

An analysis was performed to determine the sensitivity of the ET model to changes in model parameter values. Parameter values were varied and impacts on model estimates were examined. By determining to which parameters the model was most sensitive, the modeler would know which parameters required the most attention and the most accurate estimates, and which parameters could be estimated less accurately without greatly affecting the performance of the model.

The sensitivity analysis was performed using the model development data set and the modeling results obtained under all conditions encountered throughout the year, shown in Table 6.7. These results, which represented the best efforts in modeling the resistance terms and estimating other parameters which were input to the ET model, were used as a basis for comparison. As parameter values were varied, updated model results were compared to the results shown in Table 6.7 and reported as increases or decreases relative to Table 6.7 results. Three quantities were compared; average model ETs, correlation coefficients, and standard errors, and were reported as percent changes relative to the original values shown in Table 6.7.

Parameter values were varied over different ranges depending on the parameter selected. Some parameters were varied over a relatively broad range of values by doubling and halving (multiplying by 2.0 and 0.5, respectively) the original parameter values. Other parameters, whose true values would not be expected to vary significantly from the estimated values, were tested over a narrower range by varying the value 20% above and below (multiplying by 1.2 and 0.8, respectively) the original estimate. In some cases, the original parameter estimates were not varied but rather were replaced by constant values.

Parameters which were examined include weather variables which were not measured and had to be estimated, vegetative properties which were periodically measured and had to be estimated between measurements, and aerodynamic, canopy, and soil surface resistances. Results of the sensitivity analysis are summarized in Table 6.15, with each parameter, the change in parameter values tested, and the increase (shown as positive) or decrease (shown as negative) in model performance listed.

Weather Parameters

Soil heat flux had been estimated originally as a function of net radiation, which in turn had been estimated based on solar radiation. It had been assumed that the amount of radiant energy used in heating the soil on a daily basis was small, and soil heat flux was estimated as 1% of daily net radiation. Soil heat flux was increased and tested at 10% and 20% of net radiation. Standard errors were slightly lower at all sites when soil heat flux was increased. Goodwell and Marena, the sites with the largest amount of exposed soil surface and the sparsest canopies, showed increases in correlation coefficients of a few percent, while the other sites showed slight decreases. Results suggest that the magnitude of the soil heat flux term could be estimated within the range of 1% to 20% of net radiation without significant impact on model performance.

In-canopy net radiation at the soil surface was estimated as a function of net radiation and an extinction coefficient describing the decrease in net radiation with depth into the canopy. A range of extinction coefficients had been tested previously and found to have a small impact on in-canopy net radiation estimates. To test the impact of in-canopy net radiation estimates on ET model estimates, values were varied by doubling and halving the original values. The impact on model performance was small for the most part, with increases and decreases in performance of a few percent. The largest impact was at Goodwell, where doubling the values resulted in a significant decrease in performance. Results suggest that the ET model results are , in general, not very sensitive to this parameter, and that the parameter could be estimated as proposed originally.

<u>Vegetative Parameters</u>

Leaf-area index (LAI) was varied at four different levels: doubling, increasing and decreasing by 20%, and halving the original values. At all sites, correlation coefficients varied within 1% when parameter values were within 20% of the original estimates, and within 6% when doubled or halved. Significant increases in standard error resulted from doubling the parameter values at most sites, while halving the parameter values decreased standard errors. Varying parameter values by 20% gave mixed results among the sites, with a decrease in LAI values generally resulting in lower standard errors by about 5%. Thus, while LAI estimates are important, measuring or estimating LAI to within 20% does not significantly impact model performance. Results in Table 6.15 seem to imply that in measuring or estimating leaf-area index, it is better to underestimate than overestimate.

Table 6.15. Sensitivity Analysis of ET Model Parmeters.

Percent changes in model results compared to results shown in Table 6.7.

Parameter	Parameter change	Goodwell Avg model ET	Goodwell Corr coeff r^2	Goodwell Std err	Apache Avg model ET	Apache Corr coeff r^2	Apache Std err	Marena Avg model ET	Marena Corr coeff r^2	Marena Std err	Wister Avg model ET	Wister Corr coeff r^2	Wister Std err
Soil Heat Flux													
	*10	-3	+2	-7	-2	-1	-1	-2	+2	-4	-4	0	-4
	*20	-5	+2	-13	-4	-3	-2	-3	+3	-6	-8	-1	-8
In-Canopy Net Radiation at Soil Surface													
	*2	-1	-12	+13	-3	-3	-4	-1	+2	-6	-1	0	-2
	*0.5	0	+2	-2	+2	+1	+3	+1	-1	+3	+1	0	+1
Leaf-Area Index													
	*2	+5	-5	+25	+11	-3	+19	+9	-2	+13	+1	+1	+1
	*1.2	+1	-1	+6	+3	0	+4	-7	+1	-14	-3	0	-5
	*0.8	-2	0	-5	-4	-1	-5	+2	-1	+4	+1	0	+1
	*0.5	-5	-4	-9	-14	-6	-14	-3	+1	-5	-1	0	-2

note: *10 means original parameter values were multiplied by 10
*20 means original parameter values were multiplied by 20
*2 means original parameter values were multiplied by 2
*0.5 means original parameter values were multiplied by 0.5
*1.2 means original parameter values were multiplied by 1.2
*0.8 means original parameter values were multiplied by 0.8

Table 6.15. (continued)

Percent changes in model results compared to results shown in Table 6.7.

Parameter	Parameter change	Goodwell Avg model ET	Goodwell Corr coeff r^2	Goodwell Std err	Apache Avg model ET	Apache Corr coeff r^2	Apache Std err	Marena Avg model ET	Marena Corr coeff r^2	Marena Std err	Wister Avg model ET	Wister Corr coeff r^2	Wister Std err
Canopy Height													
	*2	-1	+1	-2	0	+1	+1	-1	-1	+1	-2	-28	+9
	*0.5	+1	0	-1	0	-1	-1	+1	+1	-1	-1	+10	-4
Aerodynamic Resistances													
Aerodynamic resistance of mean flow	*2	+4	-2	+6	+1	-2	-2	+2	+1	-2	-2	+14	-5
	*0.5	-3	0	-2	-1	+1	+2	-1	-2	+3	-1	-20	+6
Aerodynamic resistance of canopy to in-canopy flow	10	0	-1	+3	+3	+1	+6	0	-4	+5	-1	-13	+3
	100	0	-1	+3	-3	-4	-3	-1	0	-3	-2	+15	-6
Aerodynamic resistance of soil surface to in-canopy flow	10	-1	+2	-3	-1	0	0	0	0	0	0	0	0
	100	+1	-2	+4	+1	0	0	+1	0	0	0	0	0

Table 6.15. (continued)

Percent changes in model results compared to results shown in Table 6.7.

Parameter	Parameter change	Goodwell Avg model ET	Goodwell Corr coeff r^2	Goodwell Std err	Apache Avg model ET	Apache Corr coeff r^2	Apache Std err	Marena Avg model ET	Marena Corr coeff r^2	Marena Std err	Wister Avg model ET	Wister Corr coeff r^2	Wister Std err
Canopy Resistance													
	*2	-10	-11	-6	-22	0	-22	-17	-13	-12	-18	-10	-15
	*1.2	-4	-2	-3	-6	+1	-7	-5	-1	-5	-5	-2	-3
	*0.8	+5	+2	+3	+8	-1	+8	+6	+1	+6	+5	+2	+4
	*0.5	+15	0	+21	+24	-6	+26	+19	+2	+17	+16	+8	+8
Constant value all year	200	+119	-34	+78	+35	-60	+15	+41	-30	+3	+14	-37	-19
	1000	+24	-14	-5	-31	-55	-36	-19	-32	-35	-37	-49	-49
	1500	+9	-14	-14	-41	-54	-44	-29	-34	-40	-46	-55	-55
	2000	+2	-18	-14	-47	-53	-49	-34	-36	-43	-51	-60	-58
Constant value when	200	+11	-29	+105	+8	-36	+37	+16	-21	+26	-5	+13	-6
vegetation is active,	1000	+1	-13	+12	-36	-40	-32	-22	-32	-30	-37	-49	-49
r_{ccmax} when dormant	1500	-4	-16	+3	-45	-42	-43	-31	-33	-37	-46	-55	-55
or water stressed	2000	-7	-14	-7	-49	-42	-48	-36	-34	-41	-51	-60	-58

Table 6.15. (continued)

Percent changes in model results compared to results shown in Table 6.7.

Parameter	Parameter change	Goodwell Avg model ET	Goodwell Corr coeff r^2	Goodwell Std err	Apache Avg model ET	Apache Corr coeff r^2	Apache Std err	Marena Avg model ET	Marena Corr coeff r^2	Marena Std err	Wister Avg model ET	Wister Corr coeff r^2	Wister Std err
Soil Surface Resistance													
Constant value all year	200	+137	-28	+97	+49	-23	+10	+48	-13	+8	+24	-41	+7
	800	+36	-6	+17	+11	-4	+2	+10	+3	-3	+6	-5	-4
	1500	+2	+1	-5	+1	-4	+4	0	+3	-1	+1	+1	-3
	2000	-10	+2	-10	-2	-4	+5	-3	+3	0	0	+2	-3
Constant value when water is available, r_{ssmax} when dry	200	+27	-38	+128	+21	-24	+35	+17	-19	+18	+2	-4	+16
	800	+4	-5	+13	+8	0	-2	+23	-4	+3	+1	-6	+5
	1500	-9	+7	-18	0	0	0	-4	-2	-3	0	-1	-1
	2000	-10	+2	-10	-2	-1	+2	-6	-1	+3	0	0	-2

Canopy height values were doubled and halved, with almost no impact on model results at three sites. Significant differences were noted at Wister, however, where canopy heights varied most throughout the year. Halving the height estimates resulted in an improvement in model performance, while doubling significantly worsened model results. The main difference between the vegetation at Wister and that at the other sites was that it was cut for hay, resulting in a dramatic change in height after cutting, and knowing the exact date of cutting would be necessary. For the other sites, where canopy heights did not vary abruptly, canopy heights could be changed significantly without significant impact on model performance.

Resistance Parameters

Aerodynamic resistance of the mean flow was varied by doubling and halving resistance estimates. Results at three sites showed small changes in correlation coefficients, with slightly larger changes in standard errors. A significant impact was noted at Wister, however, where doubling the resistance estimates significantly improved model results. Since the resistance was modeled based on canopy height, errors in height estimates would also affect resistance estimates. Abrupt changes in height due to cutting of the vegetation may have contributed to errors in resistance estimates. At the other sites, where height did not vary abruptly, resistance estimates could vary greatly without significantly affecting model performance.

Aerodynamic resistance of the canopy to in-canopy flow was varied from its original value of 40 s/m and tested at values of 10 and 100 s/m. Results were similar to those encountered above in varying the aerodynamic resistance of the mean flow: little change was noted at three sites, with significant impact noted at Wister. With the exception of Wister, it appears that a broad range of resistance values could be used without significantly affecting model performance.

Aerodynamic resistance of the soil surface to in-canopy flow was varied from its original value of 40 s/m and tested at values of 10 and 100 s/m. The Et model showed almost no sensitivity to this parameter, with the largest changes, of only a few percent, noted at Goodwell.

Canopy resistance values were varied at four levels by doubling, increasing and decreasing by 20%, and halving the original parameter estimates. Large changes in parameter values, doubling and halving, resulted in significant changes in model performance. Increasing or decreasing by 20% had less of an impact, with model results changing by 8% at most. To determine whether the canopy resistance model could be replaced with constant resistance values, as has been suggested by others, a range of constant resistance values was tested. Two approaches were tested, one in which the resistance value was constant for every day of the year, and another in which a constant value was assigned when the vegetation was active and a very large resistance was assigned to represent inactive stomates during periods of dormant vegetation. Results indicate that the two constant-value approaches significantly decreased model performance, suggesting that the range of stomatal response conditions was too broad for constant daily values to be assigned, and a resistance model was needed.

Soil surface resistance values were not varied but rather were replaced with constant values to determine whether the empirical resistance model developed was needed. Farahani and Baush (1994) had replaced their empirical resistance model with a constant resistance value and reported little impact on model performance. Two approaches were used, one in which a constant resistance value was assigned for every day of the year, and another in which a value was assigned when water in the near-surface soil layer was available and a very high value was assigned when the soil layer was dry. Results shown in Table 6.15 suggest that either approach could be used and that constant values did about as well as the resistance model. Using a value of 1500 s/m at each site, either constantly throughout the year or with an increase to 10000 s/m when the soil was dry, resulted in improvements in model performance at Goodwell, and mixed increases and decreases within 4% at the other sites. While the resistance value of 1500 s/m is different from that reported by Farahani and Bausch (1994), the results suggest that a constant soil surface resistance could be used in place of the empirical model to estimate soil surface resistance without significantly decreasing ET model performance. The need still exists, however, to study processes involved in determining and modeling soil surface resistance.

Chapter 7

SUMMARY AND CONCLUSIONS

Evapotranspiration is a major component of both the energy balance and the hydrologic balance at the earth's surface. Improved measurements and estimates of evapotranspiration are needed for many different applications. Much work has been done involving ET and irrigated agricultural crops, with less attention paid to pasture and native vegetation, which comprise a much larger land area.

Evapotranspiration has been measured and estimated using a variety of methods. Lysimeters have been used to provide measurements of ET, and have been used in verifying ET estimation methods. Increasingly sophisticated methods of estimating ET are being used based on surface energy balance and mass transfer theories, and weather data required to make ET estimates are becoming more routinely measured and readily available.

A project was undertaken to study evapotranspiration occurring from areas under conditions of pasture and native vegetation covers. Evapotranspiration was measured using electronic weighing lysimeters installed at four sites in Oklahoma. The lysimeters were operated remotely and data were collected and reported via a network of automated weather stations. Lysimeter ET measurements were used in the development of models for estimating resistance parameters for input into the Shuttleworth-Wallace ET model. The ET model, which describes evaporation under the sparse canopy conditions encountered at the sites, was then evaluated to determine its overall performance.

Installation of Lysimeters

Four lysimeters were designed, constructed, and then installed in diverse climatological regions of the state. Low cost and minimal maintenance requirements were desired to make the project feasible and to allow remote operation and data collection.

The lysimeters were installed by hand in order to minimize damage to the vegetation on and around the lysimeter. The labor of three people working approximately four days was required to completely install and calibrate the lysimeter equipment.

Lysimeter measurements were collected during the period from February 1994 through July 1995 at three sites, and from May 1994 through July 1995 at the fourth site. The time periods of lysimeter operation and the locations of the lysimeters allowed for a variety of climatic, vegetative, and soil-water conditions to be observed. Conditions included periods of active and dormant vegetation, and a wide range of soil-water availability.

Suspected thermal effects on electronic components influenced ET measurements on short time scales, but appeared to be negligible on daily time scales. Thermally induced apparent weight losses and weight gains occurring throughout the day affected actual weight-change measurements on time scales of less than 24 hours. By confining the use of weight measurements to a 1-hour period centered at sunrise, when temperature-induced influences were assumed to be minimal, daily lysimeter weight changes were considered to provide reliable ET estimates. Efforts are underway to address the thermal influence problem to determine if reliable ET measurements may be made on shorter time scales.

A few installation-related problems were encountered which resulted in periods of lost data. Following heavy rains and saturated-soil conditions, water leaked into the outer lysimeter tanks of two of the lysimeters, resulting in buoyant forces on the inner tanks which affected weight measurements. The problem was a result of incomplete sealing of the lysimeter outer tank during installation.

Incompletely sealed electrical wiring connections resulted in water damage to wires at three of the sites. Enclosing the connections in water-proof plastic enclosures protected the wiring and prevented further damage.

Remote Lysimeter Operation and Data Collection

Locations of the lysimeters were as far as 5 hours driving time from Stillwater, and remote operating and data collection capability were required. Lysimeter sites were chosen adjacent to automated weather stations in the Oklahoma Mesonet in order to utilize the remote operating capability of the weather station network.

The lysimeters were connected to the weather stations and lysimeter data were collected continuously and automatically along with regularly measured weather data. Regularly collected data included measurements of lysimeter weight, solar radiation, air temperature, relative humidity, wind speed, and rainfall. During periodic visits to the sites, measurements were made of soil-water content, leaf-area index, and canopy height inside and outside the lysimeter.

Very few problems were encountered operating the lysimeters remotely through the Mesonet weather stations. Data were made available in near-real time, and only a few instances of missing data were encountered.

Due to the remoteness of the sites from Stillwater, however, visits to the sites were relatively infrequent. When lysimeter problems were encountered, they often could not be addressed immediately, resulting in periods of lost data. The collection of periodic information at the site, such as soil-water content, leaf-area index, and vegetation height and activity, as well as maintenance of the vegetation on and around the lysimeter were also infrequent.

Resistance Parameter Estimation

Five resistance parameters were used to characterize surface and aerodynamic conditions controlling the evaporation process: aerodynamic resistance of the mean flow, aerodynamic resistance of the canopy to in-canopy flow, aerodynamic resistance of the soil surface to in-canopy flow, canopy resistance, and soil surface resistance. Aerodynamic resistances were estimated in a manner similar to that reported by other researchers. Models for canopy and soil surface resistances were developed based on weather, vegetative, and soil-water conditions at each site.

In general, the resistances need to be better understood in order to allow them to be properly modeled. More information is needed about in-canopy air flow and turbulence in order to understand vapor transport mechanisms and the effects of sparse canopies on air flow. In-canopy aerodynamic resistances were estimated as constant values, however, with apparently little impact on model performance.

Canopy resistance models were developed for the different vegetative cover conditions at each site. The model was developed based on atmospheric variables which influence stomatal behavior, and included estimates of daily total solar radiation, average daytime atmospheric vapor-pressure deficit, and soil-water availability. The model provided better ET estimates under conditions of non-limiting soil water than under limiting water conditions. While the model did not entirely account for large day-to-day variability observed in ET measurements from the lysimeter, averaging ET estimates over several days provided estimates in very good agreement with measured values. Using weather data averaged on a daily time scale may have resulted in a loss of important information needed to accurately model plant response to environmental variables.

A soil surface resistance model was developed based on a two-stage bare-soil evaporation concept and estimates of soil-water availability in the near-surface soil layer. While the model was intended to account for changes in resistance due to drying soil, the model proved to be less than adequate and further work is needed to better understand the soil processes regulating evaporation. The empirical model was tested against constant values of soil surface resistance, and the constant resistance approach was found to perform as well as the model when input to the ET model. This suggests that, until soil surface resistance is better understood and modeled, it may be possible to estimate the resistance as a constant value.

Evapotranspiration Model Performance

The ET model proposed by Shuttleworth and Wallace was developed to describe evaporation occurring from a vegetated surface. It explicitly allows for sparse canopy conditions to exist, such as those encountered at the pasture and rangeland lysimeter sites. Vegetative and soil surface conditions are characterized in terms of resistance parameters which describe the regulation of water-vapor transfer from plant and soil surfaces. Aerodynamic resistances regulate water-vapor transfer from plant and soil surfaces to the atmosphere. Weather variables determine evaporative conditions imposed by the atmosphere.

The Shuttleworth-Wallace model is based on energy balance and mass transfer theories, and describes physical processes involved in evaporation. The model contains many parameters, some of which can be reliably measured or calculated using well-founded methods. Others, however, must be estimated using empirical methods. Since some of the parameters needed in the model were introduced when the model was first proposed, little work has yet been done which allows these parameters to be reliably estimated.

Modeling methods have been proposed which estimate canopy resistance based on stomatal response to environmental variables. The methods involve empirical functions whose functional form and parameter values must be fit to the specific vegetative conditions encountered. Soil surface resistance is a newly introduced parameter whose behavior is largely unknown. Regulation of evaporation by the soil surface has been described empirically, but a reliable method to estimate soil surface resistance has yet to be determined. In the absence of a resistance model, constant values have been empirically determined.

Estimation of aerodynamic resistances has been based largely on wind speed and canopy height and density. More information would be useful, however, regarding the behavior of air flowing over and through plant canopies, especially under sparse-canopy conditions. While a relationship has been used extensively to estimate the aerodynamic resistance above a densely vegetated surface, its applicability under sparse-canopy conditions has been debated. It has frequently been applied under sparse-canopy conditions, however, due to a lack of information and a better alternative.

Relationships to describe aerodynamic conditions within the canopy have been proposed but attempts to verify their accuracy have been infrequent and inconclusive.

Constant values for in-canopy aerodynamic resistances have been used, and at this time appear to work as well as more complex empirical relationships.

The overall performance of the Shuttleworth-Wallace is directly related to the parameter values input to it. The theoretical development of the model appears sound, and offers a physically based description of the evaporation process. Model estimates ultimately depend on empirical resistance parameters, however, which must be modeled based on weather, vegetative, and soil-water conditions. Due to the large areas of land under sparse cover conditions, and the importance of evapotranspiration from these areas in hydrologic and other applications, it is worthwhile to pursue further studies involving the Shuttleworth-Wallace model. Better understanding and modeling of the resistance parameters will allow more widespread use of the model and improved evapotranspiration estimates under sparse-canopy conditions.

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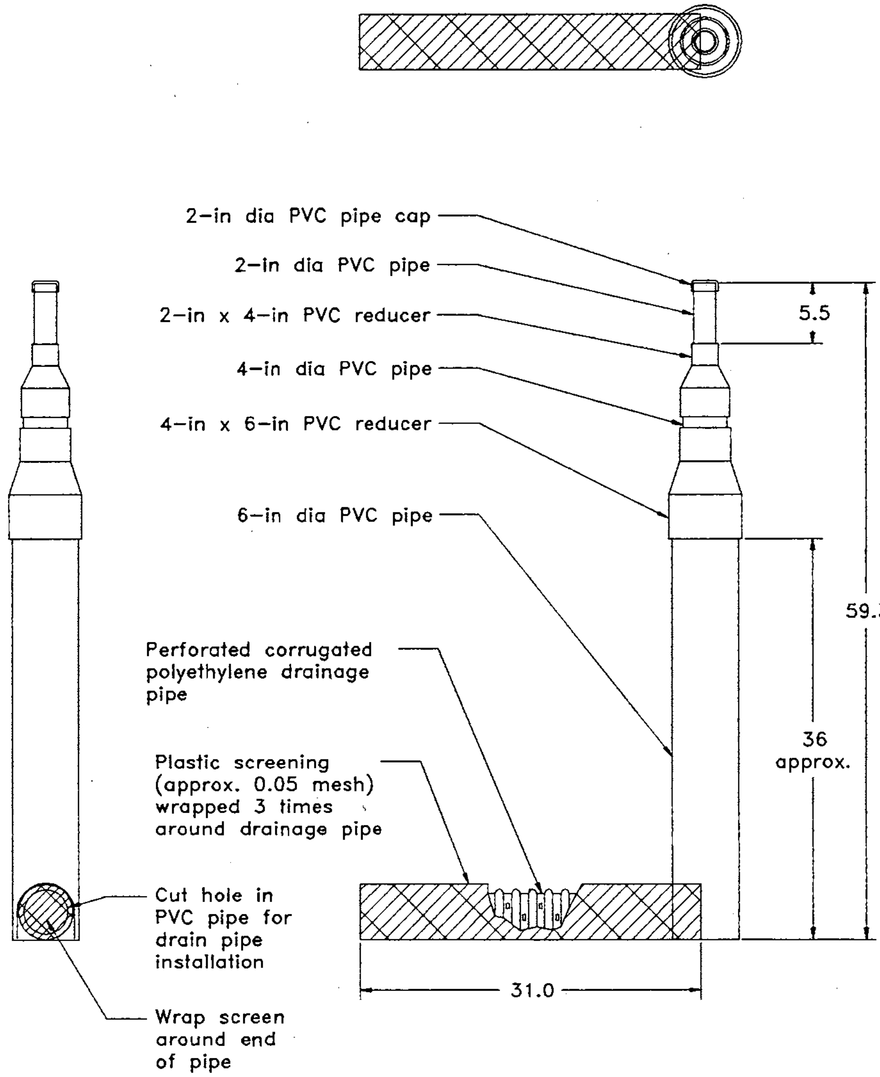
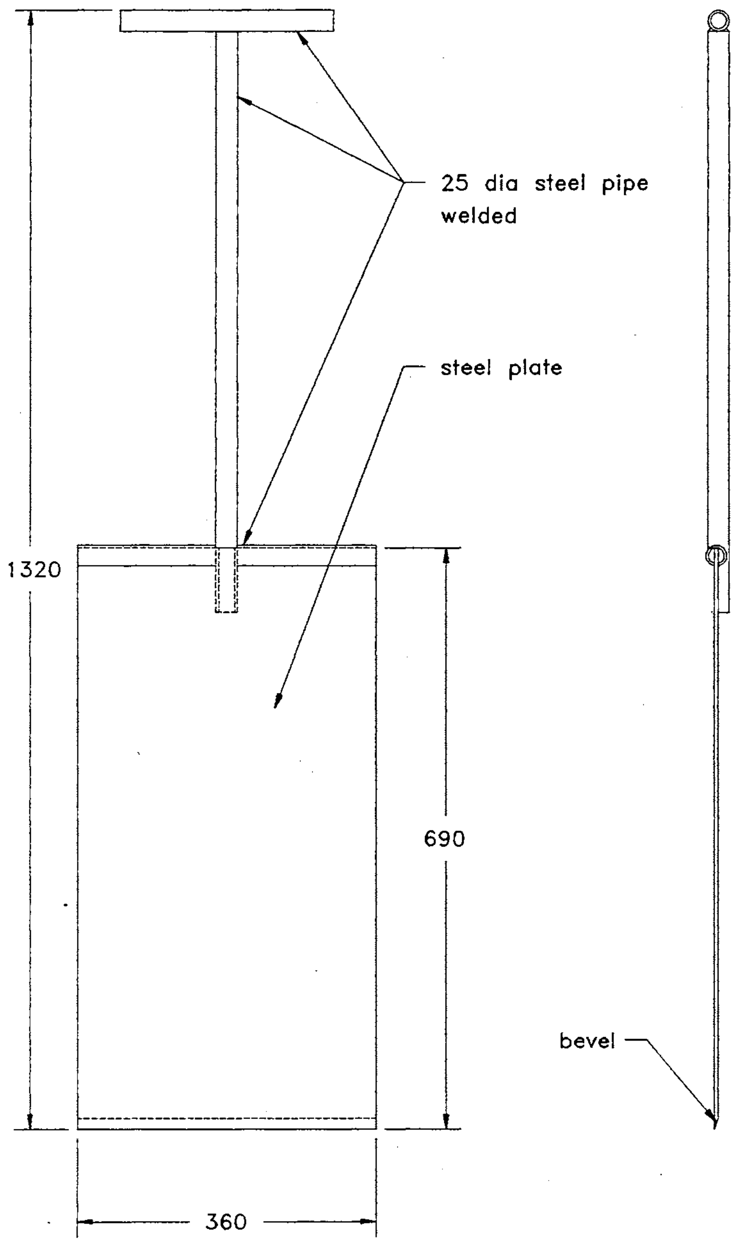
APPENDICES

APPENDIX A

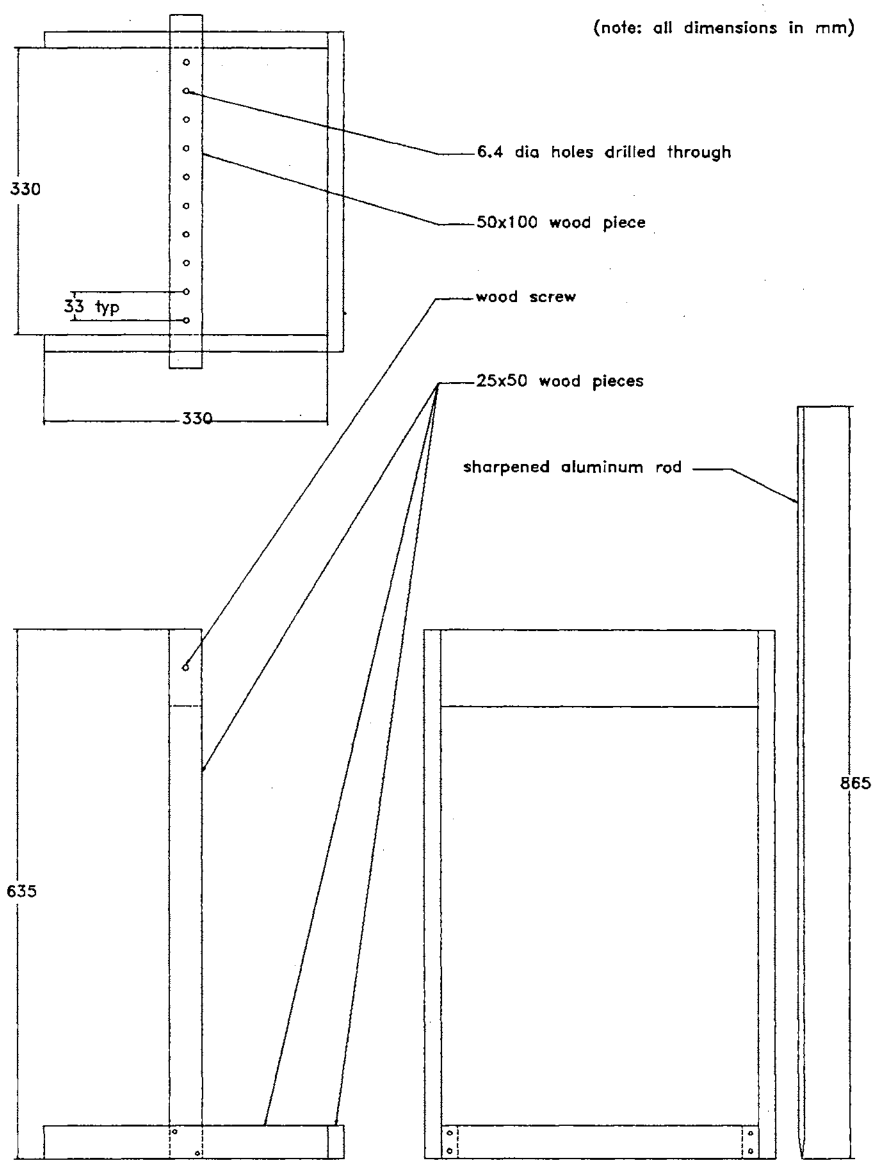
Equipment Drawings



Drain Assembly



Flat-Bladed Spade



Leaf-Area Index Pin Frame

APPENDIX B

VEGETATION MEASUREMENTS

GOODWELL

Canopy Height (mm)

	field avg	lys min	fence max
11 May 1994	3	3	3
13 July 1994	2	3	3
26 Aug 1994	2.1	2.0	3.0
24 Jan 1995	1	1	1
2 May 1995	1.2	1.0	2.0

Ground Cover

	field avg	lys min	fence max
26 Aug 1994	0.5	0.2	0.8
24 Jan 1995	0	0	0
2 May 1995	0.4	0.2	0.7

Leaf-Area Index

	Method 1			Method 2		
	field avg	lys min	fence max	field avg	lys min	fence max
26 Aug 1994	0.8	0.3	1.5	1.0	0.5	1.8
24 Jan 1995	0.0	0.0	0.0	0.0	0.0	0.0
2 May 1995	0.4	0.0	0.9	0.4	0.2	0.6

APACHE

Canopy Height (mm)

	field avg	lys min	fence max
15 Apr 1994	7	7	7
11 Jul 1994	11	13	14
cut	11	10	10
27 Jul 1994	10	12	12
10 Aug 1994	8	11	13
cut	8	7	7
5 Sept 1994	7	4	9
20 Oct 1994	6	10	10
cut	6	5	5
15 Nov 1994	4.5	3	6
13 Jan 1995	5	5	5
17 Mar 1995	3.9	1.0	6.0
14 Apr 1995	4.3	3.0	5.0
28 Apr 1995	5.4	3.0	7.0

Ground Cover

	field avg	lys min	fence max
5 Sept 1994	0.9	0.7	1
15 Nov 1994	0.7	0.5	0.8
13 Jan 1995	0	0	0
17 Mar 1995	0.7	0.5	0.9
14 Apr 1995	0.8	0.6	1.0
28 Apr 1995	0.7	0.4	0.8

Leaf-Area Index

	Method 1			Method 2		
	field avg	lys min	fence max	field avg	lys min	fence max
5 Sept 1994	2.2	1.3	2.9	2.6	1.8	3.9
15 Nov 1994	1.3	0.7	2.0	1.2	0.6	2.0
13 Jan 1995	0	0	0	0	0	0
17 Mar 1995	1.0	0.3	1.7	1.2	0.9	1.8
14 Apr 1995	1.6	0.9	2.4	2.0	1.2	3.1
28 Apr 1995	1.6	0.9	2.3	1.9	1.1	2.8

MARENA

Canopy Height (mm)

	field avg	lys min	fence max
29 May 1994	12	12	12
2 Aug 1994	17	13	17
22 Aug 1994	12.2	7.0	17.0
30 Nov 1994	12	12	12
12 Jan 1994	12	12	12
26 Feb 1994	8	8	9
27 Mar 1994	3.9	2.0	6.0

Ground Cover

	field avg	lys min	fence max
22 Aug 1994	0.7	0.4	0.8
30 Nov 1994	0	0	0
12 Jan 1994	0	0	0
26 Feb 1994	0	0	0
27 Mar 1994	0.2	0.1	0.4

Leaf-Area Index

	Method 1			Method 2		
	field avg	lys min	fence max	field avg	lys min	fence max
22 Aug 1994	1.9	0.8	2.9	2.1	1.5	2.9
30 Nov 1994	0.0	0.0	0.0	0.0	0.0	0.0
12 Jan 1994	0.0	0.0	0.0	0.0	0.0	0.0
26 Feb 1994	0.0	0.0	0.0	0.0	0.0	0.0
27 Mar 1994	0.3	0.0	0.4	0.3	0.1	0.5

WISTER

Canopy Height (mm)

	field avg	lys min	fence max
15 Apr 1994	7	9	10
25 May 1994	37	37	37
2 Jun 1994	37	37	37
cut	12	12	12
3 Aug 1994	9	8	9
8 Sep 1994	7.4	6.0	9.0
26 Oct 1994	8.6	7.0	10.0
cut	5.6	4.0	6.0
18 Nov 1994	5	6	6
13 Dec 1994	5	5	5
11 Jan 1995	5	5	5
31 Mar 1995	7.6	4.0	12.0

Ground Cover

	field avg	lys min	fence max
8 Sept 1994	0.5	0.3	0.8
26 Oct 1994	0.7	0.7	0.8
cut	0.7	0.6	0.9
31 Mar 1995	0.9	0.7	1.0

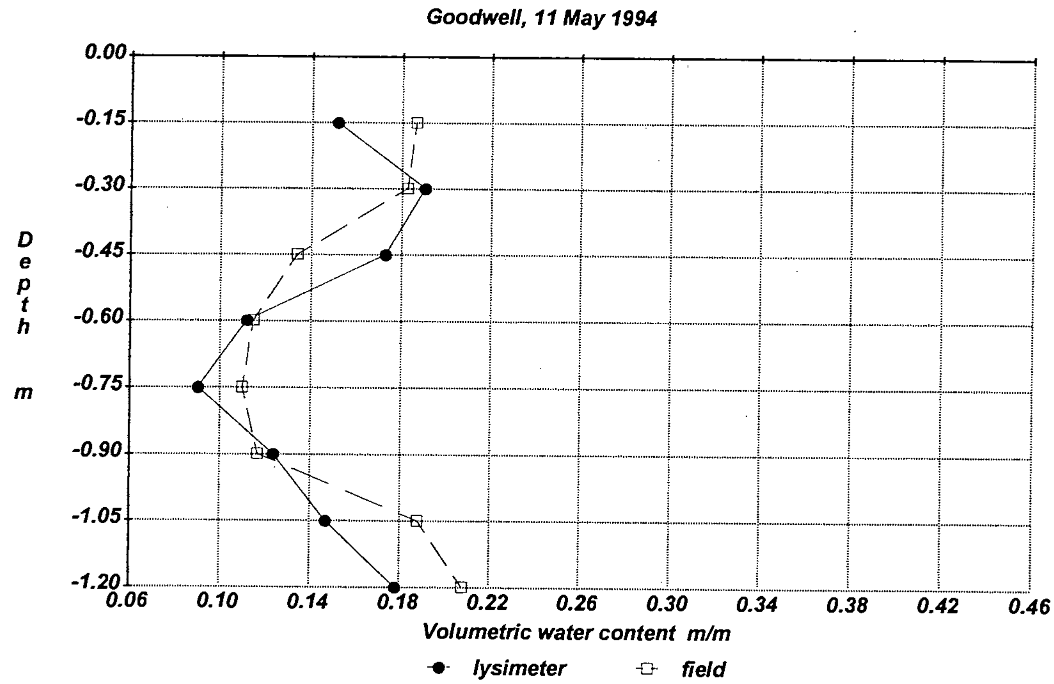
Leaf-Area Index

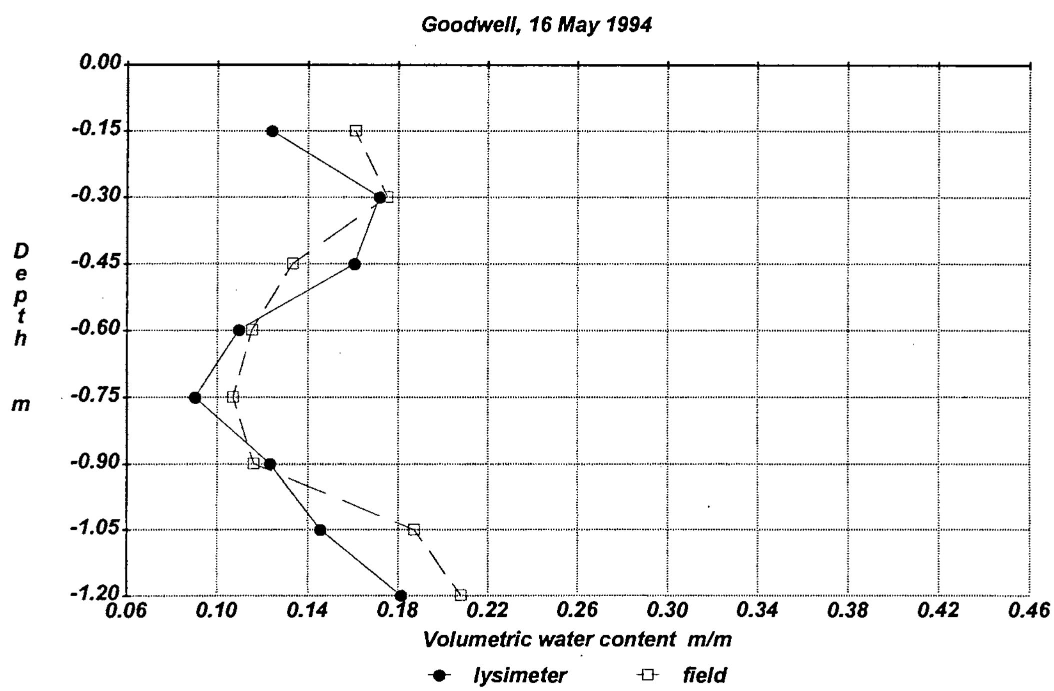
	Method 1			Method 2		
	field avg	lys min	fence max	field avg	lys min	fence max
8 Sept 1994	2.1	1.2	3.2	2.3	1.3	3.5
26 Oct 1994	2.1	2.0	2.3	2.0	1.8	2.3
cut	1.4	1.1	2.0	1.4	1.1	2.1
31 Mar 1995	3.3	2.3	5.4	3.4	1.7	4.7

APPENDIX C

SOIL WATER MEASUREMENTS

GOODWELL


Goodwell, 11 May 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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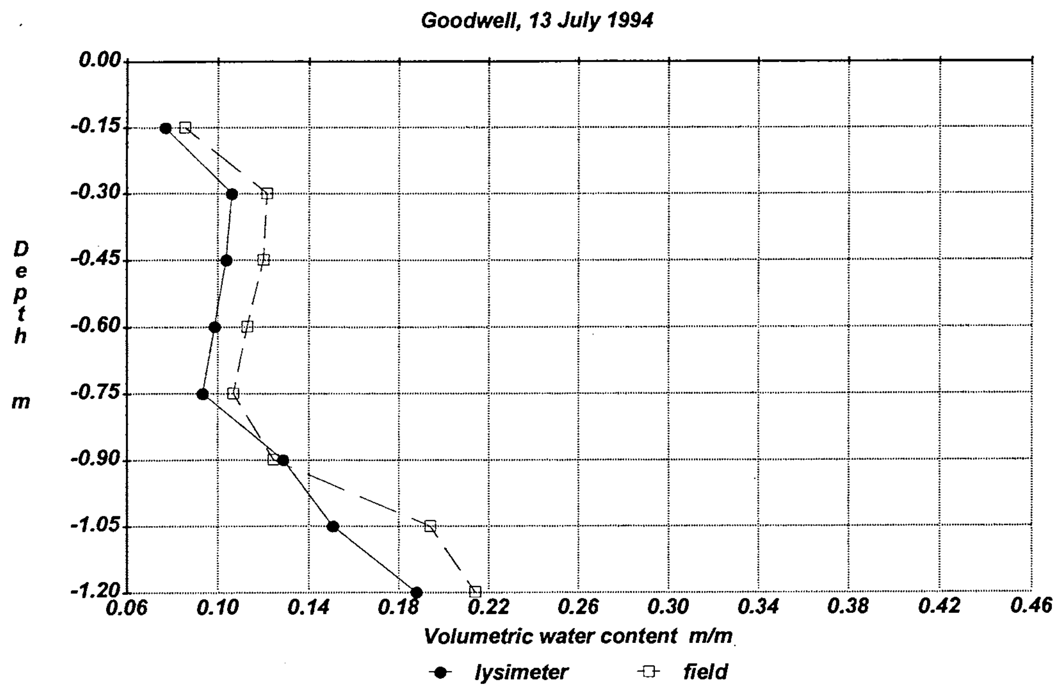
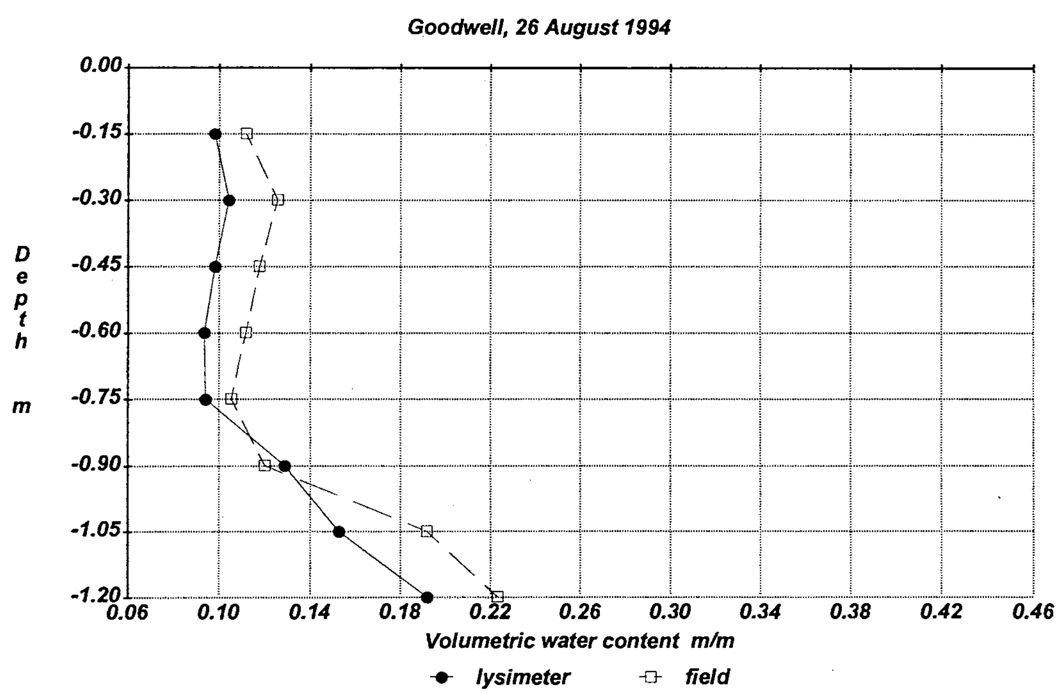
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field


Goodwell, 13 July 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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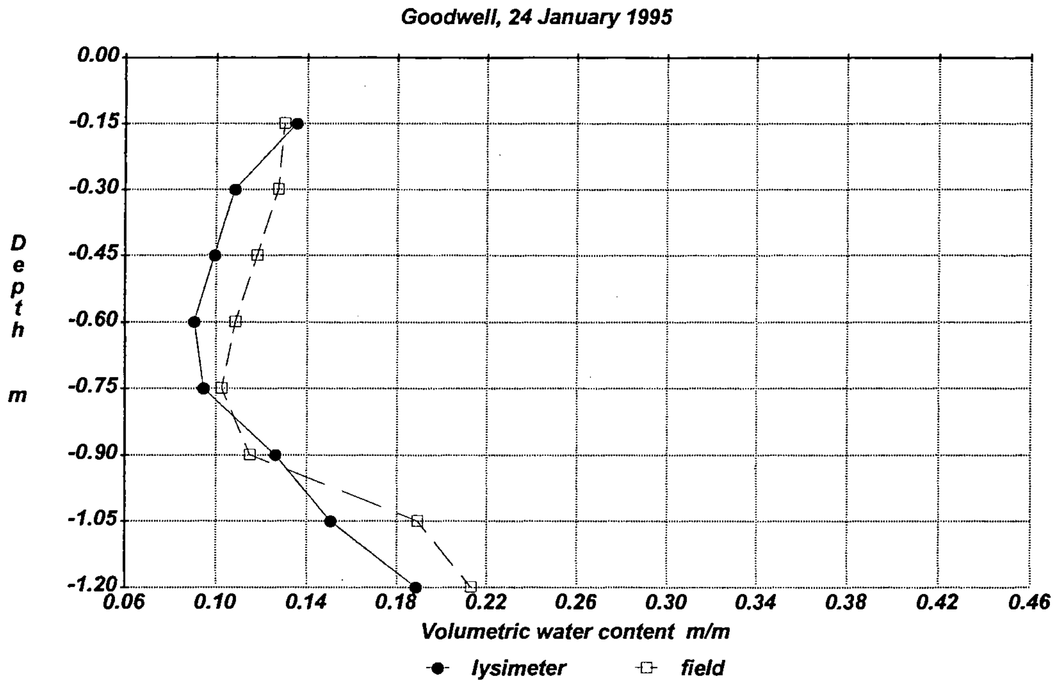
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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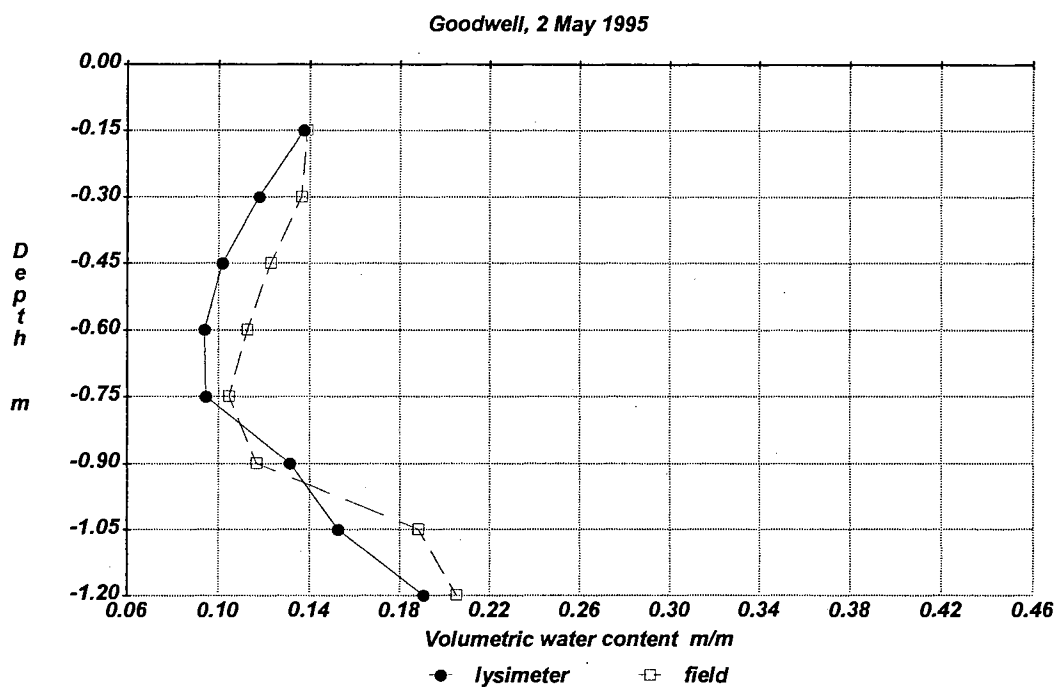
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D
e
p
t
h
m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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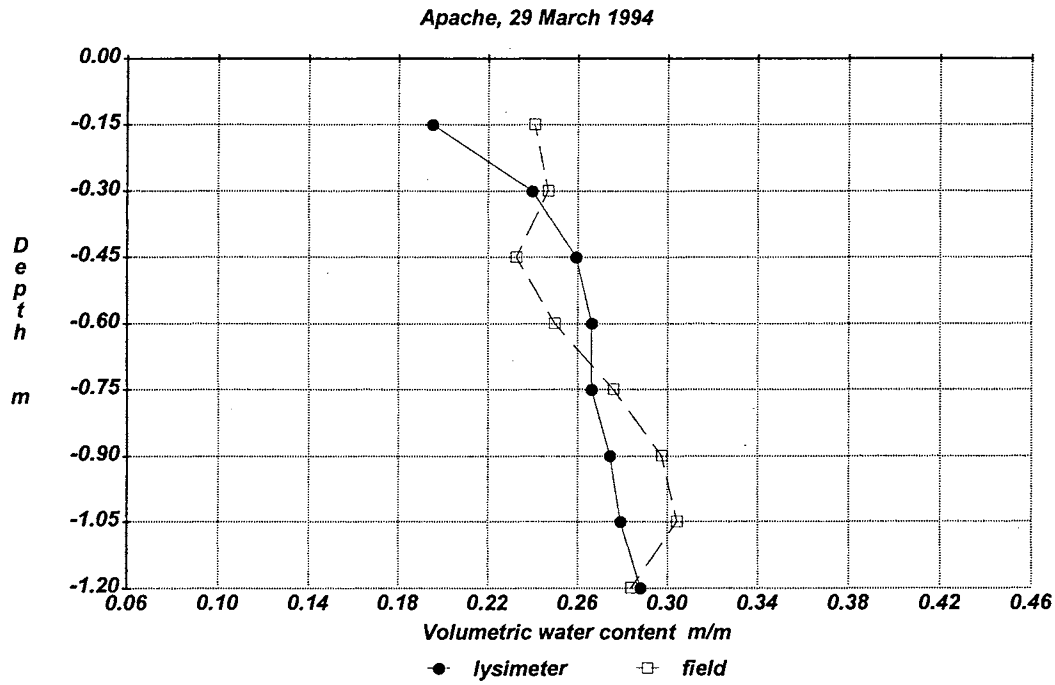
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D
e
p
t
h
m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

APACHE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-0.60
-0.75
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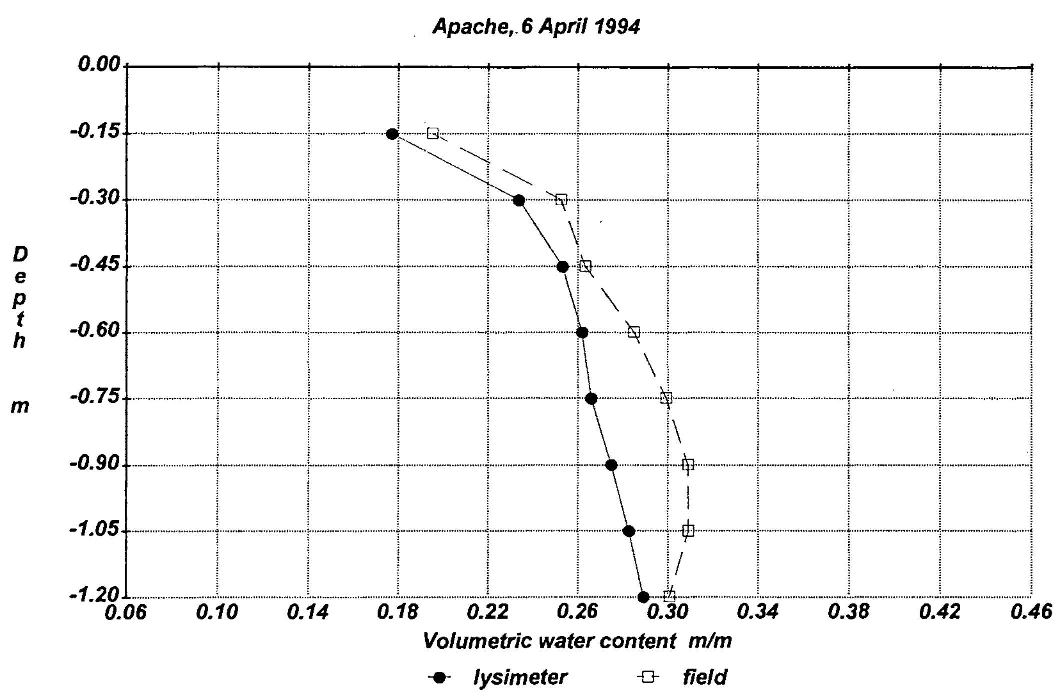
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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-0.75
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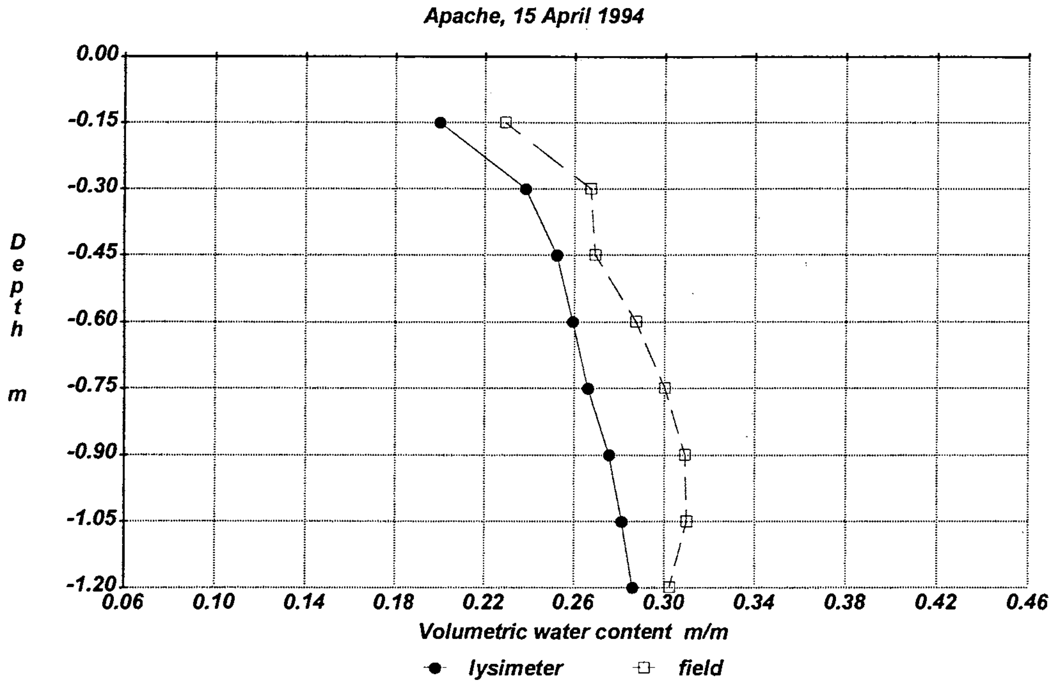
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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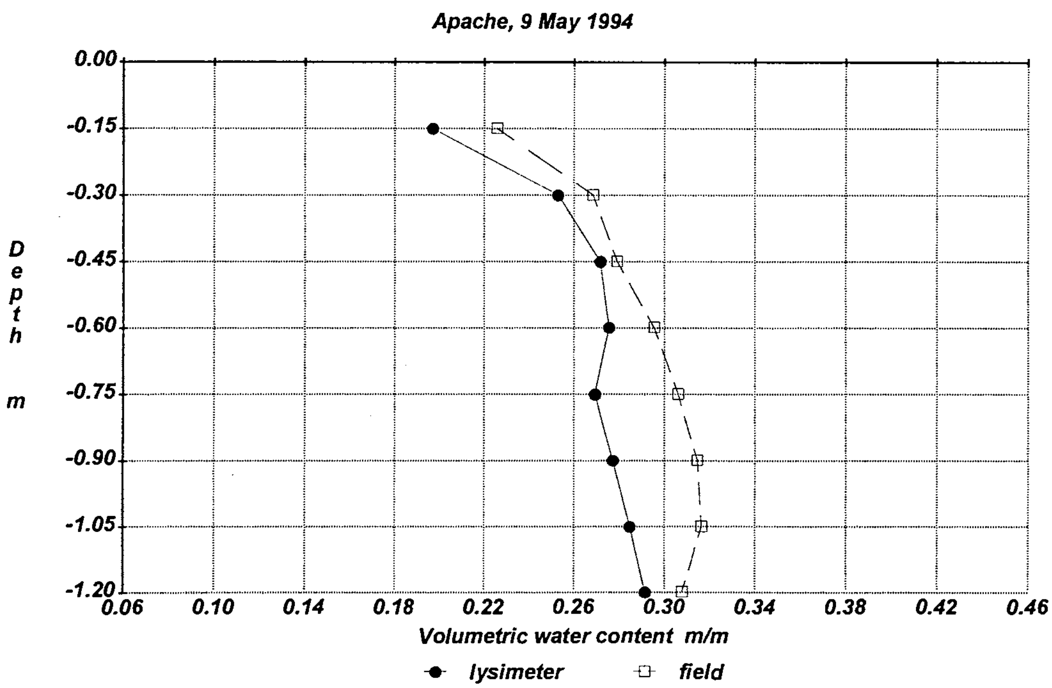
-0.75
-0.90
-1.05
-1.20
Depth
m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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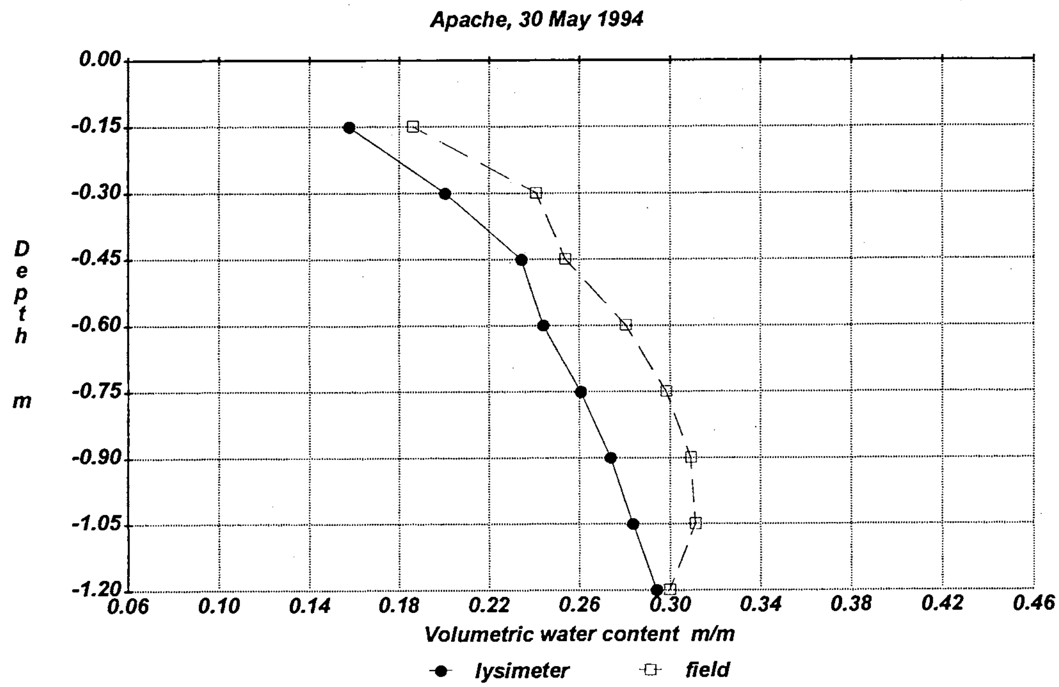
-1.05
-1.20
Depth
m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field



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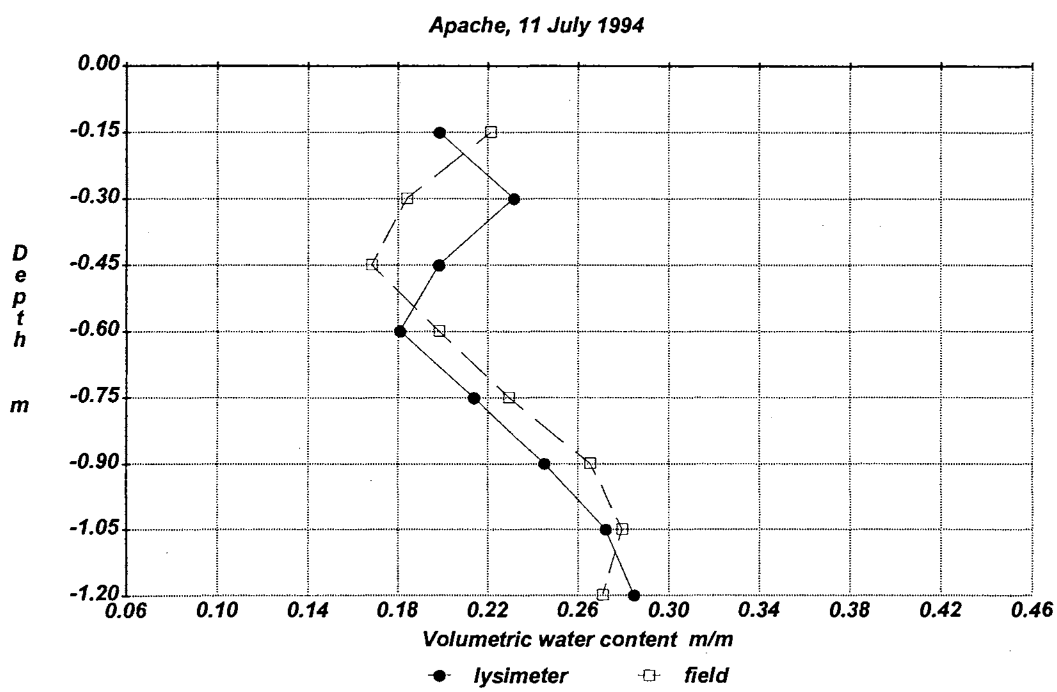
-0.90
-1.05
-1.20
D e p t h m
0.06 0.10 0.14 0.18 0.22 0.26 0.30 0.34 0.38 0.42 0.46
Volumetric water content m/m
lysimeter
field



Apache, 11 July 1994
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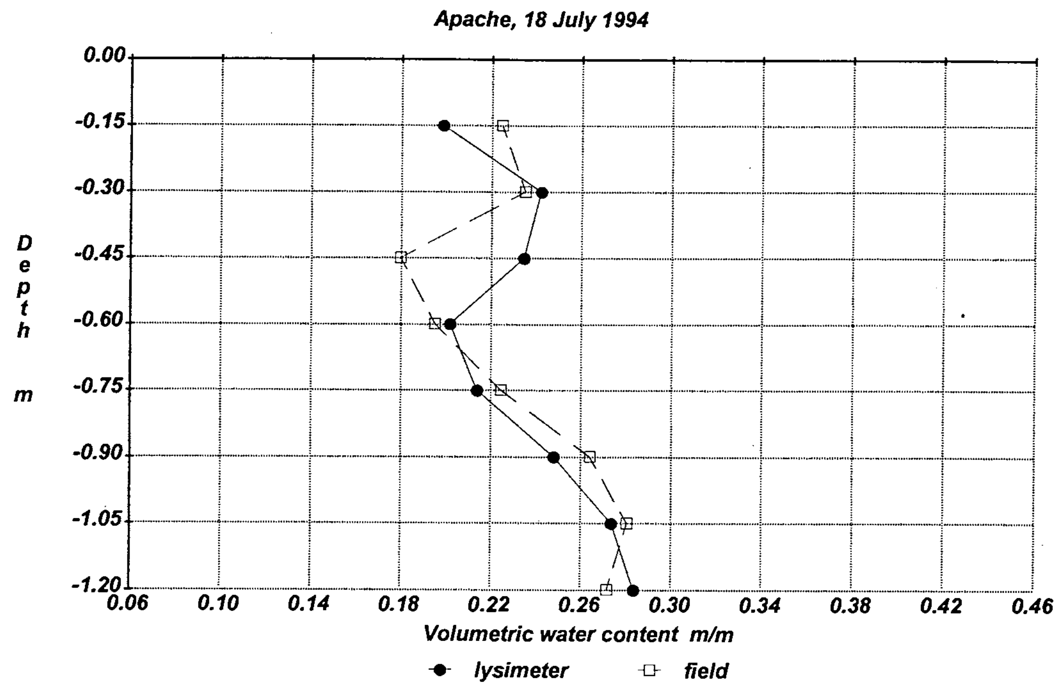
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06 0.10 0.14 0.18 0.22 0.26 0.30 0.34 0.38 0.42 0.46
Volumetric water content m/m
lysimeter
field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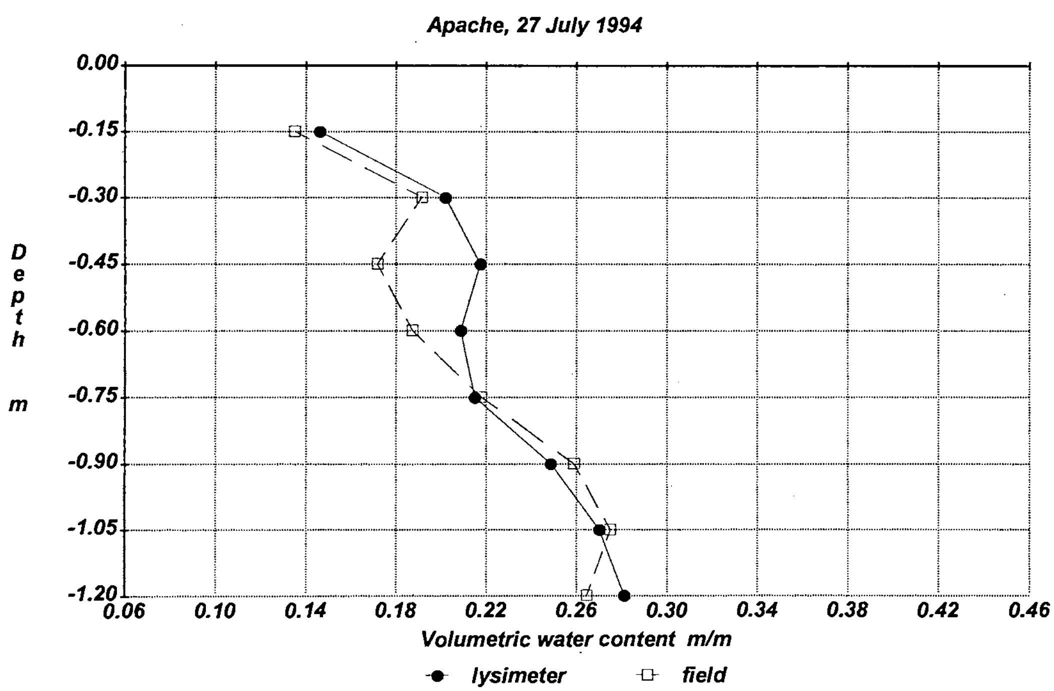
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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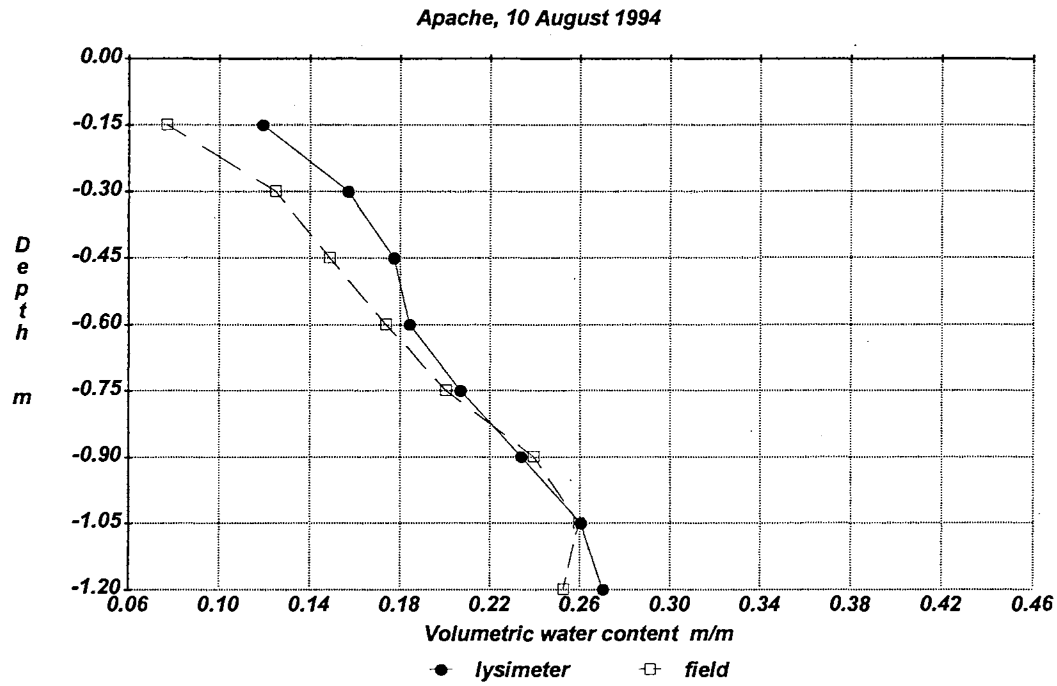
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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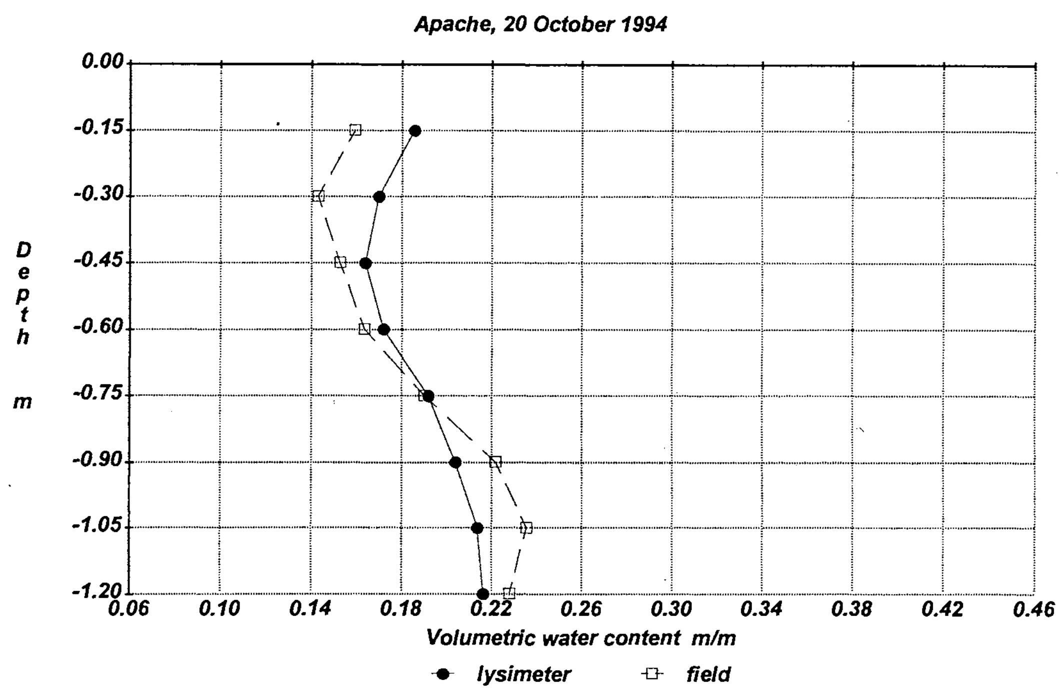
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field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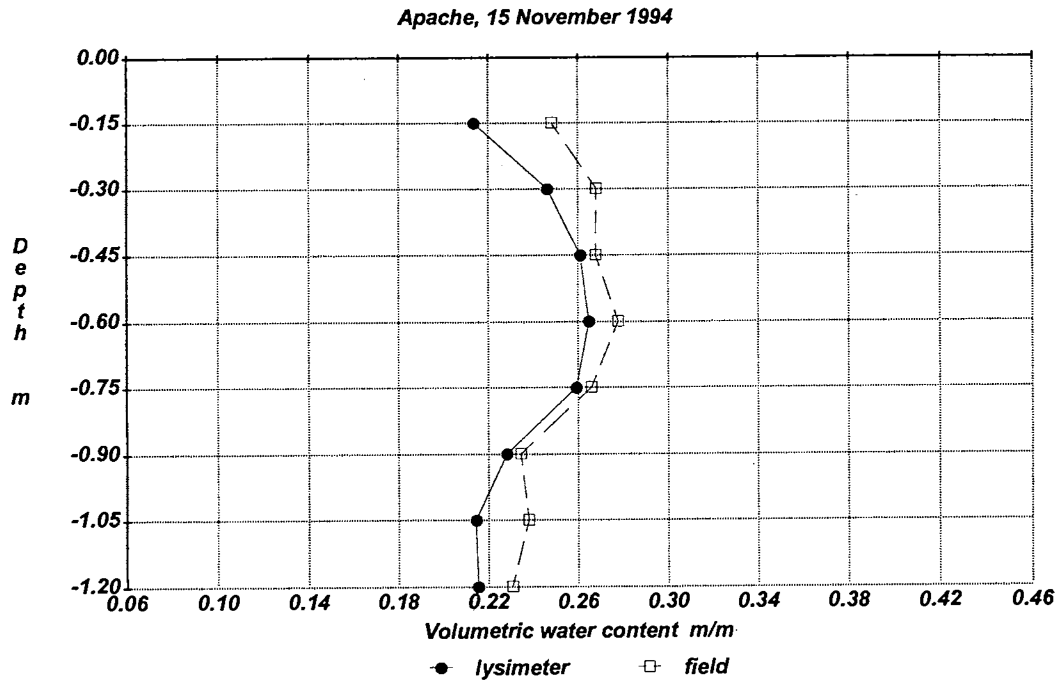
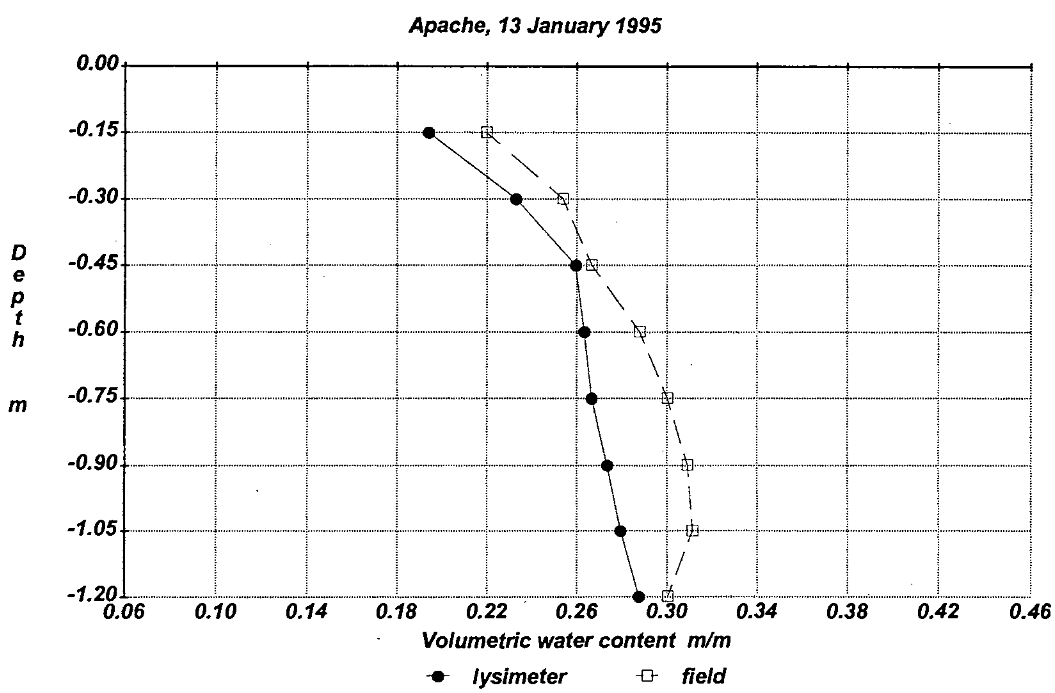
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

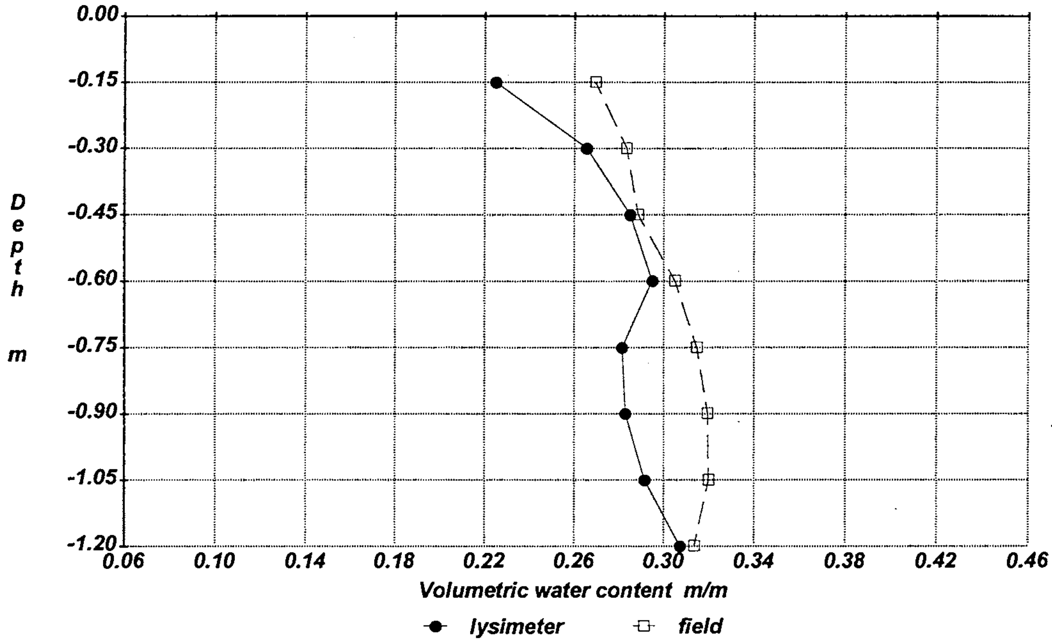


Apache, 15 November 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

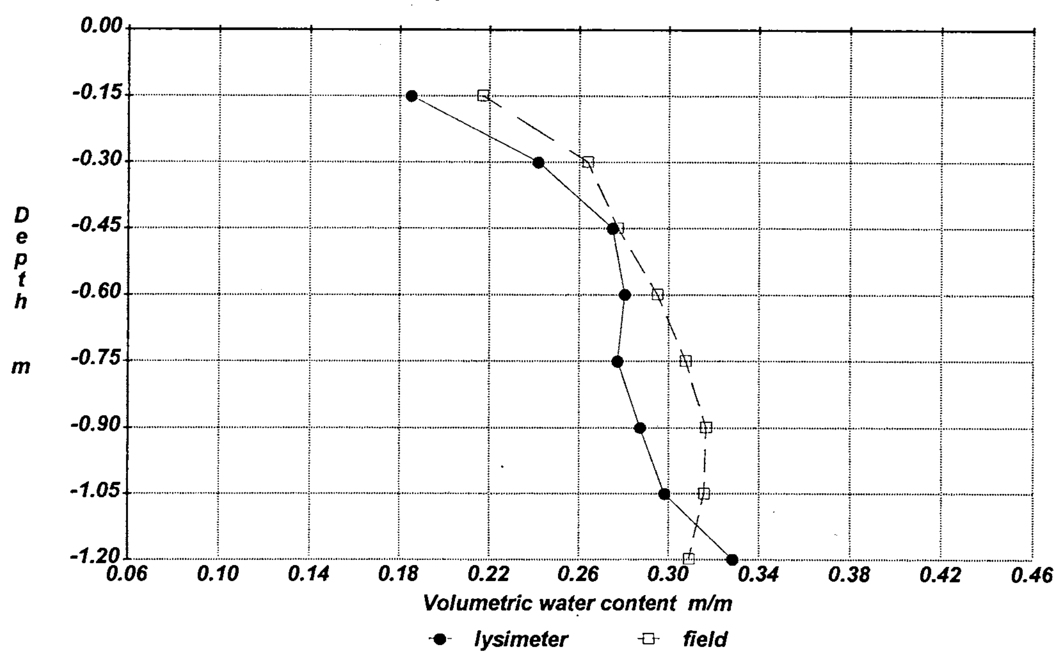


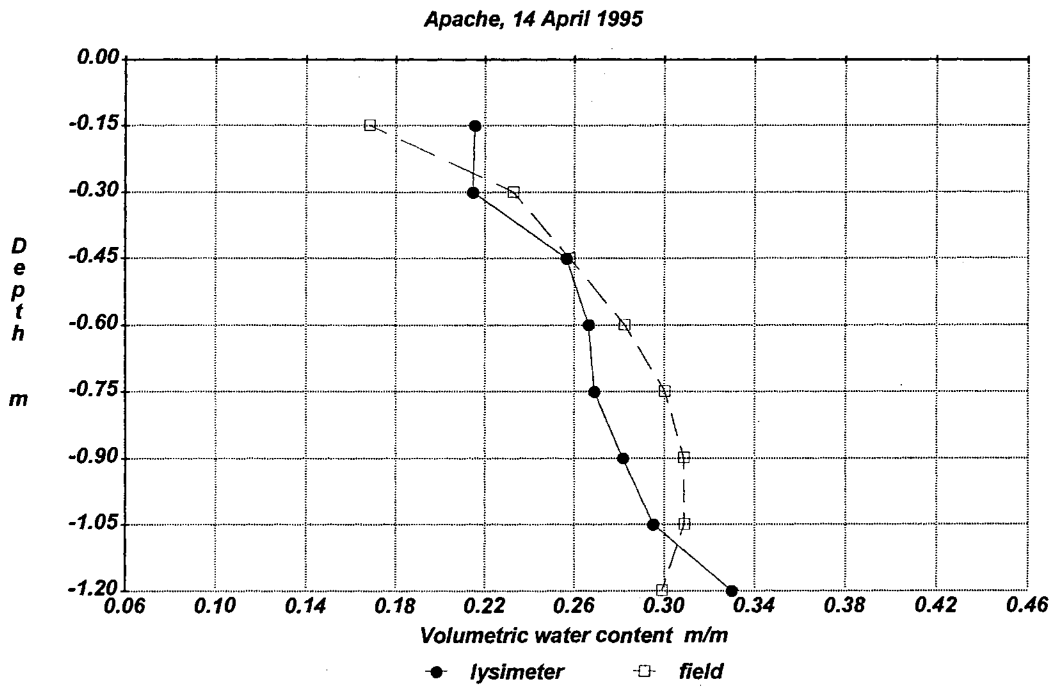
Apache, 13 January 1995
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

Apache, 17 March 1995



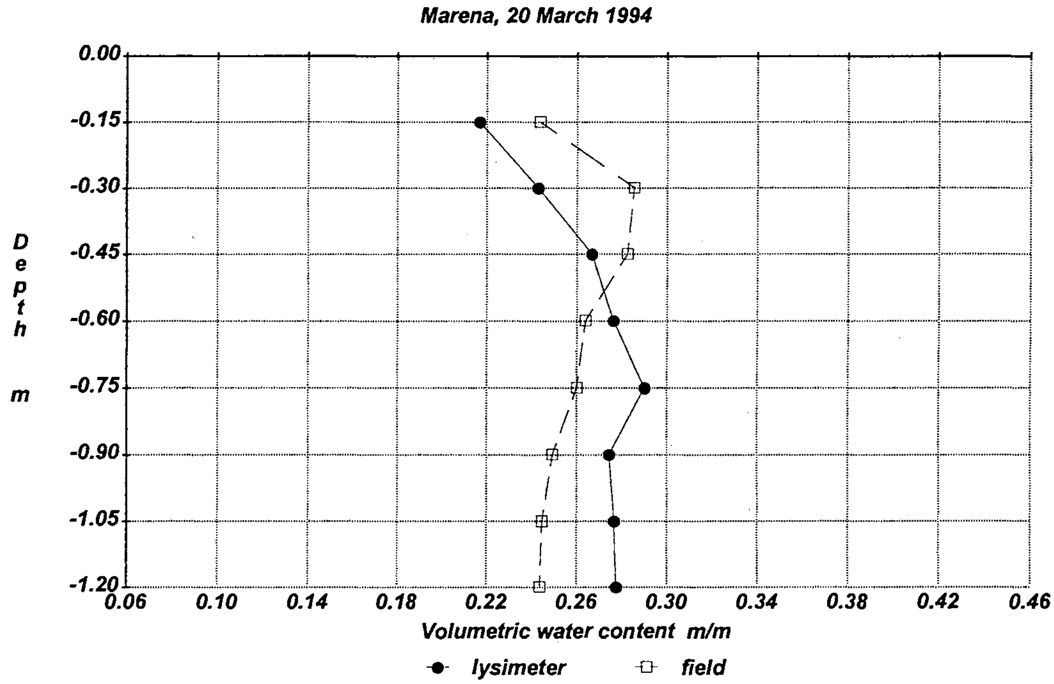
Apache, 24 March 1995



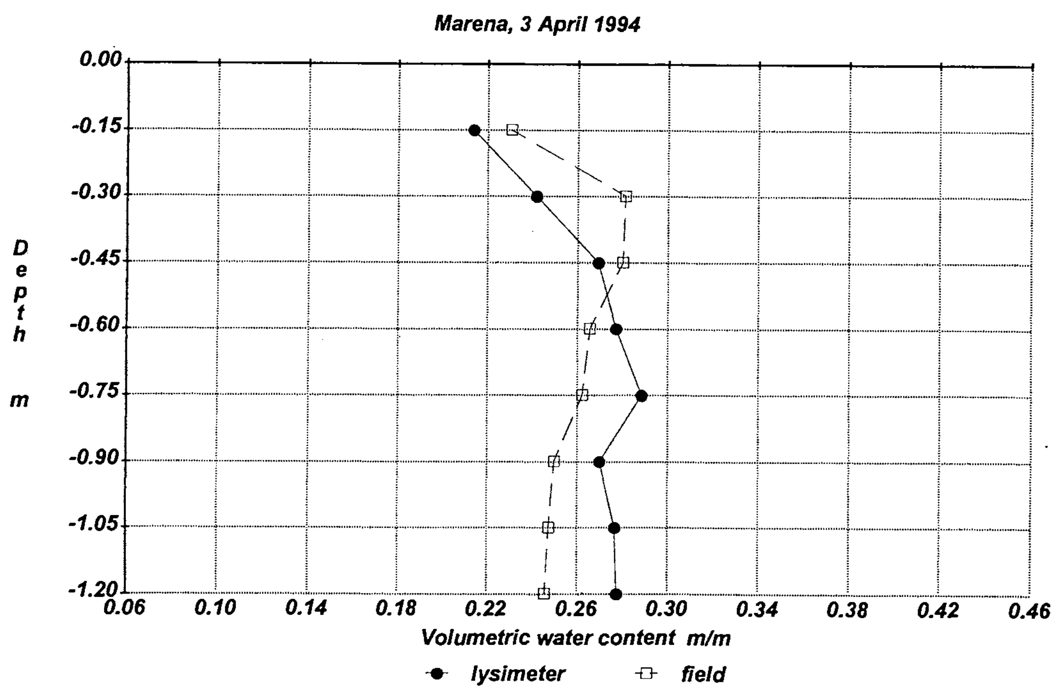


Apache, 14 April 1995
Depth m
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

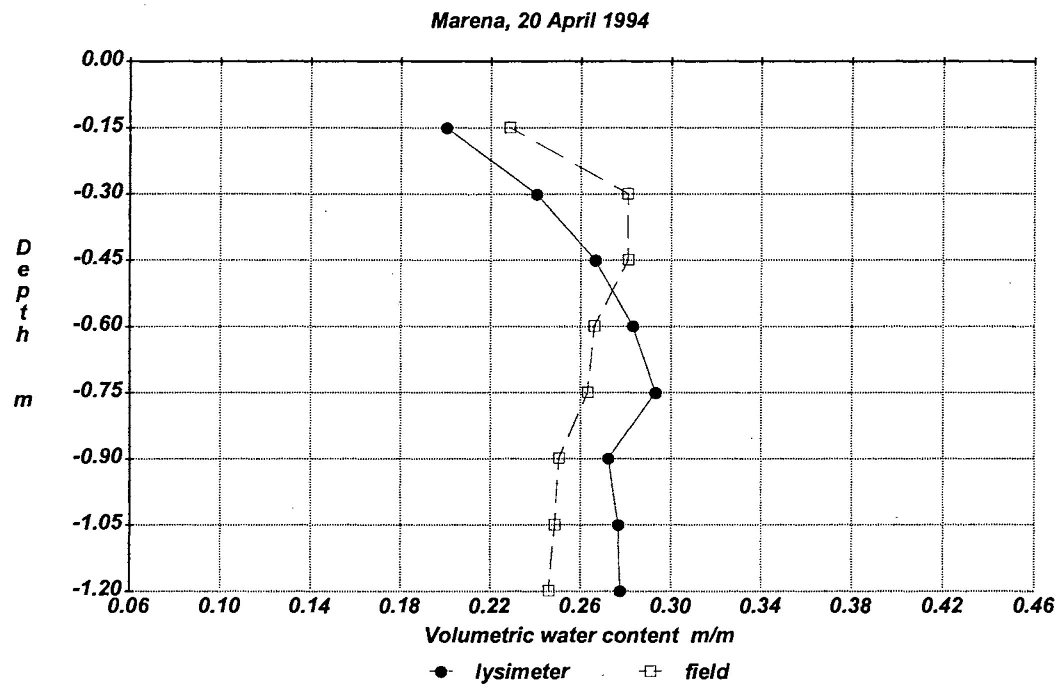
MARENA



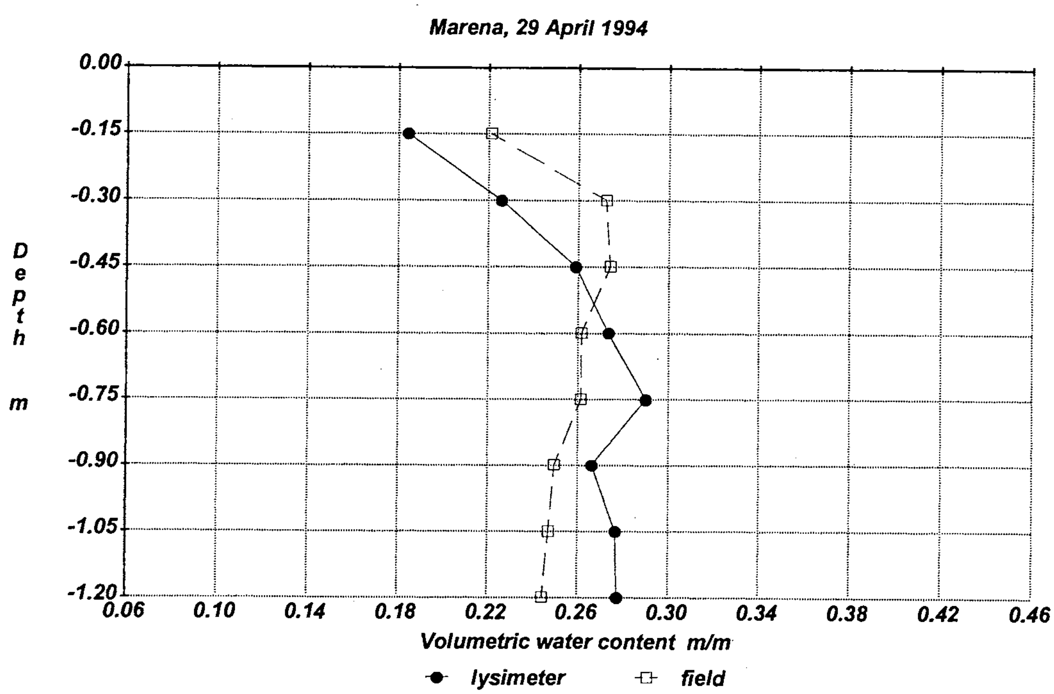
Marena, 20 March 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06 0.10 0.14 0.18 0.22 0.26 0.30 0.34 0.38 0.42 0.46
Volumetric water content m/m
lysimeter
field



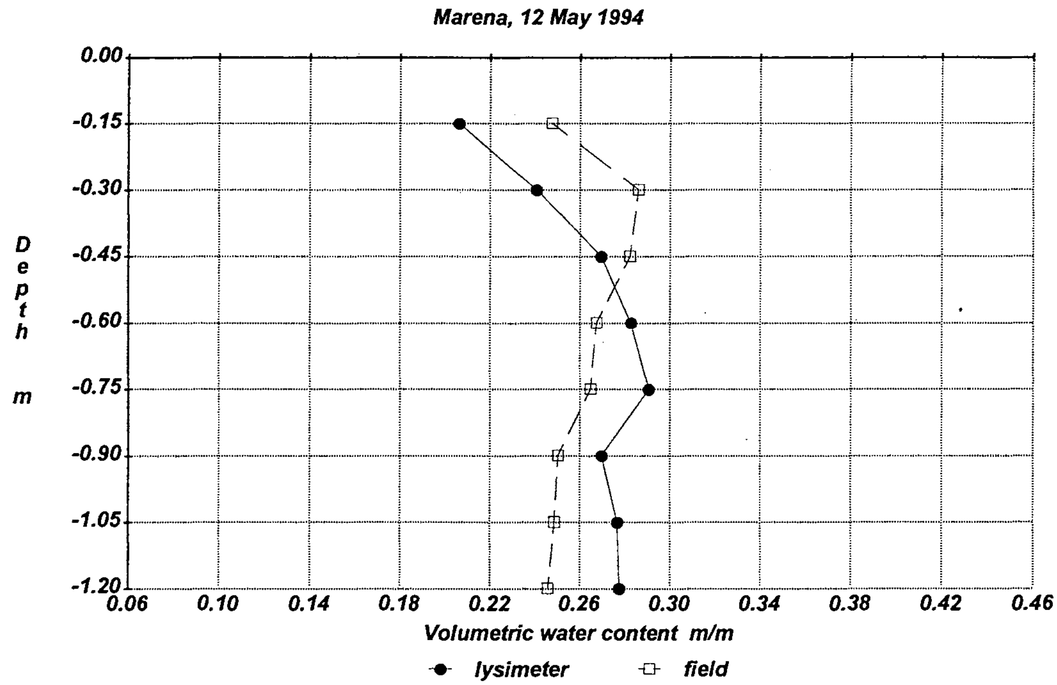
Marena, 3 April 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06 0.10 0.14 0.18 0.22 0.26 0.30 0.34 0.38 0.42 0.46
Volumetric water content m/m
lysimeter
field



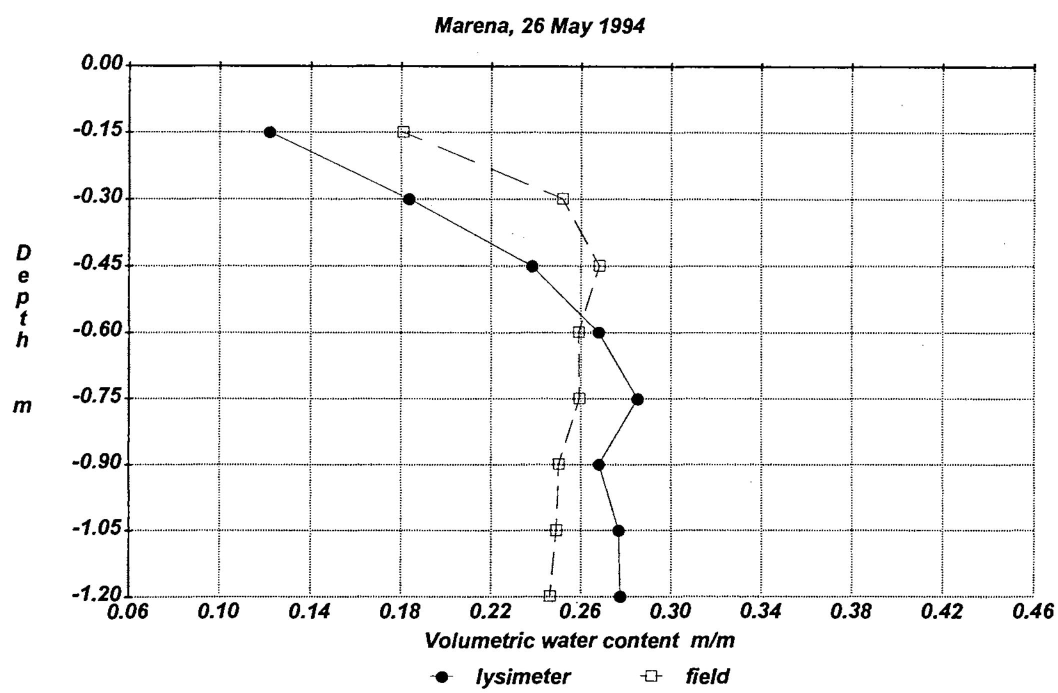
Marena, 20 April 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field



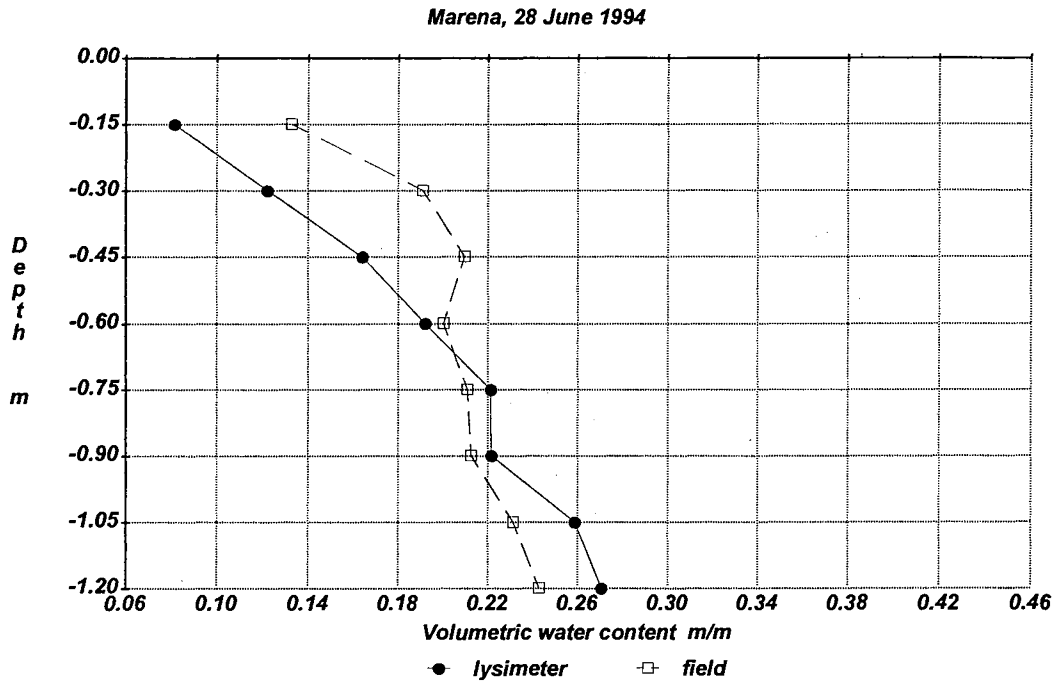
Marena, 29 April 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

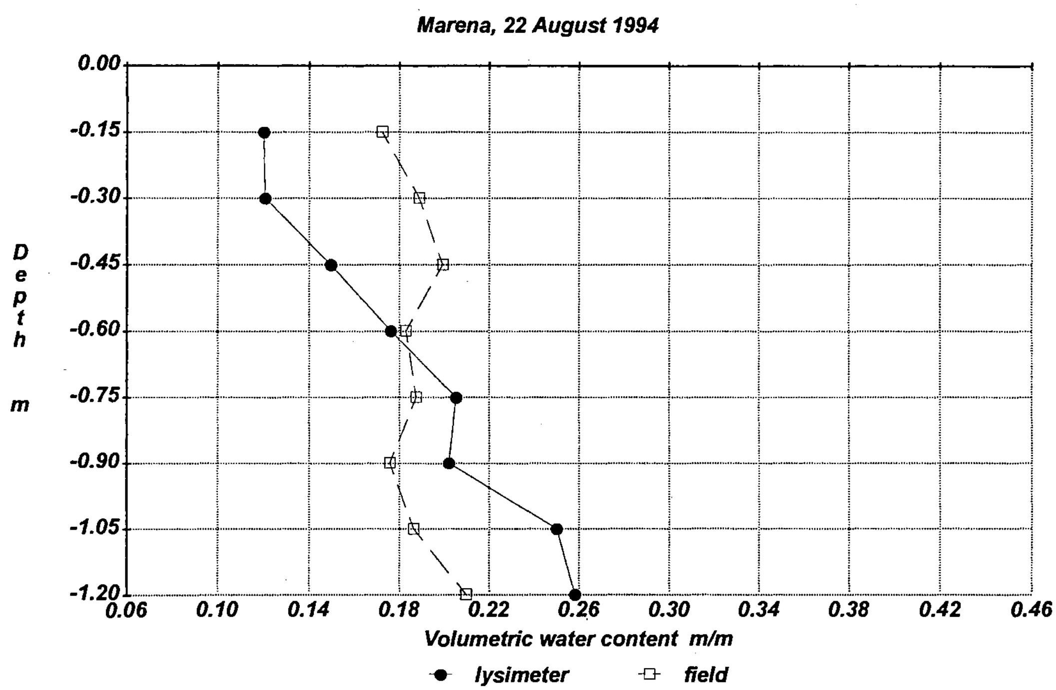


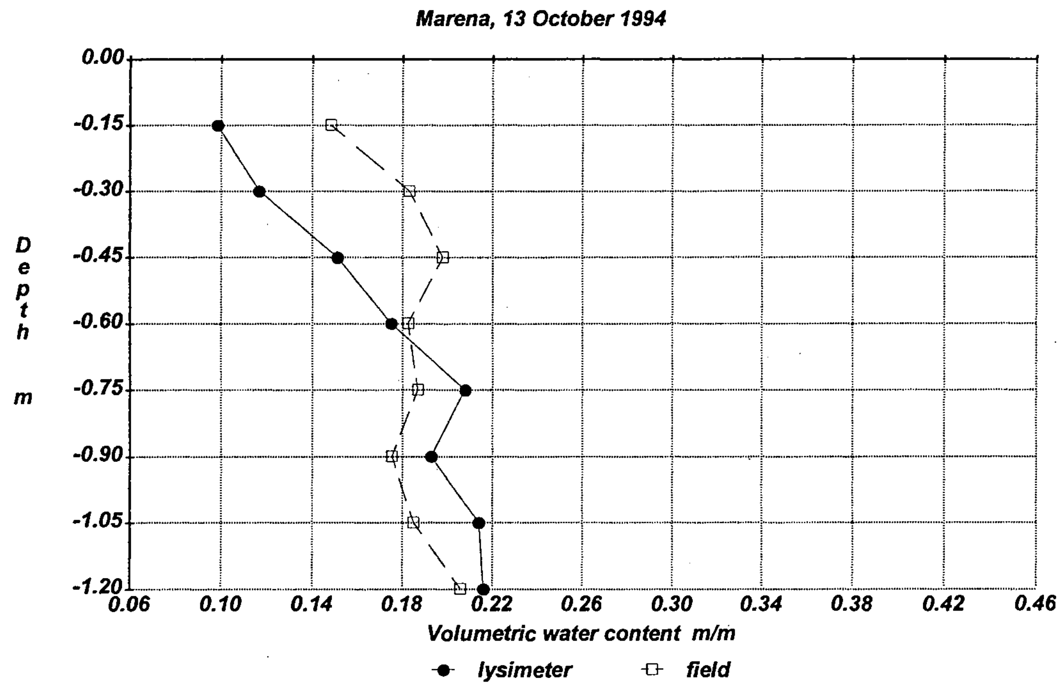
Marena, 12 May 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

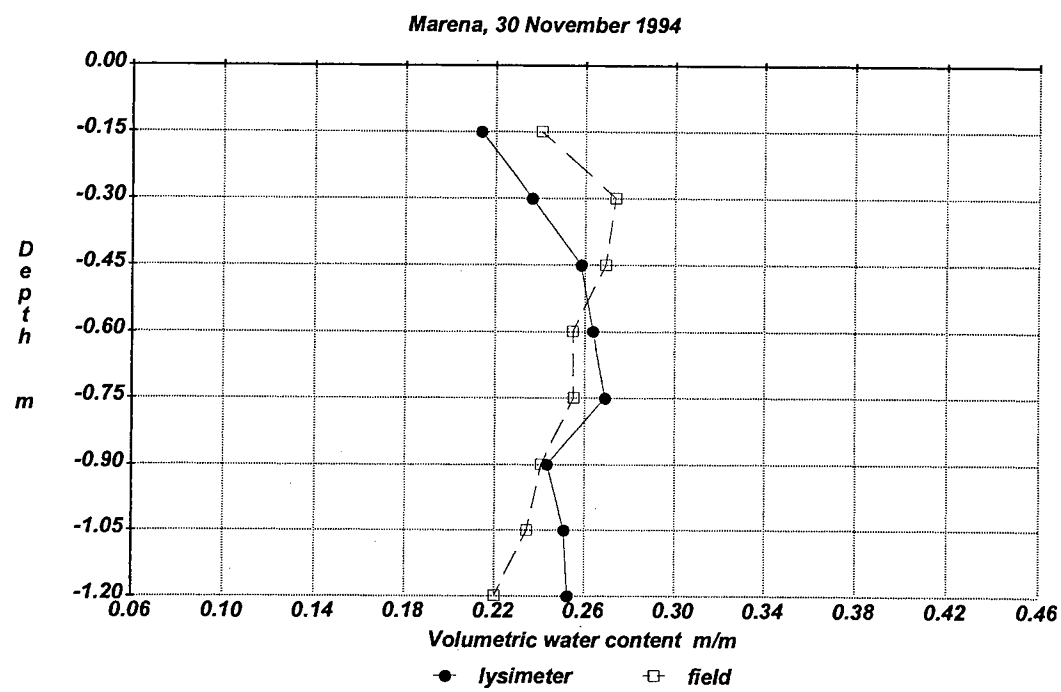


Marena, 26 May 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

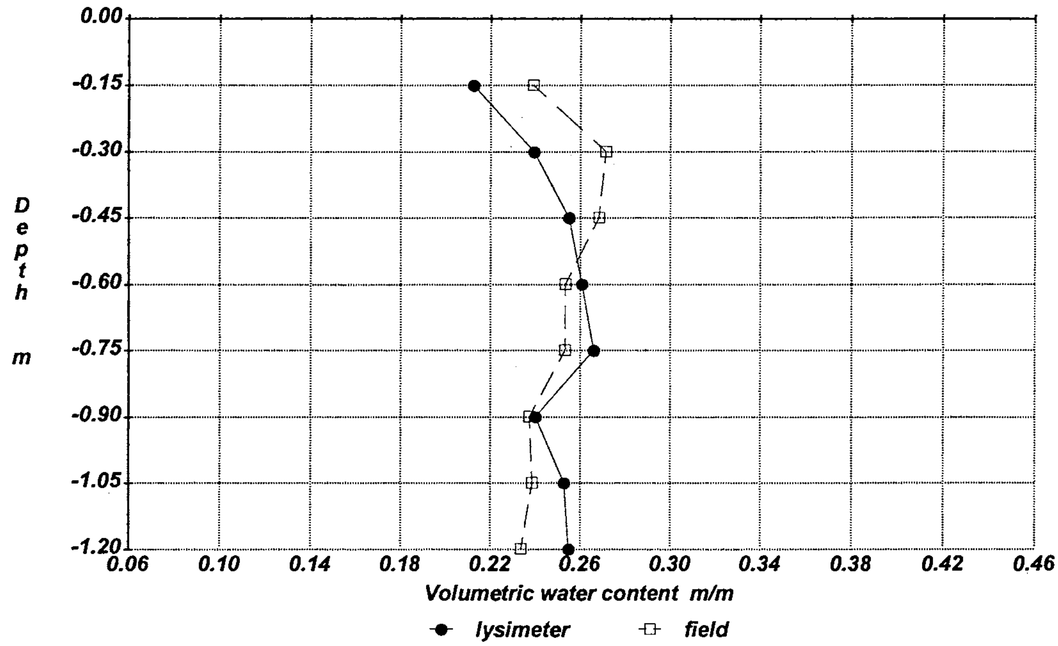

Marena, 28 June 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06 0.10 0.14 0.18 0.22 0.26 0.30 0.34 0.38 0.42 0.46
Volumetric water content m/m
lysimeter
field


Marena, 22 August 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06 0.10 0.14 0.18 0.22 0.26 0.30 0.34 0.38 0.42 0.46
Volumetric water content m/m
lysimeter
field

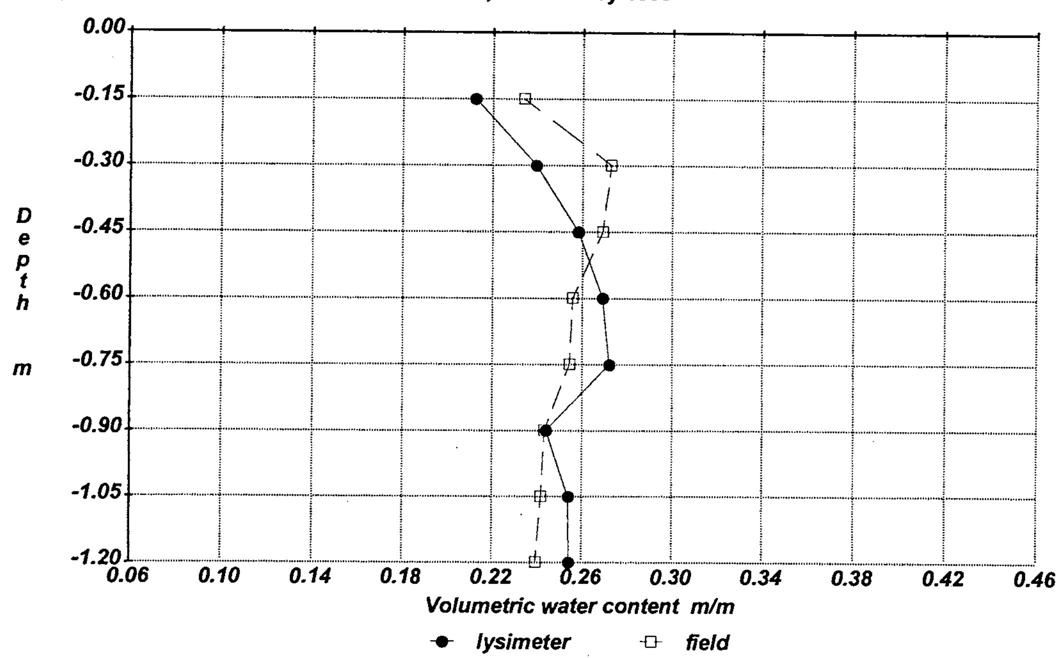

Marena, 13 October 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

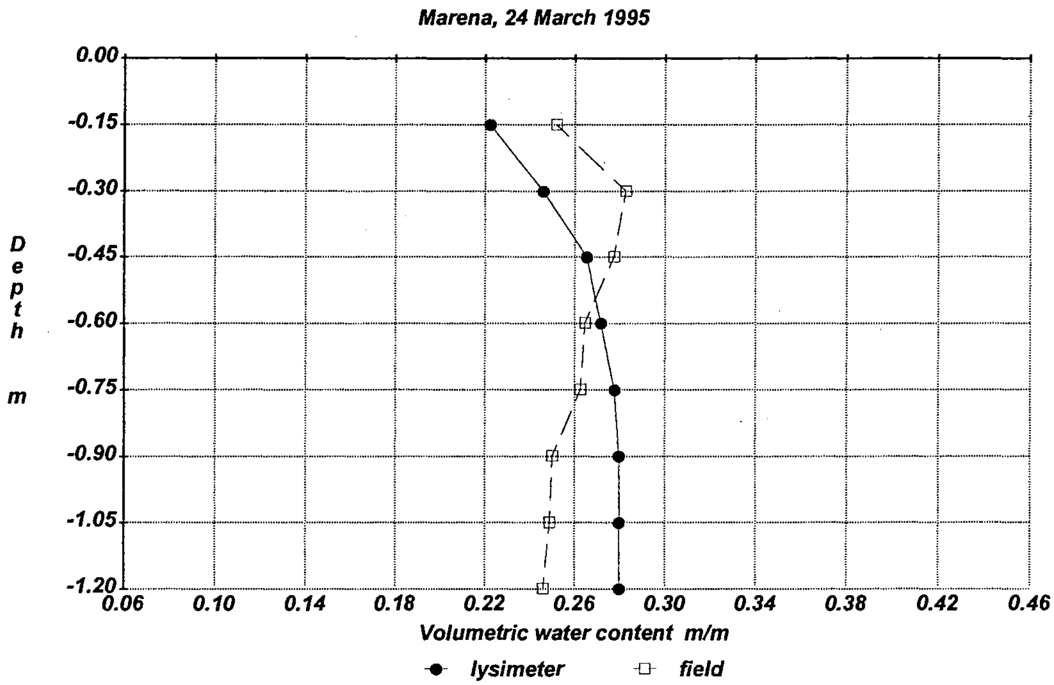

Marena, 30 November 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

Marena, 12 January 1995

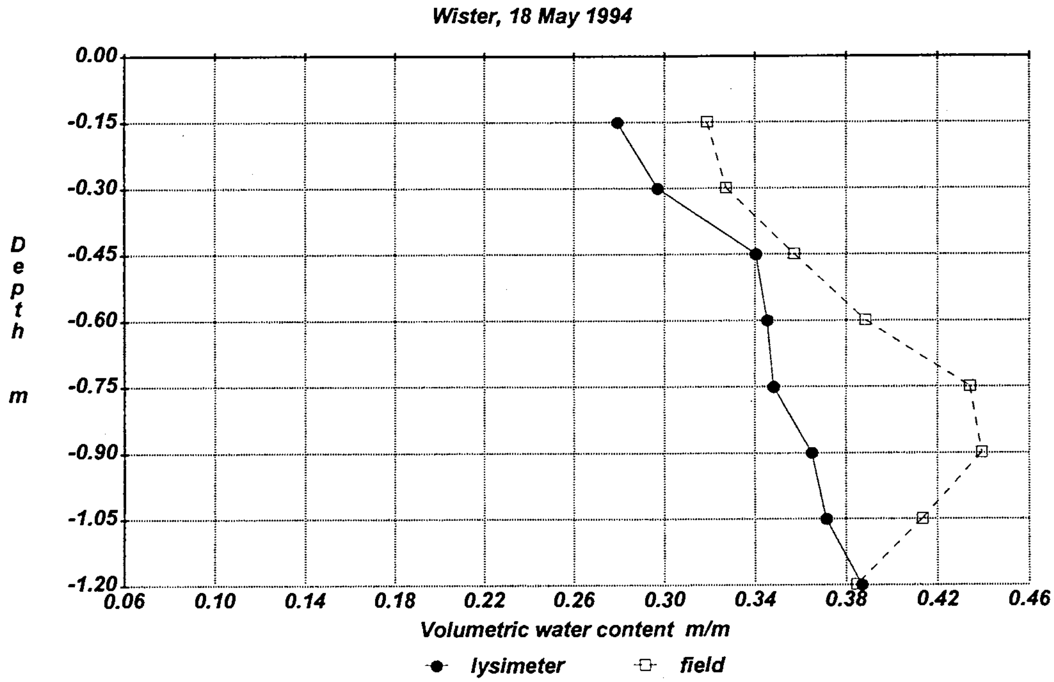


Marena, 26 February 1995

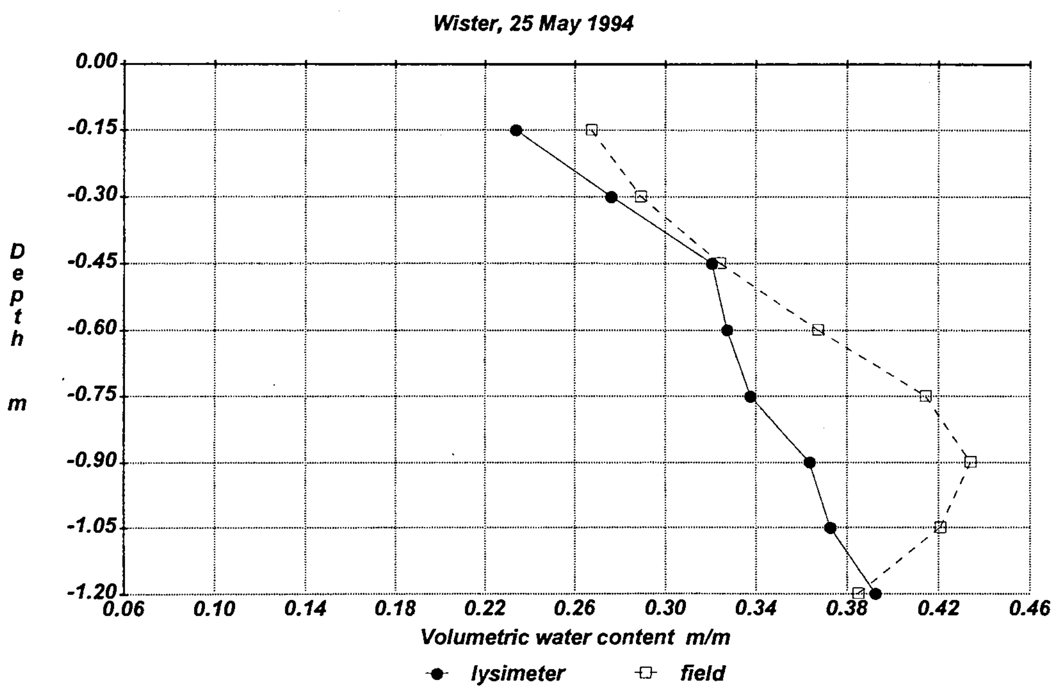



Marena, 24 March 1995
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

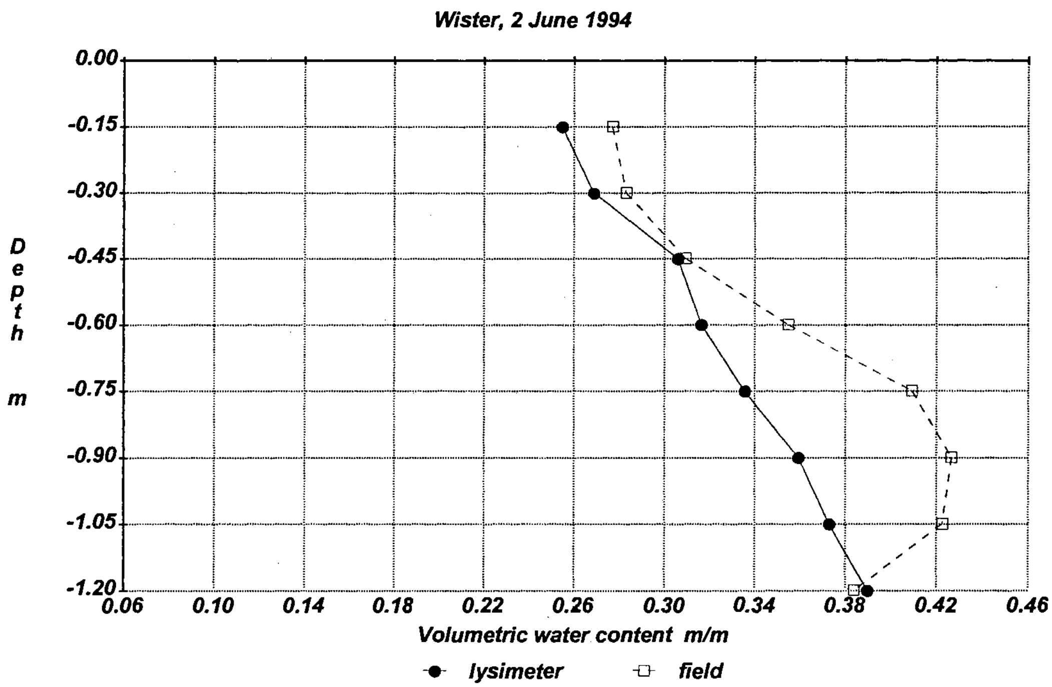
WISTER



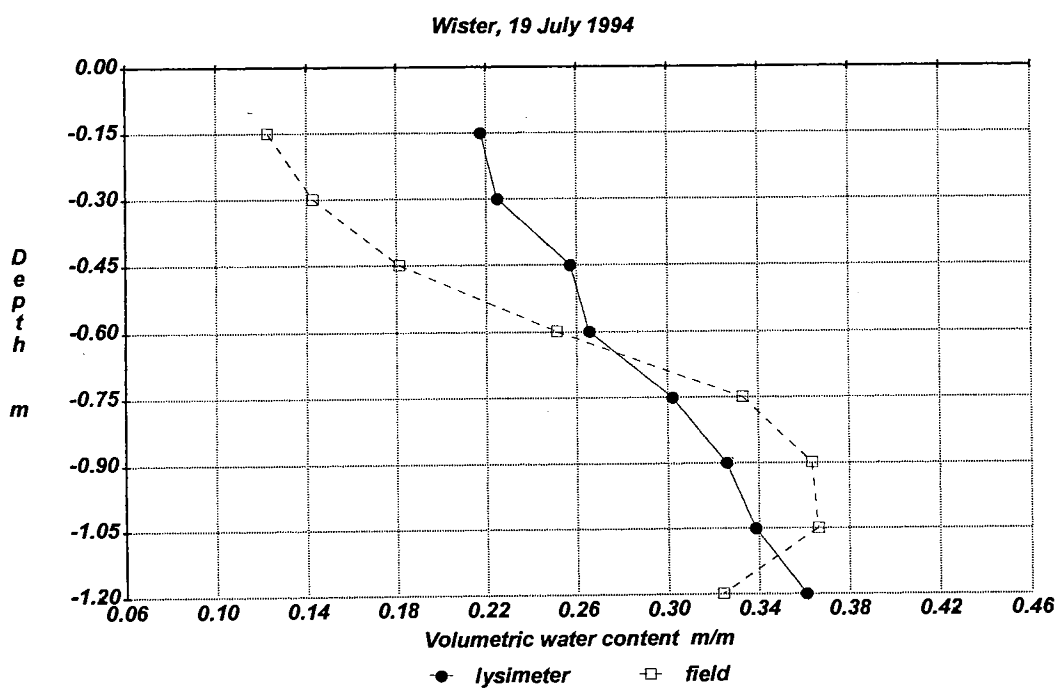
Wister, 18 May 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field



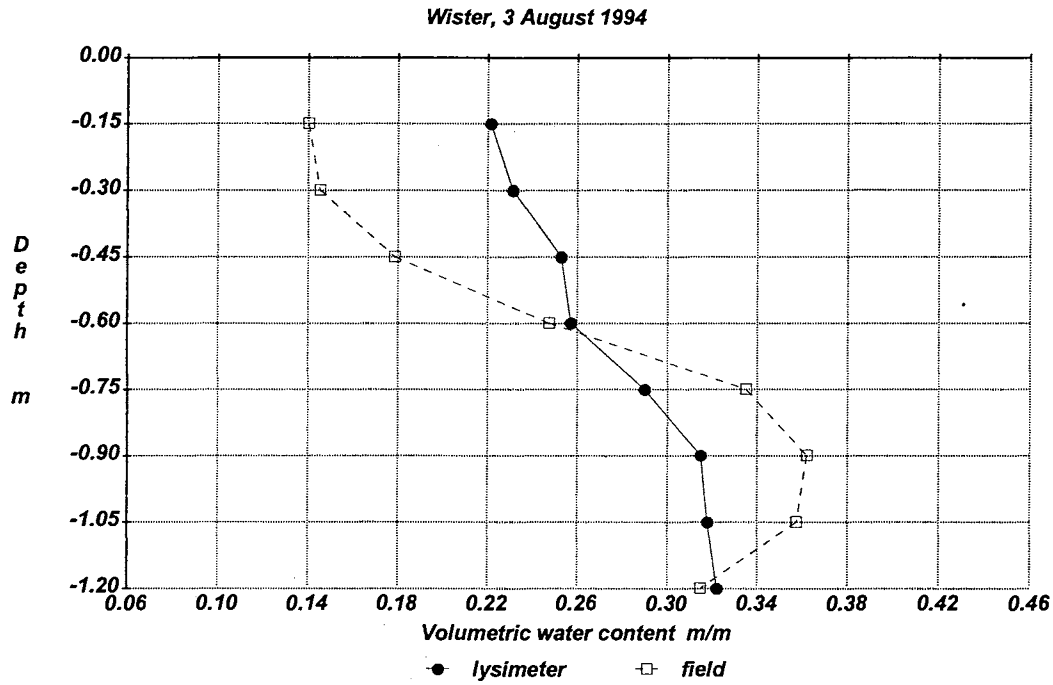
Wister, 25 May 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

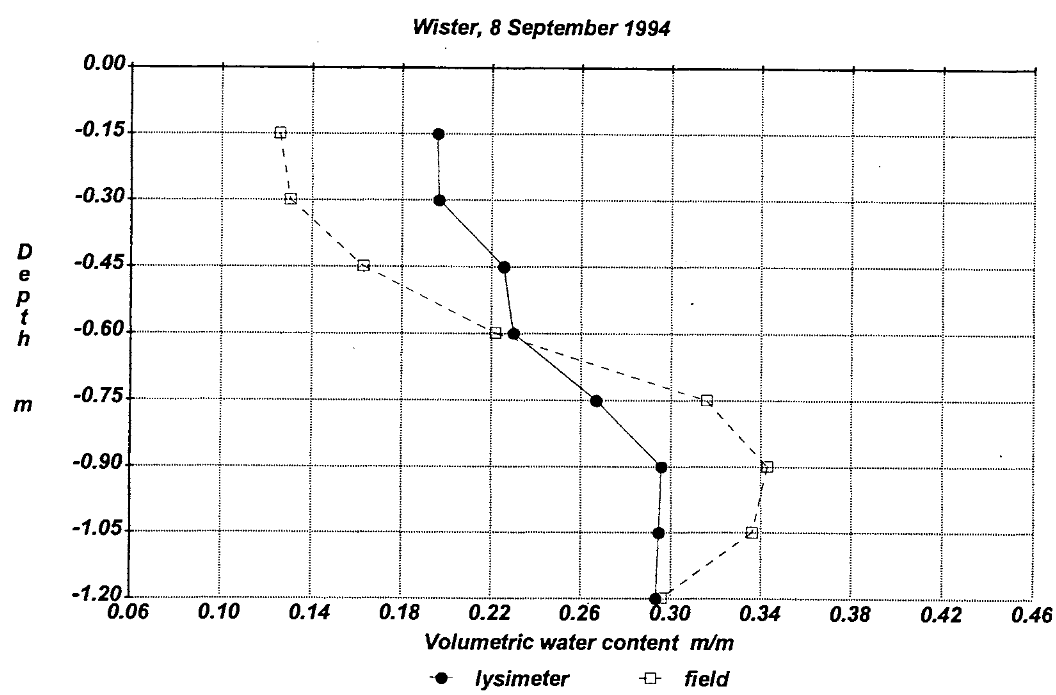


Wister, 2 June 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

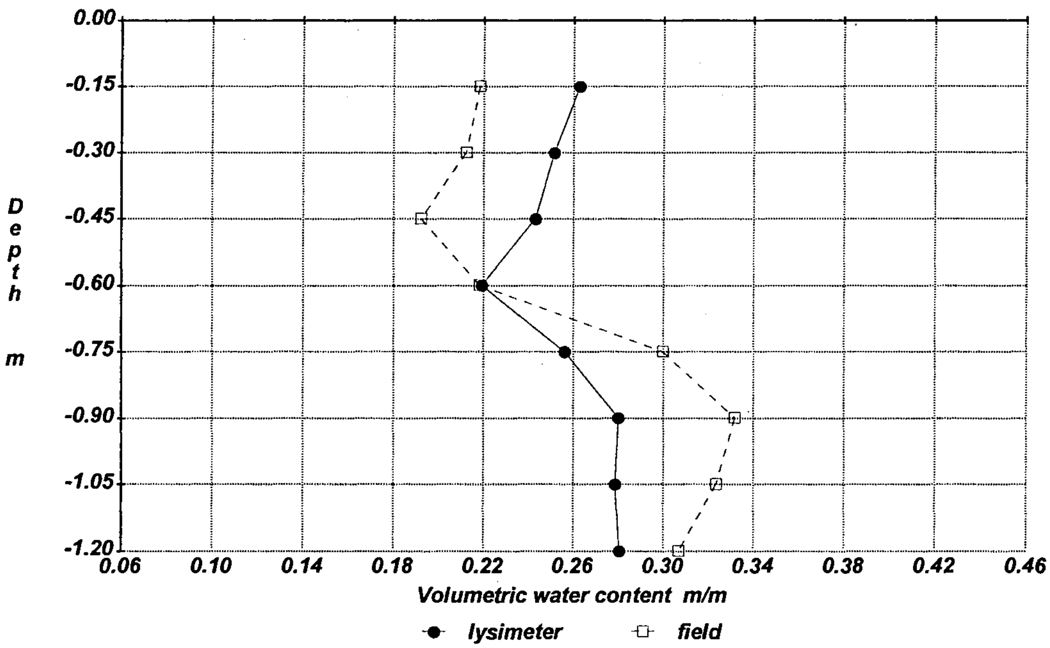


Wister, 19 July 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

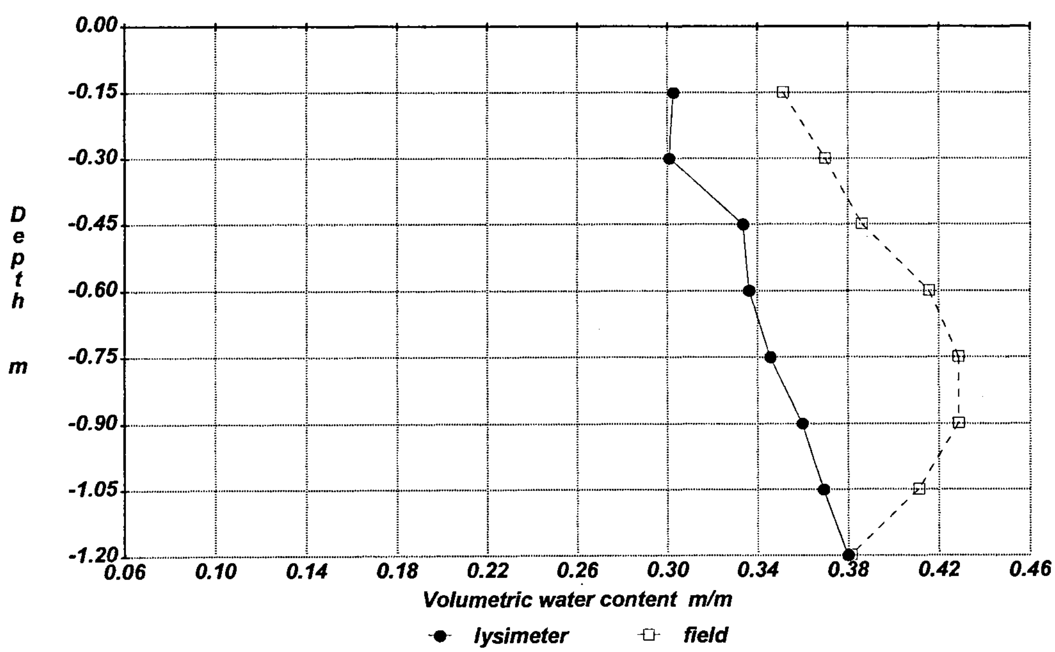

Wister, 3 August 1994
D e p t h m
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
0.06 0.10 0.14 0.18 0.22 0.26 0.30 0.34 0.38 0.42 0.46
Volumetric water content m/m
lysimeter
field

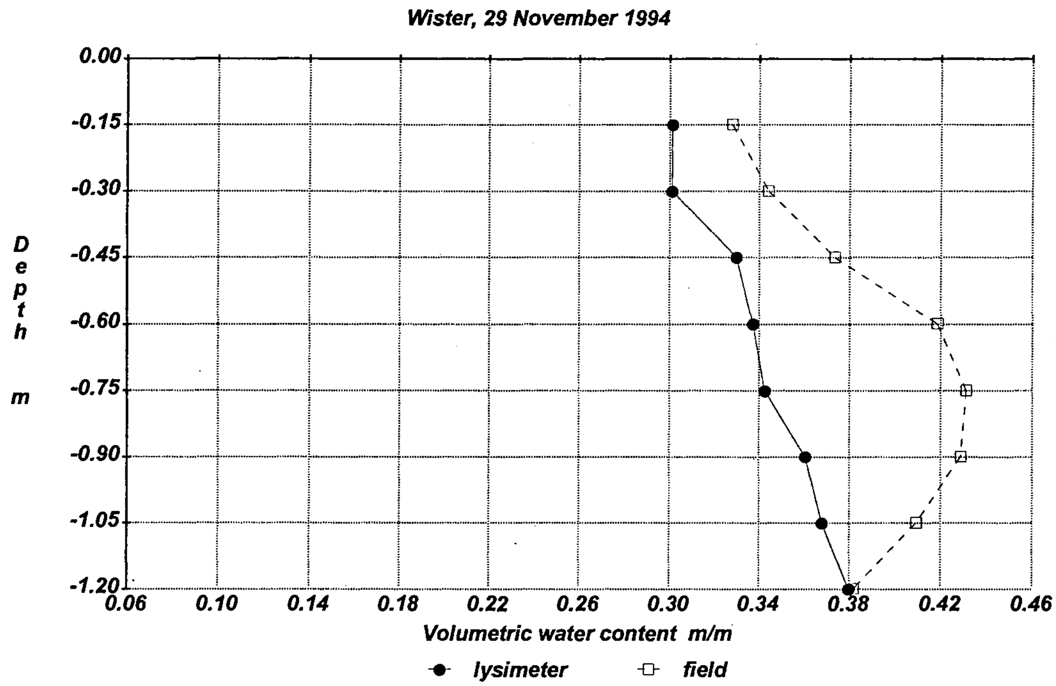

Wister, 8 September 1994
D e p t h m
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
0.06 0.10 0.14 0.18 0.22 0.26 0.30 0.34 0.38 0.42 0.46
Volumetric water content m/m
lysimeter
field

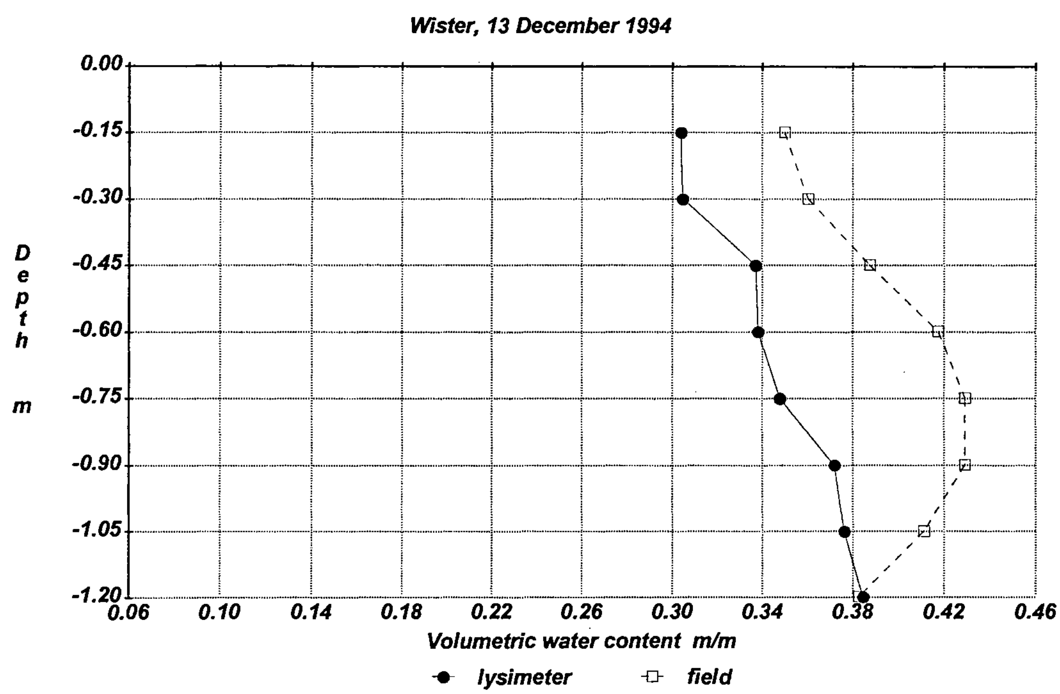
Wister, 26 October 1994

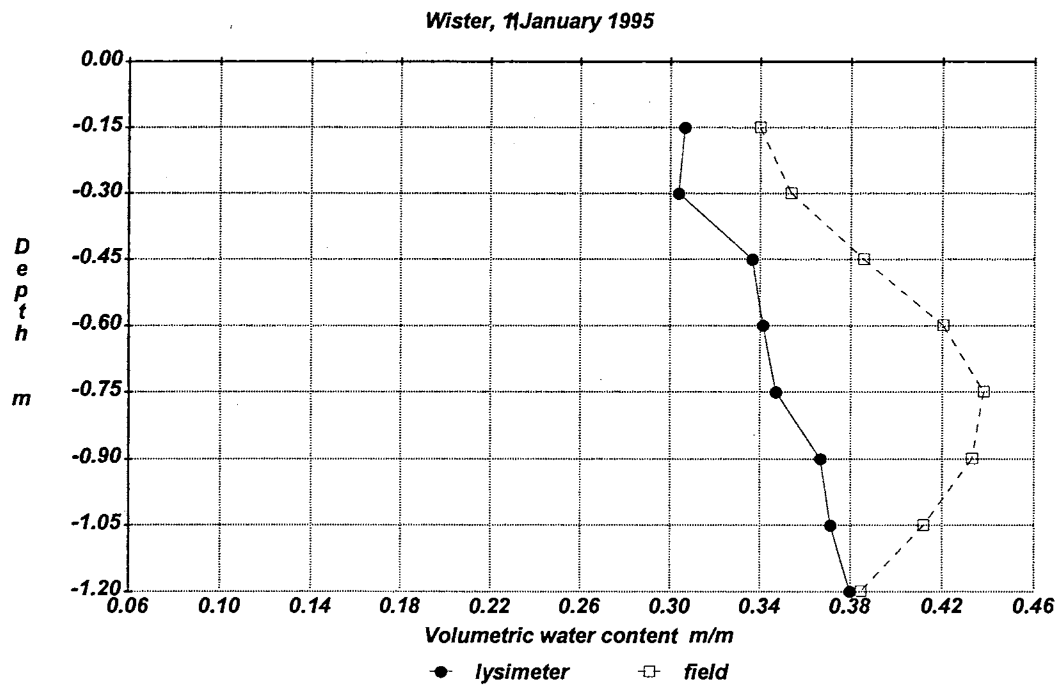


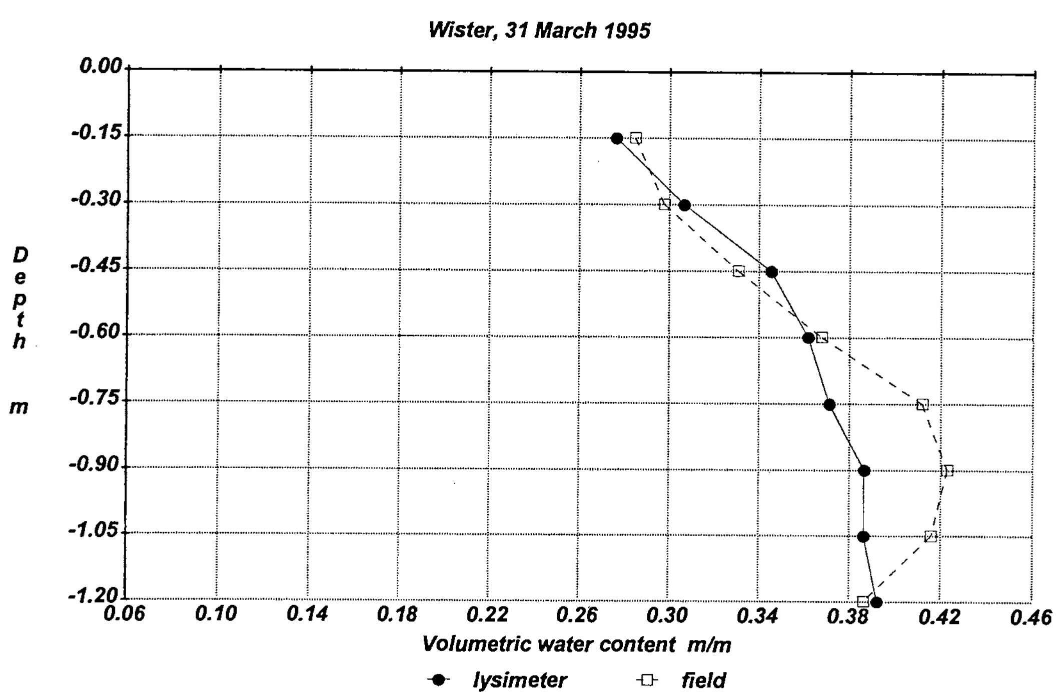
Wister, 18 November 1994




Wister, 29 November 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field


Wister, 13 December 1994
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
D e p t h m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field


Wister, 11 January 1995
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field


Wister, 31 March 1995
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
-1.20
Depth m
0.06
0.10
0.14
0.18
0.22
0.26
0.30
0.34
0.38
0.42
0.46
Volumetric water content m/m
lysimeter
field

APPENDIX D

DAILY LYSIMETER AND WEATHER DATA SUMMARIES

GOODWELL

Date	ET lys mm	ET std dev mm	RH max %	RH min %	T air avg C	T air max C	T air min C	Atm pres kPa	Rs MJ/m^2	Rain mm	Wind run km	Wind day/ night ratio	T dew avg C	Vap pres defct kPa
517	2.29	0.06	94	35	25.8	31.1	16.7	901	28.48	0.00	650.0	1.9	16.2	1.65
518	1.07	0.09	95	51	23.7	26.8	15.6	904	15.16	0.00	437.3	3.5	16.2	1.03
519	1.48	0.11	94	38	24.0	28.8	11.1	903	23.82	0.00	431.7	2.9	12.5	1.42
520	2.35	0.09	85	32	25.1	30.5	11.7	900	28.34	0.00	568.2	2.0	11.5	1.90
521	1.85	0.07	79	27	26.1	32.1	14.5	901	26.59	0.00	396.6	1.4	11.9	2.16
522	-3.75	0.08	95	30	23.8	31.5	14.0	904	18.85	4.06	281.8	2.1	13.5	1.53
523	2.80	0.08	99	23	25.3	31.8	12.9	902	27.64	0.00	263.3	2.4	13.7	1.82
524	-12.61	0.09	99	38	22.7	29.8	13.4	901	20.98	11.18	229.5	3.1	15.0	1.11
525	-20.12	0.08	97	55	19.7	25.4	12.6	899	14.64	21.84	108.9	2.3	14.2	0.62
526	1.07	0.03	94	58	16.5	19.5	9.9	902	10.40	0.00	269.4	5.7	11.3	0.45
527	2.79	0.03	98	53	18.7	22.8	10.1	903	18.34	0.00	337.0	1.9	12.8	0.76
528	4.87	0.12	98	33	26.0	32.2	13.1	899	28.45	0.00	306.6	1.4	15.2	1.79
529	5.07	0.13	96	21	26.1	31.8	13.3	900	30.84	0.00	214.3	2.6	11.5	2.20
530	4.49	0.09	82	22	29.3	35.2	15.5	901	30.64	0.00	214.3	0.6	14.3	2.62
531	1.19	0.10	86	26	30.0	35.9	18.3	902	25.01	2.03	327.8	9.0	15.3	2.70
601	3.98	0.09	84	27	28.3	33.5	18.5	901	28.03	0.00	464.3	2.5	15.4	2.27
602	-0.92	0.08	99	36	26.8	31.8	16.7	903	26.77	4.06	315.1	1.5	16.4	1.72
603	2.84	0.06	99	52	23.2	27.9	17.6	906	21.65	0.00	311.7	1.5	17.5	0.88
604	3.72	0.07	95	23	29.7	35.8	18.2	899	29.69	0.00	526.5	1.8	16.2	2.53
605	3.65	0.12	96	20	31.4	36.9	16.0	896	30.88	0.00	269.3	3.2	14.2	3.30
606	2.44	0.12	98	30	29.6	35.8	17.2	896	29.18	0.00	415.7	1.9	17.1	2.28
607	2.36	0.06	87	7	33.8	39.6	16.0	892	31.29	0.00	413.0	2.5	4.7	4.50
608	1.49	0.09	95	25	27.2	31.7	17.0	898	30.02	0.00	380.3	2.2	16.6	1.81
609	-39.99	0.09	98	45	22.9	27.8	14.7	904	22.67	30.99	388.6	1.8	15.0	1.22
610	4.60	0.10	96	49	24.0	28.8	16.3	904	29.14	0.00	293.1	1.0	17.6	1.08
611	3.80	0.10	86	26	27.0	32.0	17.1	901	28.66	0.25	505.6	1.8	14.8	1.91
612	4.65	0.04	90	30	29.8	35.4	16.5	897	30.11	0.00	449.9	1.9	15.6	2.53
613	4.79	0.03	69	13	33.6	39.5	21.5	894	30.97	0.00	545.6	1.2	13.5	3.95
614	1.56	0.04	84	30	31.8	36.4	20.8	892	30.42	0.00	886.3	1.8	16.6	2.95
615	1.62	2.61	85	7	31.6	39.4	20.6	895	31.20	0.00	647.6	1.5	14.5	3.33
616	-5.12	2.61	84	6	33.5	40.1	21.9	897	32.21	0.00	574.8	1.4	11.7	4.21
617	0.95	0.12	80	21	33.1	39.6	21.4	900	27.66	0.00	510.8	1.7	16.6	3.35
618	6.75	0.13	81	24	31.5	36.1	19.3	903	30.86	0.00	367.7	3.6	15.5	2.98
619	-4.02	0.14	86	29	30.4	34.8	18.9	904	27.31	0.00	330.0	1.8	15.6	2.79
620	1.58	0.13	87	26	30.6	36.3	18.9	904	27.83	0.00	314.1	2.9	15.4	2.83
621	5.49	0.05	90	35	28.0	33.4	21.0	903	16.49	0.25	272.8	2.2	17.0	1.96
622	3.53	0.08	94	18	31.4	39.2	17.4	898	26.99	1.27	412.5	3.9	16.2	3.10
623	—	0.10	90	30	27.3	32.0	18.3	901	29.69	0.00	384.0	6.0	14.3	2.03
624	4.44	0.08	82	17	32.4	37.8	17.3	900	28.41	0.00	304.5	3.6	10.0	3.80
625	2.18	0.21	78	7	36.7	44.0	19.2	897	29.87	0.00	340.4	3.5	8.7	5.52
626	1.82	0.21	82	20	32.2	39.3	17.6	900	31.08	0.00	328.0	2.7	13.9	3.52
627	1.39	0.13	62	14	34.2	37.9	17.9	900	31.10	0.00	434.8	7.0	8.5	4.45
628	0.52	0.14	81	19	31.8	38.1	18.6	903	28.53	0.25	302.2	1.4	14.9	3.22
629	-6.92	0.12	89	20	31.1	39.7	17.8	902	24.15	3.56	395.6	2.2	15.6	3.23
630	3.00	0.09	90	16	32.0	40.4	17.7	899	27.25	0.00	293.0	2.1	14.1	3.27
701	-6.60	0.03	79	13	32.0	42.3	18.4	897	22.57	5.08	445.1	2.4	14.0	3.62
702	-3.97	0.03	82	18	33.4	40.3	21.9	896	27.66	4.57	465.7	2.1	16.0	3.65
703	0.14	0.08	89	21	30.2	39.1	20.6	897	23.11	1.52	377.4	1.9	17.4	2.57
704	4.15	0.10	86	17	32.1	37.9	20.7	898	23.68	0.00	636.6	2.4	13.6	3.38
705	2.70	0.06	74	15	32.0	38.2	18.2	898	23.39	0.00	485.9	4.0	12.8	3.36
706	0.60	0.13	87	26	30.9	37.0	16.7	896	30.15	0.00	570.3	1.8	17.4	2.84
707	-0.17	0.13	93	41	24.0	27.9	11.8	900	27.00	0.00	514.9	6.1	13.5	1.42

708	2.07	0.08	91	21	23.9	31.2	11.4	907	29.33	0.00	249.0	1.1	10.0	1.97
709	1.42	0.09	89	17	29.2	34.2	16.8	906	28.12	0.00	356.4	2.2	12.3	2.84
710	2.02	0.11	91	17	30.4	35.8	16.8	905	29.86	0.00	416.0	1.7	13.4	3.13
711	-1.76	0.09	93	26	30.6	36.9	18.0	901	29.21	1.52	378.9	2.3	17.3	2.60
712	2.55	0.09	94	29	28.4	34.5	16.9	901	27.98	0.00	292.2	1.2	16.4	2.11
713	-0.79	0.11	96	36	28.1	33.5	16.5	902	26.90	1.27	310.3	1.3	16.0	2.12
714	2.68	0.08	96	33	27.2	32.9	16.7	905	27.65	0.00	224.3	2.3	16.4	1.98
715	-8.43	0.05	97	25	30.8	37.5	16.4	904	25.79	4.06	388.6	4.8	16.8	2.75
716	-3.60	0.06	97	29	29.3	35.3	16.5	905	26.42	3.56	431.5	2.3	17.1	2.29
717	4.11	0.11	91	30	29.3	34.8	18.4	906	26.26	0.00	401.7	2.5	16.3	2.30
718	3.63	0.11	72	23	32.5	37.3	21.7	902	27.58	0.00	552.0	2.0	12.8	3.44
719	2.62	0.13	95	17	34.3	40.4	20.2	897	28.38	0.25	497.1	2.4	14.6	4.22
720	1.76	0.14	90	49	25.6	29.9	19.3	904	25.47	0.00	363.7	4.5	17.9	1.29
721	1.62	0.13	94	26	27.9	33.1	18.8	906	23.39	0.00	228.2	1.6	13.8	2.19
722	2.49	0.12	76	22	32.2	38.0	18.5	902	22.53	0.00	282.6	3.6	15.3	3.22
723	1.74	0.05	81	17	33.7	40.3	17.5	903	26.20	0.00	240.3	1.7	13.9	4.06
724	-3.53	0.03	98	22	31.0	39.2	18.9	902	21.06	2.03	408.8	1.0	16.0	2.12
725	-11.87	0.04	98	37	27.7	34.0	18.3	903	27.43	5.08	517.5	1.5	18.5	1.69
726	1.00	0.05	92	50	22.5	25.9	13.8	907	18.25	0.00	517.5	1.5	15.4	0.90
727	2.47	0.09	91	34	26.0	30.4	14.2	906	25.42	0.00	344.4	7.0	13.6	1.92
728	2.26	0.11	86	25	27.4	32.8	14.6	904	28.59	0.00	277.4	1.3	12.6	2.38
729	1.54	0.08	91	22	28.0	33.3	16.6	903	26.00	0.00	340.5	2.7	13.7	2.46
730	1.83	0.05	93	27	28.8	33.6	16.9	902	28.04	0.00	462.7	1.3	15.3	2.47
731	2.32	0.07	93	25	30.9	36.1	18.5	902	27.80	0.00	447.7	2.1	16.3	2.81
801	-7.89	0.11	97	31	29.8	35.3	19.7	902	22.95	4.32	426.8	1.5	18.3	2.29
802	1.84	0.10	92	54	24.6	28.3	19.7	903	17.41	0.00	394.0	1.9	18.5	0.90
803	0.52	0.09	92	39	27.5	32.5	18.8	903	23.69	1.02	283.9	1.9	17.9	1.72
804	2.98	0.09	93	32	28.5	32.5	16.1	907	27.17	0.00	290.1	4.5	16.5	2.05
805	1.67	0.08	92	35	27.0	32.1	17.4	909	24.54	0.00	353.9	1.5	15.7	1.83
806	1.73	0.08	85	21	32.7	38.9	19.2	900	26.47	0.00	452.5	3.6	15.3	3.52
807	2.07	0.14	82	14	33.7	40.6	19.2	899	24.17	0.00	276.2	2.1	13.0	3.99
808	0.85	0.15	90	28	31.5	36.8	20.1	903	23.09	0.00	470.2	1.7	17.1	2.91
809	0.53	0.09	92	36	30.3	35.7	19.4	906	26.58	0.00	516.8	1.7	16.7	2.30
810	2.16	0.06	87	32	30.8	36.6	19.9	905	23.59	1.02	405.4	3.6	15.4	2.78
811	1.78	0.10	87	25	31.1	35.9	19.4	906	25.22	0.00	379.6	1.8	14.6	2.91
812	1.37	0.11	73	22	32.2	37.0	19.5	904	27.76	0.00	489.0	2.6	12.9	3.46
813	-13.74	0.08	97	22	33.2	39.2	19.1	903	23.58	6.86	358.2	2.0	16.1	3.71
814	-10.35	0.04	98	73	19.5	21.0	13.9	911	8.51	5.84	260.7	4.9	16.3	0.19
815	2.99	0.03	93	29	23.1	28.2	14.2	907	21.85	0.00	254.6	1.9	12.1	1.48
816	3.05	0.05	83	24	28.3	34.9	14.4	902	26.87	0.00	358.4	1.4	16.0	2.33
817	4.26	0.07	98	25	32.3	37.9	16.7	900	26.82	0.00	227.9	2.4	17.0	3.20
818	2.31	0.27	99	18	31.6	39.6	16.5	901	26.01	0.25	266.7	1.6	17.5	3.03
819	-0.43	0.27	91	28	30.5	35.7	17.0	900	25.00	1.52	370.6	1.1	16.8	2.55
820	1.17	0.06	97	36	22.5	27.5	14.7	905	15.09	0.00	201.3	3.9	14.7	1.10
821	2.26	0.07	97	30	26.5	31.2	15.4	903	26.38	0.00	405.3	2.0	13.2	2.01
822	1.92	0.08	83	39	28.7	33.3	16.3	900	24.10	0.00	493.7	2.1	15.8	2.11
823	-3.35	0.10	94	34	31.0	37.0	18.4	902	23.75	3.30	472.8	1.4	18.1	2.60
824	-14.06	0.11	87	29	29.1	35.4	19.1	906	20.99	8.89	341.2	2.2	17.7	2.23
825	3.59	0.09	83	23	32.7	37.8	21.8	903	24.94	0.00	500.4	1.8	15.1	3.28
826	3.06	0.04	74	17	32.9	38.0	18.9	903	26.26	0.00	234.0	2.3	13.2	3.65
827	3.39	0.07	71	18	34.3	38.9	19.8	902	24.79	0.00	513.6	1.6	13.1	4.11
828	1.82	0.07	91	36	30.5	34.8	18.1	903	24.89	0.00	337.0	1.5	16.9	2.55
829	0.87	0.04	90	27	27.2	35.0	18.6	902	14.23	0.00	262.9	1.4	15.3	1.93
830	-0.45	0.05	96	43	25.7	30.6	18.2	900	8.03	0.25	236.2	0.8	17.7	1.30
831	-10.15	0.04	100	87	18.1	18.8	15.0	907	5.09	3.81	381.9	1.7	16.4	0.14
901	0.49	0.05	100	86	17.2	19.4	15.0	908	5.68	0.00	340.7	1.3	16.1	0.15
902	2.95	0.08	100	45	26.5	31.9	16.9	906	20.27	0.00	484.2	1.2	18.9	1.41
903	2.62	0.12	94	36	29.2	33.5	19.5	903	22.75	0.00	579.2	1.8	15.9	2.22
904	1.08	0.12	89	31	28.9	33.6	18.1	901	15.46	0.00	333.3	3.4	15.7	2.38
905	1.63	0.10	99	39	26.7	30.5	16.1	907	22.78	0.00	336.2	3.6	17.0	1.77

906	0.65	0.08	100	49	24.2	28.3	16.4	910	13.63	0.00	321.9	1.5	17.3	1.06
907	-20.20	0.07	99	30	28.0	33.1	12.6	905	22.96	9.40	450.5	1.6	14.9	2.16
908	2.61	0.08	98	46	24.4	28.6	13.4	906	22.81	0.00	214.9	2.6	15.6	1.33
909	3.24	0.05	97	38	25.6	30.6	13.4	905	23.76	0.00	392.4	1.2	16.2	1.58
910	2.28	0.11	93	38	26.7	31.6	17.6	903	21.62	0.00	640.0	1.4	16.1	1.75
911	2.30	0.11	87	34	28.1	32.7	18.4	903	23.01	0.00	681.3	1.7	15.6	2.10
912	2.18	0.08	89	33	27.9	32.4	18.3	904	22.99	0.00	600.6	1.7	15.9	2.11
913	2.41	0.08	90	36	28.7	33.1	18.4	902	22.76	0.00	624.9	1.4	16.7	2.13
914	0.90	0.08	94	32	28.3	33.1	14.7	900	17.18	0.00	611.1	1.6	15.9	2.06
915	0.86	0.18	79	19	24.5	28.7	9.8	903	23.61	0.00	266.0	3.1	6.4	2.19
916	0.97	0.18	80	23	22.9	27.4	9.9	909	23.00	0.00	156.7	1.9	5.1	2.00
917	1.62	0.08	79	18	26.3	32.0	10.6	909	20.95	0.00	216.2	1.0	6.8	2.68
918	1.83	0.07	80	21	26.3	32.9	11.6	907	22.44	0.00	282.4	1.4	8.3	2.57
919	1.46	0.07	81	18	27.1	33.9	13.6	905	21.25	0.00	390.3	1.1	10.3	2.59
920	0.78	0.13	90	34	24.6	30.5	12.8	903	20.26	0.00	194.1	1.2	12.7	1.73
921	-1.80	0.16	92	27	24.6	30.1	4.3	901	17.18	0.25	570.5	0.7	8.1	1.83
922	0.50	0.13	85	21	13.8	18.5	4.2	907	22.77	0.00	436.0	3.0	-2.5	1.08
923	0.05	0.09	87	20	19.1	23.2	3.4	898	20.09	0.00	370.6	1.1	0.0	1.72
924	0.78	0.07	86	33	17.5	23.6	4.3	904	21.49	0.00	363.0	1.1	5.3	1.24
925	1.11	0.05	78	25	20.8	26.1	9.6	906	20.95	0.00	363.0	1.1	6.0	1.55
926	0.43	0.09	60	10	26.7	32.9	9.8	899	21.75	0.00	263.2	2.2	1.8	2.98
927	0.46	0.09	49	10	27.2	33.7	9.8	901	20.98	0.00	227.8	2.5	-0.1	3.24
928	1.14	0.09	56	8	29.3	36.9	9.8	901	20.93	0.00	304.7	0.8	1.5	3.83
929	0.78	0.12	55	5	30.4	38.2	10.5	897	21.33	0.00	398.7	1.2	0.9	4.20
930	0.73	0.09	83	13	29.7	36.0	15.5	895	19.82	0.00	483.8	1.3	5.7	3.52
1001	-3.66	0.11	95	37	22.0	28.1	13.4	897	12.18	1.78	230.3	1.2	13.1	1.25
1002	0.58	0.13	100	57	18.1	22.7	11.0	894	13.88	1.78	192.6	3.1	13.3	0.53
1003	1.33	0.09	100	38	20.6	27.5	15.0	900	13.17	0.00	294.3	0.9	15.4	0.82
1004	-6.15	0.06	100	49	22.6	27.5	16.1	906	15.49	3.81	415.4	1.3	16.1	1.00
1005	1.84	0.09	97	43	23.3	27.4	15.1	898	12.00	0.00	721.9	1.0	15.1	0.90
1006	0.65	0.19	76	14	23.2	27.3	9.1	889	20.39	0.00	551.4	1.9	-0.4	2.28
1007	-0.57	0.18	76	27	14.4	17.8	5.5	903	8.97	0.00	289.4	2.0	0.8	1.00
1008	0.32	0.04	79	23	15.1	19.4	1.7	910	19.20	0.00	305.8	3.5	-1.3	1.18
1009	0.92	0.08	77	18	17.1	22.4	2.0	910	19.59	0.00	217.1	1.1	-1.3	1.54
1010	0.81	0.07	76	17	18.3	24.1	3.0	906	19.32	0.00	423.8	1.0	0.0	1.66
1011	0.50	0.06	75	14	19.8	25.4	7.0	903	19.27	0.00	501.1	1.4	0.0	1.89
1012	0.24	0.06	81	13	21.1	27.5	4.8	900	19.10	0.00	330.4	2.7	-0.7	2.11
1013	0.50	0.08	94	20	18.3	24.8	4.2	904	18.44	0.00	275.4	1.3	4.0	1.54
1014	-3.42	0.16	97	55	14.9	17.6	8.9	901	7.16	2.03	628.6	0.7	9.7	0.51
1015	1.60	0.16	94	29	17.0	20.3	10.4	888	15.69	0.25	704.2	1.6	7.8	0.96
1016	0.88	0.11	97	30	21.6	25.2	14.4	896	11.94	0.00	402.6	1.5	12.6	1.19
1017	-0.44	0.09	93	16	21.1	23.6	5.8	895	18.08	0.00	508.9	2.0	1.9	1.59
1018	-0.19	0.04	80	14	17.8	22.8	2.1	898	17.85	0.00	147.7	1.4	-2.2	1.67
1019	0.55	0.04	96	34	16.8	21.5	2.5	902	16.42	0.00	157.7	1.3	4.5	1.14
1020	0.40	0.06	93	19	19.9	26.4	4.4	902	17.05	0.00	330.0	1.0	3.9	1.56
1021	0.20	0.08	70	16	19.1	23.6	5.8	900	17.21	0.00	243.4	1.2	-1.1	1.74
1022	-0.02	0.08	76	23	17.7	22.1	3.5	901	16.99	0.00	312.7	2.9	0.7	1.48
1023	0.52	0.08	90	32	17.5	23.7	3.3	903	16.35	0.00	339.6	1.6	5.5	1.24
1024	-0.06	0.05	66	30	12.7	15.6	6.4	908	10.82	0.00	364.8	1.8	-1.4	0.95
1025	-0.37	0.03	82	31	11.3	14.8	2.0	910	16.03	0.00	280.3	0.8	-1.0	0.78
1026	0.24	0.03	83	40	13.7	18.5	2.3	906	15.24	0.00	553.2	1.4	2.2	0.86
1027	0.12	0.05	95	30	17.1	23.5	5.2	901	15.90	0.00	366.7	0.7	5.8	1.21
1028	0.18	0.06	94	21	19.8	27.5	6.5	895	15.23	0.00	565.7	0.9	6.3	1.62
1029	-0.11	0.07	97	43	11.6	14.6	7.6	904	6.83	0.00	328.1	3.9	4.4	0.71
1030	-12.65	0.06	97	73	11.8	13.0	3.7	901	2.65	5.59	343.4	0.3	7.0	0.26
1031	0.85	0.02	93	23	11.2	15.9	2.9	906	15.59	0.00	248.7	0.8	1.0	0.72
1101	2.33	0.12	79	17	19.3	26.5	4.5	892	15.81	0.00	456.5	0.7	0.1	1.75
1102	0.28	0.15	94	8	21.2	28.6	1.6	887	11.69	0.00	458.1	1.6	-1.5	2.21
1103	-0.23	0.10	97	50	8.7	14.0	1.5	896	12.98	0.25	354.1	0.5	3.6	0.43
1104	-0.90	0.06	98	79	4.6	6.1	-3.2	898	3.40	0.25	183.6	3.4	1.1	0.11

1105	0.97	0.06	97	26	11.1	18.7	-3.9	898	14.95	0.00	143.7	1.0	0.8	0.81
1106	1.77	0.06	93	24	16.7	23.1	1.3	905	14.54	0.00	650.6	0.9	4.4	1.28
1107	1.64	0.06	75	24	19.5	26.0	9.9	899	10.81	0.00	626.7	1.0	5.4	1.46
1108	-2.65	0.05	92	35	12.4	15.1	-1.1	898	5.66	0.51	336.5	1.1	2.1	0.59
1109	-0.15	0.06	93	47	6.5	10.2	-2.8	908	14.38	0.00	216.4	1.4	-1.5	0.41
1110	1.46	0.13	91	39	10.7	16.4	-0.9	904	14.27	0.00	526.8	1.0	1.7	0.67
1111	1.27	0.12	80	32	17.1	23.0	6.3	900	13.38	0.00	580.6	1.2	5.7	1.22
1112	-1.46	0.10	94	78	11.9	15.0	10.7	895	3.69	1.02	728.3	0.9	11.2	0.17
1113	-0.41	0.12	87	12	16.2	19.4	-0.6	895	14.23	0.00	493.3	1.7	-2.1	1.24
1114	-0.28	0.10	91	44	6.9	9.4	-4.9	910	10.13	0.00	333.5	2.0	-3.3	0.47
1115	0.37	0.06	90	35	7.0	11.4	-4.4	914	13.81	0.00	256.2	0.4	-3.8	0.57
1116	1.10	0.04	76	30	11.5	15.3	1.3	899	11.33	0.00	800.3	0.9	-0.6	0.87
1117	-0.75	0.07	77	10	13.8	16.6	-3.0	890	13.34	0.00	593.6	2.3	-10.9	1.18
1118	1.23	0.16	89	10	9.4	16.6	-4.2	902	13.48	0.00	469.7	0.8	-5.4	1.05
1119	-6.36	0.20	99	72	7.2	9.3	0.0	899	1.59	3.81	309.4	0.5	5.8	0.03
1120	-2.94	0.18	97	53	2.9	6.8	-1.1	885	7.45	1.02	449.1	1.8	-1.3	0.17
1121	0.75	0.12	93	47	6.8	9.9	-1.9	906	12.88	0.00	245.4	1.0	-1.4	0.44
1122	0.00	0.07	94	60	1.0	1.8	-4.4	917	2.65	0.00	238.9	1.9	-4.2	0.19
1123	0.89	0.19	93	46	6.4	11.4	-3.9	915	12.79	0.00	481.4	0.9	0.5	0.41
1124	0.25	0.23	92	20	10.0	16.5	-2.8	903	12.13	0.00	208.0	1.3	-4.2	0.81
1125	0.44	0.17	92	38	5.2	9.3	-1.0	902	5.35	0.00	220.7	0.5	-1.8	0.41
1126	1.48	0.14	82	11	14.8	22.5	0.3	890	12.56	0.00	519.9	0.8	-2.8	1.36
1127	-0.81	0.10	69	12	5.6	8.6	-6.5	895	10.80	0.00	446.7	1.9	-13.9	0.72
1128	0.15	0.05	69	12	5.8	9.8	-6.7	898	12.67	0.00	267.0	1.4	-12.7	0.76
1129	0.14	0.03	65	12	3.2	6.4	-6.9	911	12.52	0.00	317.1	0.9	-16.0	0.63
1130	1.32	0.02	57	16	10.9	16.3	-3.4	908	12.19	0.00	321.7	0.6	-8.6	1.07
1201	0.57	0.02	54	9	15.6	22.7	1.4	900	12.62	0.00	539.7	1.2	-7.5	1.57
1202	-0.28	0.04	72	8	15.5	22.7	-1.4	893	12.47	0.00	290.0	1.7	-8.5	1.64
1203	0.54	0.05	90	21	13.0	18.4	-1.6	900	12.13	0.00	218.4	0.8	-2.9	1.14
1204	0.38	0.09	98	10	15.3	22.8	-0.3	897	10.44	0.00	373.8	1.4	-2.5	1.50
1205	-6.65	0.66	98	83	2.6	7.2	-0.7	904	2.79	3.30	313.5	0.9	2.3	0.05
1206	-6.37	0.66	99	91	0.5	1.6	-1.9	896	1.48	3.30	229.0	0.5	-0.7	0.01
1207	0.33	0.05	99	77	2.1	7.8	-4.0	905	4.84	0.00	303.4	1.5	-0.3	0.07
1208	-0.23	0.05	97	81	-0.3	0.3	-6.4	906	1.88	0.00	347.9	1.2	-3.5	0.05
1209	0.17	0.06	92	29	0.9	3.8	-6.5	908	11.95	0.00	177.4	0.5	-8.0	0.36
1210	0.64	0.07	81	33	1.1	4.3	-5.0	914	11.67	0.00	347.9	0.7	-7.6	0.35
1211	0.73	0.06	66	37	4.1	8.5	-1.5	899	9.50	0.00	681.7	1.4	-7.2	0.46
1212	0.94	0.09	73	24	6.0	9.3	-1.2	906	8.40	0.00	280.8	1.4	-6.8	0.64
1213	0.19	0.10	90	34	9.7	13.3	-0.2	900	10.34	0.00	582.8	0.8	-1.5	0.63
1214	0.00	0.06	93	41	6.7	9.4	-6.6	900	11.45	0.00	205.1	1.8	-4.0	0.48
1215	0.11	0.08	98	46	5.3	11.7	-5.2	902	8.11	0.00	406.9	1.2	-0.5	0.28
1216	0.32	0.09	78	20	7.3	11.7	-3.8	906	11.65	0.00	277.1	0.7	-8.1	0.74
1217	0.45	0.07	80	24	10.5	14.1	-3.5	910	11.39	0.00	221.2	1.4	-5.7	0.92
1218	1.07	0.08	71	20	11.9	17.0	-0.2	905	11.51	0.00	530.3	0.9	-4.7	1.04
1219	-0.20	0.07	81	8	13.2	17.9	-4.1	898	11.48	0.00	264.0	1.1	-7.0	1.22
1220	-0.08	0.05	75	13	10.5	14.8	-3.1	903	11.47	0.00	311.1	1.7	-11.0	1.11
1221	0.19	0.06	73	18	9.8	15.6	-4.2	907	11.54	0.00	233.1	1.7	-8.0	0.94
1222	0.45	0.06	86	15	11.5	17.8	-4.6	911	11.39	0.00	170.0	0.7	-7.1	1.14
1223	0.44	0.05	87	33	7.3	13.8	-3.2	909	7.47	0.00	162.8	0.9	-2.3	0.55
1224	0.34	0.04	89	24	12.2	16.7	0.4	906	10.55	0.00	304.2	1.0	-2.5	0.98
1225	0.18	0.12	92	44	11.3	15.1	-1.5	905	11.05	0.00	419.7	1.4	1.1	0.65
1226	0.06	0.13	93	41	11.3	16.3	-0.4	903	10.92	0.00	383.4	1.4	1.1	0.69
1227	0.86	0.09	89	37	11.2	16.6	-0.9	903	10.86	0.00	179.5	0.9	0.3	0.76
1228	-0.69	0.09	98	55	7.6	11.3	-2.6	904	7.11	0.00	193.0	1.7	0.1	0.39
1229	0.26	0.07	99	70	4.5	10.2	-1.0	902	3.86	0.25	281.2	0.9	2.5	0.11
1230	-11.32	0.76	98	87	6.0	7.0	-4.7	900	1.56	3.05	424.0	0.6	3.0	0.05
1231	0.13	0.76	95	83	-4.2	-3.5	-11.6	906	5.80	0.00	484.3	1.5	-7.8	0.05
101	0.28	0.09	90	66	-3.1	1.6	-11.4	912	12.11	0.51	245.9	0.8	-7.0	0.12
102	-1.51	0.10	93	57	1.3	5.4	-7.7	912	6.30	0.00	384.9	0.4	-4.3	0.18
103	0.07	0.07	91	74	-6.5	-5.5	-7.8	912	5.67	0.00	253.7	0.7	-8.5	0.07

104	0.34	0.06	92	78	-4.0	-2.7	-6.1	912	4.04	0.25	463.4	0.2	-5.5	0.07
105	-0.19	0.04	96	76	-2.0	2.7	-2.8	912	4.34	0.00	778.0	1.1	-2.2	0.06
106	0.84	0.04	88	44	0.6	3.0	-8.7	912	10.23	0.00	308.4	2.8	-8.5	0.29
107	1.23	0.06	87	28	6.2	13.4	-7.3	912	11.29	0.25	429.9	0.4	-2.0	0.54
108	0.64	0.06	90	24	12.4	16.8	-0.9	912	11.49	0.00	228.7	0.5	-1.8	0.97
109	0.89	0.16	91	24	12.6	18.7	-0.4	912	10.30	0.00	223.2	0.7	-0.2	0.97
110	1.39	0.16	72	18	14.9	20.9	2.2	912	10.42	0.00	287.8	0.6	-2.8	1.26
111	1.40	0.06	50	11	18.5	24.6	5.8	912	11.85	0.00	392.6	1.0	-4.7	1.85
112	-1.04	0.04	84	38	8.9	10.9	-4.3	912	5.68	0.00	270.3	1.7	-3.3	0.61
113	0.35	0.02	83	20	9.1	14.1	-3.8	912	12.13	0.00	171.7	0.7	-6.2	0.83
114	0.63	0.02	80	20	10.3	16.3	-3.4	912	12.26	0.00	297.3	0.7	-5.6	0.93
115	2.09	0.06	69	13	16.5	23.3	0.8	912	10.23	0.00	432.7	0.8	-3.5	1.57
116	-1.21	0.06	88	13	14.2	18.3	-6.1	912	9.04	0.00	554.6	2.1	-7.4	1.21
117	-0.10	0.10	88	37	3.9	7.7	-6.1	912	11.67	0.00	166.1	1.5	-5.9	0.43
118	0.05	0.11	97	28	4.8	8.8	-7.1	912	11.69	0.00	213.2	0.7	-6.8	0.54
119	0.24	0.05	83	23	6.6	12.1	-5.8	912	12.97	0.00	283.3	2.1	-8.0	0.70
120	0.56	0.04	84	36	7.3	11.2	-5.3	912	10.77	0.00	214.0	1.7	-4.5	0.60
121	-0.19	0.12	98	58	0.7	2.6	-2.6	912	5.27	0.25	213.9	0.8	-1.0	0.14
122	-0.33	0.12	97	40	1.3	4.4	-8.5	912	9.44	0.00	282.4	1.5	-7.1	0.23
123	0.34	0.05	88	15	6.5	12.7	-7.9	912	13.81	0.00	253.6	1.8	-7.7	0.74
124	0.42	0.08	84	17	7.3	14.9	-4.3	912	11.67	0.00	156.5	0.9	-8.3	0.77
125	0.54	0.43	93	32	8.4	13.7	-3.9	912	12.48	0.00	190.0	1.1	-1.8	0.66
126	-1.93	0.42	98	67	8.2	10.1	4.5	912	2.67	1.52	467.6	0.6	5.4	0.07
127	0.53	0.06	92	74	7.4	8.2	3.1	912	5.06	0.00	729.9	1.0	2.9	0.23
128	-1.77	0.08	94	69	4.4	6.0	-1.8	912	4.56	0.00	581.0	1.1	-0.5	0.21
129	-1.19	0.09	92	54	1.1	3.4	-5.9	912	9.81	0.25	426.0	2.1	-5.0	0.20
130	0.98	0.12	85	13	7.4	13.8	-5.5	912	14.64	0.00	236.9	1.4	-8.4	0.76
131	1.09	0.10	75	12	11.3	17.0	-3.2	912	14.17	0.00	295.8	0.9	-4.4	1.05
201	1.22	0.05	74	16	17.8	23.4	3.0	912	13.90	0.00	225.5	2.7	-15.6	1.62
202	0.77	0.06	77	18	16.5	23.1	1.7	912	10.66	0.00	446.2	0.9	-2.5	1.45
203	-0.42	0.06	73	17	9.6	13.1	-3.0	912	14.57	0.00	473.9	2.3	-8.1	0.83
204	0.50	0.08	84	12	16.0	22.6	-5.4	912	14.91	0.00	331.6	2.5	-6.1	1.57
205	-0.03	0.07	85	32	7.1	12.9	-5.2	912	12.48	0.00	194.4	1.2	-3.7	0.59
206	0.93	0.03	84	23	10.4	16.4	-2.8	912	15.17	0.00	204.9	0.6	-4.3	0.90
207	-0.46	0.06	83	23	3.9	6.8	-6.7	912	14.49	0.00	291.3	2.5	-10.1	0.49
208	0.50	0.07	74	22	8.7	13.8	-3.7	912	13.26	0.00	579.0	1.9	-6.4	0.82
209	0.25	0.07	77	30	8.6	14.1	-2.9	912	15.60	0.00	313.1	0.9	-5.0	0.73
210	-0.44	0.09	92	32	5.8	9.5	-5.9	912	15.86	0.00	382.4	0.5	-6.7	0.56
211	-2.71	0.39	91	77	-6.7	-5.2	-8.9	912	7.58	0.00	406.1	0.8	-9.3	0.06
212	-1.21	0.39	94	85	-6.4	-4.9	-8.7	912	5.11	0.00	435.7	2.7	-8.1	0.05
213	-0.96	0.08	99	92	-5.7	1.1	-7.4	912	4.74	0.00	542.8	1.7	-4.3	0.03
214	2.37	0.12	99	35	10.7	20.5	-4.1	912	8.87	2.03	649.9	0.8	2.0	0.58
215	-0.43	0.14	90	37	-0.2	3.6	-8.2	912	12.64	0.00	220.6	2.1	-8.7	0.32
216	0.75	0.09	89	18	4.7	10.5	-8.3	912	16.86	0.00	289.7	1.7	-9.1	0.59
217	1.13	0.08	64	13	12.9	18.4	-2.7	912	17.79	0.00	500.5	1.2	-9.3	1.28
218	0.95	0.06	87	10	14.4	20.0	-0.8	912	15.78	0.00	448.2	1.6	-4.5	1.42
219	1.28	0.03	87	21	12.5	18.2	0.5	912	16.98	0.00	282.4	0.9	-2.7	0.99
220	0.33	0.04	79	25	17.2	21.8	3.8	912	17.11	0.00	265.3	1.5	0.3	1.40
221	0.94	0.10	74	16	18.7	25.0	5.2	912	17.39	0.00	593.5	1.6	-1.0	1.68
222	0.32	0.11	80	14	17.9	23.4	0.8	912	14.40	0.00	319.5	1.3	-2.1	1.63
223	-0.18	0.07	82	24	13.0	17.6	-2.5	909	18.14	0.00	214.8	3.6	-3.7	1.08
224	1.04	0.05	82	20	13.8	19.9	-1.4	911	18.44	0.00	613.6	1.2	-0.4	1.18
225	1.36	0.10	81	24	19.4	24.0	7.6	899	18.14	0.00	669.2	1.0	6.5	1.47
226	-0.01	0.11	98	17	17.7	23.2	2.1	895	18.06	0.00	269.3	1.7	1.9	1.45
227	-2.14	0.06	99	75	7.4	9.9	-3.8	903	6.12	0.00	409.5	0.7	2.2	0.14
228	-5.43	0.28	94	89	-5.0	-4.0	-8.6	912	2.50	0.00	374.4	1.1	-7.0	0.04
301	-7.14	0.28	92	87	-8.3	-7.6	-10.6	912	10.09	0.00	311.4	1.3	-12.6	0.06
302	-3.19	0.80	94	88	-8.8	-5.5	-12.1	910	12.06	0.00	312.0	0.7	-9.7	0.03
303	0.09	0.80	99	90	-0.9	2.3	-5.4	903	10.91	3.56	468.6	0.9	-1.1	0.04
304	2.42	0.07	99	39	11.0	19.6	-0.4	892	14.44	0.51	381.0	0.9	3.3	0.52

305	1.42	0.12	95	49	6.0	11.7	-0.3	898	14.48	0.00	523.4	0.4	2.2	0.33
306	-6.30	0.13	95	73	2.7	10.8	-9.1	892	4.31	0.00	737.0	1.1	-5.1	0.12
307	1.13	0.12	91	51	-2.9	0.8	-9.1	910	21.11	0.25	318.6	1.9	-8.2	0.19
308	1.71	0.12	87	21	7.7	15.5	-5.8	909	20.94	0.00	467.2	1.0	-5.2	0.69
309	3.00	0.09	47	7	14.5	21.5	0.0	902	21.30	0.00	778.2	1.4	-10.9	1.54
310	1.80	0.08	88	14	16.8	24.4	1.5	899	21.53	0.00	630.0	1.6	-2.5	1.70
311	2.50	0.06	88	11	20.3	29.0	2.6	895	20.15	0.00	586.4	0.5	1.9	2.11
312	0.00	0.08	71	15	17.5	21.4	5.8	893	13.60	0.00	609.1	1.9	-2.2	1.50
313	0.77	0.09	74	21	14.0	18.9	3.3	903	17.94	0.00	379.2	4.0	-1.8	1.10
314	0.80	0.08	96	49	10.9	13.6	5.6	908	5.23	0.00	478.7	1.9	6.0	0.53
315	-0.23	0.07	96	53	13.6	17.5	2.2	908	9.77	0.00	176.2	2.2	6.7	0.48
316	0.47	0.07	94	37	16.0	20.9	3.4	905	16.93	0.00	196.2	9.2	5.1	0.94
317	1.33	0.10	89	29	17.9	22.3	4.5	906	17.30	0.00	409.3	1.6	3.7	1.27
318	1.22	0.09	86	23	19.4	24.4	5.8	903	22.00	0.00	192.1	3.8	4.4	1.52
319	0.40	0.10	80	12	20.3	28.1	1.2	891	16.49	0.00	329.9	3.6	1.3	1.87
320	1.68	0.11	78	17	15.7	21.2	1.4	899	21.87	0.00	370.3	0.7	-2.7	1.41
321	2.19	0.09	50	8	25.7	33.3	11.2	891	20.65	0.00	530.9	1.2	-2.3	3.02
322	-0.30	0.08	53	5	23.8	28.2	-0.6	891	22.02	0.00	444.8	12.2	-8.4	2.66
323	0.96	0.07	75	20	15.0	20.8	-0.4	901	20.29	0.00	361.1	1.0	-1.0	1.34
324	1.89	0.08	94	8	21.3	29.1	6.4	891	21.72	0.00	481.0	2.4	0.5	2.06
325	0.01	0.09	96	15	19.5	22.1	3.1	889	20.84	0.00	422.1	0.7	0.1	1.41
326	-0.80	0.09	85	35	8.2	10.9	-4.1	900	22.57	0.00	483.4	8.1	-3.9	0.58
327	0.71	0.07	84	21	9.3	13.7	-3.8	907	24.11	0.00	266.6	2.1	-1.2	0.88
328	-6.66	0.13	98	57	12.9	12.9	12.9	909	4.89	0.00	181.5	1.1	9.3	0.51
329	-1.77	0.12	99	90	2.3	12.9	0.0	907	5.19	4.06	309.4	0.7	1.9	0.04
330	-5.85	0.10	98	91	3.7	4.6	-1.0	905	3.94	2.79	245.2	1.8	2.2	0.04
331	2.07	0.11	97	20	10.2	16.1	-0.7	903	24.16	0.00	241.1	2.5	-2.0	0.79
401	2.72	0.09	79	12	15.3	20.1	1.2	903	23.79	0.00	315.7	1.1	-3.2	1.41
402	1.71	0.11	89	20	17.5	23.3	4.3	898	22.05	0.00	576.7	2.5	3.1	1.42
403	1.23	0.10	89	26	15.4	20.1	1.6	902	25.09	0.00	262.8	4.0	1.3	1.06
404	1.74	0.12	88	21	15.4	21.2	1.7	905	25.34	0.00	375.0	1.0	1.4	1.22
405	1.28	0.15	93	18	18.5	24.9	4.4	896	25.41	0.00	512.4	2.7	3.7	1.48
406	2.12	0.15	93	16	19.3	27.0	3.4	895	25.28	0.00	342.2	1.1	6.1	1.64
407	2.43	0.12	83	6	24.9	30.0	7.7	893	26.40	0.00	282.7	2.4	-5.9	2.92
408	2.00	0.07	92	8	25.0	30.1	8.1	888	24.13	0.00	396.2	1.1	-3.1	2.92
409	-2.33	0.06	97	61	9.9	13.4	0.2	888	8.92	0.51	516.0	0.8	4.1	0.31
410	-1.50	0.07	93	49	0.1	1.7	-6.5	895	10.22	0.00	657.5	2.8	-5.9	0.18
411	0.93	0.10	86	28	4.9	10.4	-6.8	897	22.11	0.00	286.6	5.9	-6.6	0.54
412	2.07	0.11	81	19	14.7	20.5	-2.5	907	25.07	0.00	315.9	3.9	-3.1	1.33
413	2.01	0.09	66	10	21.5	28.9	3.5	903	22.63	0.00	632.9	1.9	-2.0	2.23
414	1.31	0.09	57	3	25.5	31.7	5.4	889	25.56	0.00	620.4	5.1	-9.4	3.13
415	0.71	0.12	87	22	15.6	21.3	6.1	897	21.21	0.00	385.0	1.7	2.4	1.26
416	0.27	0.14	97	15	18.5	23.0	5.0	896	14.67	0.00	345.7	0.7	1.4	1.64
417	-2.11	0.12	98	17	8.8	16.4	3.2	891	7.71	1.02	538.0	0.6	1.8	0.25
418	1.25	0.07	94	26	13.5	17.6	0.1	896	27.59	0.00	336.3	1.7	-0.7	1.04
419	-9.97	0.03	98	78	4.9	7.6	0.9	895	6.09	5.08	329.4	2.0	3.0	0.12
420	2.96	0.07	95	30	12.0	18.5	2.4	891	27.63	0.00	309.9	0.7	3.5	0.75
421	-0.45	0.07	97	68	6.7	9.4	1.7	898	7.74	0.00	438.9	2.1	2.7	0.20
422	-6.71	0.02	98	74	3.9	6.6	0.3	907	5.51	1.02	386.4	2.0	1.8	0.10
423	2.75	0.08	93	33	9.5	13.6	0.7	905	20.88	0.00	277.6	4.8	0.4	0.63
424	1.04	0.14	88	43	10.1	14.9	3.6	904	7.55	0.00	246.4	0.9	3.5	0.47
425	2.53	0.12	86	11	18.5	25.5	3.9	896	29.11	0.00	507.8	2.4	0.0	1.69
426	-0.94	0.06	93	55	7.6	9.8	-1.2	901	11.18	0.00	509.6	11.7	1.1	0.33
427	2.02	0.09	91	32	12.2	17.4	-0.6	905	23.45	0.00	454.0	1.3	0.7	0.85
428	1.99	0.08	93	32	17.8	25.8	6.8	893	19.26	0.00	603.2	2.0	9.5	1.10
429	1.41	0.04	88	44	16.0	19.2	10.0	899	26.30	0.00	454.5	1.8	7.2	0.85
430	-7.96	0.03	---	---	---	---	---	---	---	---	---	---	---	---
501	2.46	0.05	---	---	---	---	---	---	---	---	---	---	---	---
502	-1.30	0.06	---	---	---	---	---	---	---	---	---	---	---	---
503	1.51	0.16	98	39	14.9	20.3	4.8	895	17.62	0.00	365.6	2.7	7.4	0.67

504	2.73	0.16	95	31	16.3	21.5	5.3	906	29.33	0.00	274.7	1.2	5.5	1.05
505	-8.93	0.05	99	89	10.8	12.9	8.0	904	4.94	4.32	462.4	1.5	10.2	0.09
506	-30.16	1.69	99	15	20.3	26.3	8.9	895	26.33	15.75	531.5	1.2	10.4	1.38
507	-3.62	1.69	98	23	18.5	25.5	6.4	888	20.27	3.56	404.3	1.2	6.9	0.94
508	3.62	0.07	88	34	16.2	21.0	5.5	884	23.40	0.00	488.9	1.2	6.0	0.94
509	3.81	0.07	80	27	18.6	23.8	7.9	895	27.97	0.00	584.4	2.2	4.8	1.36
510	2.56	0.06	92	31	17.1	21.4	8.0	902	28.36	0.51	352.0	6.2	4.8	1.23
511	2.81	0.03	93	35	19.3	24.7	10.4	896	20.24	0.00	569.7	1.2	9.8	1.21
512	2.49	0.09	89	11	24.8	30.5	8.1	882	24.35	0.00	516.1	4.4	4.8	2.31
513	3.73	0.11	81	12	23.5	30.2	6.6	888	30.50	0.00	454.8	1.3	2.4	2.35
514	2.32	0.09	94	36	16.0	22.1	6.4	904	28.08	0.00	275.5	3.7	5.4	1.09
515	3.55	0.06	93	43	22.9	29.8	10.0	900	23.79	0.00	592.4	1.2	8.1	1.77
516	1.88	0.10	92	23	25.9	30.8	12.5	890	19.06	0.00	562.5	1.7	11.8	2.05
517	-1.56	0.15	98	52	13.4	21.8	4.6	887	13.42	0.25	574.2	1.3	16.2	1.65
518	2.89	0.12	94	27	15.3	21.0	3.4	901	31.08	0.00	266.4	4.2	16.2	1.03
519	3.07	0.09	79	22	22.3	28.2	8.0	901	26.72	0.00	273.5	3.1	12.5	1.42
520	0.24	0.09	98	42	19.4	24.3	9.3	900	11.60	0.51	270.4	0.9	11.5	1.90
521	1.13	0.06	98	60	17.8	22.5	13.5	902	14.51	0.00	278.7	1.5	11.9	2.16
522	2.22	0.07	94	42	24.1	31.4	8.9	897	23.25	0.00	577.5	1.2	13.6	1.51
523	-2.79	0.07	98	78	9.9	11.6	7.5	901	6.60	0.76	504.8	2.1	13.7	1.82
524	0.43	0.05	97	84	9.4	10.8	7.6	905	5.27	0.00	257.5	2.4	15.0	1.14
525	-7.66	0.06	98	85	11.7	14.4	9.0	905	5.29	4.32	329.4	1.5	14.2	0.62
526	-2.60	0.06	97	78	16.5	19.6	9.8	898	8.71	1.52	421.1	2.7	11.3	0.45
527	3.04	0.09	92	36	18.5	23.6	9.4	895	28.53	0.25	428.1	3.4	12.8	0.76
528	3.57	0.14	89	43	17.1	20.4	9.5	905	24.98	0.00	284.9	3.8	15.2	1.79
529	-7.18	0.12	97	49	15.9	19.6	10.8	907	16.89	4.57	375.0	1.7	11.5	2.20
530	-6.60	0.10	98	61	16.1	20.6	10.3	904	15.47	3.56	225.2	3.5	14.3	2.62
531	2.36	0.09	98	52	17.6	23.2	10.5	901	17.85	0.00	125.4	1.4	15.3	2.70
601	5.14	0.13	90	25	23.7	28.5	10.9	901	28.65	0.00	201.0	6.4	9.8	1.88
602	-19.31	0.12	93	35	24.1	28.1	16.1	899	24.41	11.68	419.7	1.3	14.2	1.48
603	1.42	0.07	94	20	19.4	25.9	13.8	898	14.64	0.25	432.2	4.0	14.4	0.43
604	-1.24	0.18	97	81	18.0	19.6	14.5	899	5.55	0.76	322.3	3.0	15.4	0.20
605	3.44	0.08	98	46	21.3	27.6	13.9	895	23.24	0.00	167.6	0.8	16.3	0.82
606	5.40	0.12	98	17	27.4	33.9	13.9	888	30.29	0.00	315.9	2.8	12.0	2.28
607	3.93	0.18	95	40	24.0	29.5	15.4	894	30.69	1.78	327.1	3.0	15.9	1.48
608	1.71	0.14	98	63	21.6	26.8	12.9	895	18.21	0.00	391.0	1.8	16.8	0.50
609	6.47	0.07	98	31	21.3	26.0	12.1	901	30.95	0.00	275.7	2.4	10.3	1.38
610	-0.08	0.18	96	47	16.8	19.2	7.8	907	12.69	0.25	312.0	4.3	8.9	0.78
611	4.47	0.12	95	35	19.3	24.8	7.6	909	29.93	0.00	216.6	1.5	8.8	1.22
612	4.95	0.14	84	18	26.3	34.1	11.8	905	31.38	0.00	260.2	1.5	11.9	2.37
613	5.02	0.12	79	17	31.5	37.5	16.1	900	31.29	0.00	380.9	1.7	9.7	3.57
614	4.13	0.25	42	17	32.2	37.9	19.5	898	29.77	0.00	326.5	1.6	8.1	3.85
615	2.86	0.12	86	11	31.7	37.1	15.8	899	29.87	0.00	591.0	2.2	8.5	3.93
616	2.18	0.10	90	18	27.7	33.2	15.3	903	30.96	0.00	616.1	3.2	12.8	2.47
617	1.37	0.15	90	37	25.0	28.9	16.2	906	28.76	0.00	593.3	2.5	13.9	1.65
618	1.27	0.08	86	35	25.2	28.9	17.4	906	20.62	0.00	554.8	2.3	14.0	1.68
619	1.55	0.07	84	35	27.4	31.9	16.7	903	26.81	0.00	521.8	3.2	14.2	2.05
620	1.69	0.11	87	27	29.0	34.2	15.8	900	29.29	0.00	490.6	2.6	14.4	2.50
621	0.34	0.24	87	21	28.0	36.1	14.5	899	26.66	0.25	396.4	3.9	13.5	2.37
622	1.79	0.16	87	24	29.4	35.3	14.6	899	30.44	0.00	471.5	2.6	14.0	2.77
623	-3.53	0.12	89	33	25.3	30.5	15.1	903	28.04	2.29	378.4	1.8	13.3	1.80
624	1.61	0.12	95	39	22.2	26.4	12.6	904	28.30	0.00	325.3	5.2	12.4	1.27
625	1.67	0.15	93	21	24.5	29.8	12.8	903	28.64	0.00	280.8	4.3	9.3	1.98
626	-3.24	0.07	95	28	23.4	30.1	13.6	902	21.30	2.03	244.3	1.7	12.4	1.57
627	3.38	0.11	89	22	26.9	32.4	15.1	901	31.43	0.00	326.3	1.7	13.6	2.30
628	-6.22	0.17	95	23	28.3	34.7	16.3	899	27.08	4.06	268.1	1.7	14.8	2.35
629	-0.95	0.19	96	76	17.7	19.0	11.8	907	7.92	0.00	292.4	8.0	14.0	0.33
630	2.44	0.11	96	43	20.0	22.9	11.8	909	18.92	0.00	224.6	2.5	11.5	1.07
701	-57.51	0.11	99	43	22.3	27.9	13.6	904	17.42	19.30	473.0	4.1	13.8	1.23
702	3.11	0.11	95	52	23.4	28.6	15.1	899	23.14	0.00	300.0	2.8	17.6	0.90

703	4.53	0.14	94	14	27.2	35.3	14.9	889	28.98	0.00	338.7	1.5	12.4	2.30
704	3.21	0.21	88	28	23.6	28.3	13.1	895	27.77	0.25	442.6	3.2	10.7	1.74
705	4.79	0.16	86	25	25.6	30.4	13.0	904	30.74	0.00	219.1	3.0	11.2	2.13
706	4.56	0.15	83	21	29.3	35.2	15.3	908	30.50	0.00	434.6	2.0	12.3	2.90
707	5.20	0.13	87	22	31.4	37.0	18.3	907	30.65	0.00	409.7	2.0	14.1	3.13
708	4.68	0.12	85	12	33.9	40.3	19.9	905	29.57	0.00	297.6	5.4	11.4	4.22
709	3.79	0.09	85	17	31.7	36.5	16.6	907	30.84	0.00	231.7	5.1	13.0	3.29
710	4.44	0.11	83	14	33.1	39.5	16.7	905	30.54	0.00	329.3	1.7	11.5	3.98
711	3.65	0.24	49	11	35.4	40.7	20.7	903	30.54	0.00	455.6	2.3	8.7	4.93
712	3.71	0.21	56	12	34.3	39.6	20.2	903	30.38	0.00	436.5	2.3	8.4	4.67
713	2.83	0.14	58	17	33.0	37.5	20.8	902	29.46	0.00	317.1	12.2	10.7	3.93
714	-12.56	0.12	92	52	24.0	26.8	19.3	902	16.88	6.86	192.4	0.6	18.0	1.09
715	1.20	0.12	93	52	24.0	28.2	18.9	904	16.89	0.51	251.1	2.0	18.6	0.85
716	4.45	0.11	92	35	28.6	33.3	18.0	904	27.76	0.00	197.0	1.7	17.7	2.04
717	-9.11	0.19	94	43	25.6	31.8	18.1	905	21.99	5.59	248.0	3.8	18.5	1.31
718	-13.79	0.11	97	77	21.7	24.4	18.8	904	10.93	7.37	258.2	1.9	19.4	0.33
719	4.47	0.11	93	41	27.7	33.2	18.4	901	22.84	0.00	364.6	2.2	19.2	1.53
720	5.02	0.13	92	39	27.0	32.3	17.3	903	28.14	0.00	232.0	1.3	18.1	1.58
721	4.38	0.09	86	33	29.6	34.5	19.4	901	26.56	0.00	352.2	1.8	16.8	2.35
722	4.96	0.15	84	28	29.5	35.2	17.7	899	23.41	0.00	283.4	1.9	14.9	2.49
723	-1.25	0.12	96	39	28.4	33.4	14.8	900	22.71	4.57	278.9	2.4	15.8	2.17
724	4.96	0.10	94	25	27.7	33.3	14.9	901	26.66	0.00	277.3	1.7	15.0	2.35
725	4.23	0.11	95	13	31.7	38.6	17.8	900	26.27	0.00	267.2	2.3	15.6	3.15
726	3.86	0.10	95	17	32.4	39.3	17.1	899	26.59	0.00	173.7	1.8	16.2	3.32
727	3.41	0.12	89	14	33.3	39.3	16.5	899	29.30	0.00	292.7	4.7	13.3	4.08
728	2.61	0.10	95	21	32.9	39.4	16.4	905	28.30	0.00	254.9	2.5	18.3	3.20
729	2.12	0.10	94	15	31.4	38.4	16.6	906	27.99	0.00	330.5	2.4	16.2	3.03
730	1.46	0.08	93	31	28.8	33.5	18.6	904	24.18	0.00	428.7	2.4	17.2	2.11
731			97	35	27.2	33.1	15.0	903	20.70	27.43	382.1	1.0	16.7	1.76

APACHE

Date	ET lys mm	ET std dev mm	RH max %	RH min %	T air avg C	T air max C	T air min C	Atm pres kPa	Rs MJ/m^2	Rain mm	Wind run km	Wind day/ night ratio	T dew avg C	Vap pres defct kPa
201	---	---	84	43	2.2	4.9	-5.4	---	11.71	0.00	156.5	1.48	-5.7	0.31
202	---	---	82	39	4.0	7.9	-2.8	---	6.23	0.51	130.5	1.02	-5.3	0.43
203	0.00	0.00	94	31	9.7	15.3	-0.2	965	14.75	0.00	469.6	0.96	0.1	0.73
204	0.46	0.00	88	43	4.7	9.3	-0.3	967	11.23	0.00	219.9	1.45	-2.1	0.39
205	0.93	0.00	93	43	7.8	11.9	-1.1	966	15.59	0.00	225.0	1.71	-0.6	0.47
206	0.46	0.00	92	22	12.1	19.3	0.7	963	15.92	0.00	157.6	1.45	-2.1	0.87
207	0.46	0.00	97	38	8.4	15.7	-5.9	961	9.16	0.00	366.1	0.93	-4.8	0.56
208	-1.16	0.23	100	56	-2.7	-0.6	-11.8	958	3.35	0.00	441.0	0.26	-8.7	0.01
209	0.00	0.32	80	38	-8.2	-4.8	-11.8	971	9.09	0.00	347.3	2.74	-16.2	0.18
210	-0.24	0.23	84	36	-1.1	4.2	-10.8	967	15.64	0.25	165.5	2.36	-10.4	0.34
211	0.46	0.00	97	32	6.8	13.0	-7.5	962	16.12	0.00	466.6	0.65	-1.3	0.61
212	0.93	0.00	78	38	7.0	10.1	-7.4	968	17.05	0.00	385.8	2.56	-6.5	0.56
213	0.93	0.00	75	17	6.9	13.8	-7.1	982	18.17	0.00	245.6	0.72	-9.4	0.78
214	0.11	0.20	68	18	8.8	13.7	-3.6	971	12.13	0.00	333.9	2.24	-7.4	0.88
215	0.35	0.20	91	21	12.9	18.5	0.5	972	16.61	0.00	174.7	1.56	-2.6	1.10
216	0.11	0.20	100	41	14.7	19.8	2.7	973	16.70	0.00	334.6	1.38	6.1	0.74
217	0.81	0.20	100	45	15.8	21.7	5.6	967	15.78	0.00	534.1	0.73	8.1	0.75
218	-0.24	0.23	96	61	14.2	17.3	11.4	957	5.44	0.00	734.5	0.97	12.3	0.33
219	-11.97	0.30	100	65	15.5	17.9	3.2	956	3.10	14.73	242.4	1.44	9.7	0.17
220	1.62	0.28	98	48	12.1	16.4	-0.8	965	17.23	0.00	356.1	0.74	2.5	0.54
221	-45.19	0.38	100	90	2.7	8.3	0.1	968	2.31	48.51	356.7	1.06	4.7	0.03
222	0.93	0.32	100	83	5.7	7.1	-4.7	956	3.23	1.52	419.8	0.71	1.2	0.01
223	0.46	0.00	91	49	0.5	3.8	-4.9	966	19.08	0.00	347.0	2.12	-5.7	0.26
224	1.28	0.20	85	36	10.6	18.1	-2.2	958	19.11	0.00	602.6	1.09	0.8	0.73
225	-1.13	0.20	72	35	-0.1	2.2	-8.2	971	19.57	0.00	617.0	1.30	-11.5	0.33
226	0.29	0.07	77	33	-0.3	4.9	-8.3	976	20.00	0.00	203.4	1.22	-9.6	0.37
227	0.44	0.10	80	45	3.6	7.5	-3.3	968	9.72	0.00	408.7	1.02	-2.4	0.36
228	-9.64	0.11	100	78	7.8	8.9	3.6	962	1.59	9.14	328.3	0.93	6.6	0.04
301	-8.93	0.08	100	90	2.3	3.7	-1.2	967	5.17	10.16	337.5	2.09	0.8	0.02
302	1.91	0.08	94	40	10.9	17.2	-0.1	970	20.02	0.00	227.1	3.16	3.1	0.59
303	1.33	0.07	87	38	17.7	22.5	5.8	968	16.85	0.00	282.6	1.37	6.5	1.14
304	1.56	0.06	90	23	20.2	26.9	6.1	961	20.48	0.00	114.2	2.38	6.7	1.55
305	2.12	0.07	100	40	21.1	26.0	8.0	960	20.19	0.00	212.2	1.38	12.3	1.25
306	1.77	0.21	100	55	19.7	25.5	11.1	960	13.65	0.00	256.0	0.96	14.6	0.60
307	-31.86	0.41	98	69	12.5	14.0	4.0	966	8.66	32.00	595.0	0.74	7.2	0.37
308	-20.59	0.36	100	96	1.5	4.0	-2.0	966	1.57	9.91	694.9	1.42	-0.1	0.01
309	1.74	0.06	100	54	2.3	5.6	-1.9	970	16.59	5.08	290.5	3.18	-1.8	0.17
310	0.67	0.14	95	23	11.4	18.1	-2.2	972	21.86	0.00	220.7	0.71	0.4	0.83
311	0.34	0.15	92	33	13.5	18.1	2.7	970	20.45	0.00	465.1	1.28	2.8	0.86
312	-0.72	0.09	100	77	10.8	13.3	6.1	973	8.51	0.51	231.4	2.01	8.5	0.19
313	2.06	0.07	95	22	13.6	17.8	3.6	975	21.99	0.00	225.7	2.12	1.4	0.90
314	0.98	0.05	92	29	19.0	24.0	4.3	964	22.27	0.00	279.8	2.02	6.9	1.41
315	0.98	0.07	89	30	17.4	21.0	6.1	965	22.08	0.00	353.4	4.78	3.4	1.17
316	---	---	90	25	17.9	22.6	5.5	966	21.82	0.00	367.9	0.84	4.4	1.39
317	---	---	91	30	24.2	30.8	10.4	952	20.77	0.00	504.1	1.99	9.8	1.71
318	1.02	0.07	66	17	22.4	27.1	10.1	959	22.74	0.00	237.1	1.44	3.0	2.02
319	1.21	0.09	96	40	24.1	30.2	13.1	953	19.61	0.00	318.1	1.68	14.1	1.54
320	1.88	0.11	83	23	23.8	31.5	5.0	952	13.40	0.00	412.5	0.88	6.4	1.82
321	0.00	0.10	71	20	15.4	20.6	4.6	966	24.17	0.00	226.5	1.01	-0.9	1.27
322	---	---	97	26	18.8	24.5	6.6	959	21.99	0.00	543.2	0.93	6.8	1.50
323	---	---	98	15	24.3	30.1	13.3	952	21.47	0.00	347.0	1.07	9.5	1.85
324	-0.49	0.10	87	40	10.7	12.9	0.5	964	14.74	0.00	492.7	3.03	-0.9	0.72

325	1.70	0.12	90	45	12.6	18.3	0.6	965	17.66	0.00	291.2	1.34	7.1	0.69
326	-7.58	0.08	100	86	12.9	14.3	6.3	951	2.75	8.38	407.3	0.68	9.6	0.01
327	1.33	0.12	84	36	10.2	12.4	-1.7	961	17.89	0.00	467.2	2.27	-2.8	0.66
328	1.54	0.12	88	22	8.6	13.7	-2.7	969	24.90	0.00	305.0	1.11	-4.8	0.75
329	1.72	0.07	87	24	13.1	17.3	-0.8	971	24.35	0.00	433.6	1.15	-1.6	0.99
330	0.72	0.08	89	29	9.4	14.0	-1.1	979	25.10	0.00	204.5	1.04	-2.3	0.71
331	1.48	0.06	78	24	16.2	22.1	3.2	971	25.03	0.00	374.0	1.63	2.4	1.28
401	2.46	0.07	86	27	20.6	26.2	7.3	965	24.84	0.00	489.2	1.16	7.9	1.56
402	-0.33	0.10	97	29	20.3	29.1	1.6	958	21.50	1.52	637.4	1.48	8.3	1.11
403	2.02	0.08	97	33	13.2	18.6	1.8	971	25.34	0.00	238.8	0.84	2.3	0.87
404	1.52	0.04	93	47	18.8	23.3	5.4	955	15.35	0.00	532.9	1.34	10.7	1.09
405	-0.13	0.29	97	57	2.9	5.3	-3.0	960	6.11	0.00	570.4	1.78	-2.0	0.14
406	1.07	0.30	87	18	9.0	14.6	-3.2	969	26.56	0.00	222.2	1.75	-6.2	0.85
407	2.37	0.17	84	32	13.9	19.4	3.1	966	25.59	0.00	669.5	1.01	2.8	0.98
408	2.46	0.20	89	49	18.9	24.0	9.7	961	23.40	0.00	407.9	1.59	12.2	0.91
409	1.67	0.14	94	21	24.9	31.1	15.0	953	20.10	0.00	482.0	2.01	15.8	1.56
410	-18.22	3.36	100	90	12.6	14.3	10.5	958	5.22	8.64	379.8	1.13	11.5	0.07
411	-4.20	3.37	100	58	13.1	16.2	4.4	959	11.15	15.75	429.7	1.48	7.1	0.24
412	2.94	0.15	84	28	14.4	19.6	4.8	965	26.50	0.00	382.4	4.66	3.1	0.93
413	3.47	0.09	92	19	24.1	30.4	10.1	959	25.95	0.00	400.1	1.56	8.0	2.22
414	4.25	0.09	94	18	26.7	33.5	12.4	950	25.74	0.00	514.3	1.34	12.7	2.03
415	2.05	0.12	75	25	17.3	21.5	8.7	967	26.25	0.00	378.6	7.23	2.8	1.26
416	3.55	0.15	79	25	21.2	26.9	8.9	975	27.23	0.00	232.7	1.61	5.8	1.71
417	3.73	0.14	77	22	23.0	27.6	9.2	972	27.37	0.00	361.3	1.61	5.0	2.01
418	3.89	0.15	95	21	23.1	29.1	9.2	965	28.04	0.00	329.5	2.06	8.3	2.01
419	3.69	0.19	100	31	24.7	30.0	12.2	966	25.72	0.00	171.8	3.09	15.2	1.59
420	4.10	0.16	100	47	24.9	29.1	14.7	967	22.27	0.00	185.6	1.40	17.0	1.23
421	1.11	0.07	99	45	24.5	29.1	14.7	963	21.79	0.00	219.1	2.47	15.8	1.25
422	4.38	0.03	100	46	23.4	27.3	14.2	964	25.29	0.00	266.0	2.03	16.2	1.05
423	3.45	0.03	100	50	23.7	28.7	14.1	962	21.52	0.00	391.7	1.32	16.7	1.08
424	0.92	0.04	98	48	22.9	29.1	18.5	957	15.89	1.02	464.2	1.40	17.9	0.81
425	-7.40	0.07	97	28	22.6	26.4	12.7	950	10.40	9.65	378.1	2.29	15.2	0.56
426	6.14	0.16	100	23	24.1	29.6	10.0	954	26.49	0.00	274.3	0.57	11.0	1.90
427	-12.04	0.23	100	59	7.0	9.9	4.4	962	5.01	10.16	505.1	1.92	4.6	0.19
428	3.68	0.19	99	53	13.9	20.0	6.1	966	25.35	0.00	382.4	0.83	8.2	0.50
429	-45.89	0.14	100	70	5.0	7.1	3.9	967	2.00	49.28	510.1	1.81	4.4	0.08
430	2.88	0.14	95	61	9.5	13.2	5.1	971	21.95	0.00	373.8	2.68	5.1	0.30
501	-2.10	0.36	99	55	12.5	17.4	6.9	969	24.20	5.59	190.2	1.79	8.0	0.49
502	-16.72	0.37	100	95	10.8	11.6	8.2	964	3.50	18.54	285.4	2.11	9.9	0.02
503	2.36	0.08	100	76	13.6	17.2	8.6	966	11.44	0.00	85.6	1.83	12.1	0.20
504	3.27	0.04	100	59	20.1	24.2	12.3	966	23.62	0.00	124.1	1.93	14.9	0.69
505	4.88	0.23	99	57	22.8	26.9	13.4	967	27.50	0.00	339.3	1.27	17.2	0.91
506	4.27	0.27	99	65	25.4	29.4	14.1	960	21.92	0.51	387.7	1.90	20.5	0.78
507	2.68	0.15	100	71	15.1	17.3	8.6	965	14.69	0.25	336.4	6.88	12.7	0.26
508	1.64	0.07	100	66	18.2	24.1	8.9	962	23.71	2.79	225.8	1.42	14.1	0.32
509	-1.67	0.07	100	87	19.1	21.4	14.1	963	6.31	1.27	192.7	2.60	16.3	0.57
510	2.93	0.06	100	72	20.4	23.2	14.2	968	14.12	0.25	148.0	4.92	16.2	0.64
511	-0.84	0.12	100	81	22.0	25.1	18.2	965	7.71	1.78	108.0	3.27	16.1	0.70
512	-4.25	0.11	100	57	23.2	28.7	17.6	962	18.60	8.64	187.6	2.02	18.4	0.05
513	5.25	0.04	100	61	23.2	26.8	16.7	956	20.88	0.25	244.9	1.31	18.7	0.62
514	5.14	0.04	100	53	22.6	28.0	14.1	956	20.37	0.00	234.0	1.51	16.8	0.79
515	8.95	0.10	98	43	23.2	27.2	12.9	965	28.11	0.00	209.5	9.17	14.3	1.25
516	0.58	0.13	100	52	24.9	30.1	12.6	964	24.99	0.00	175.8	2.32	18.7	1.15
517	0.10	0.09	100	60	24.1	28.5	16.0	965	17.66	0.00	207.9	3.98	19.5	0.59
518	5.31	0.06	100	53	24.3	28.6	15.0	967	26.13	0.00	177.0	3.64	15.9	1.15
519	5.00	0.09	93	41	24.5	28.7	14.0	966	28.16	0.00	142.6	2.60	14.7	1.47
520	5.18	0.08	90	46	23.4	27.1	13.4	965	28.40	0.00	240.8	2.49	13.6	1.32
521	4.63	0.05	97	45	24.3	28.7	13.8	965	27.63	0.00	233.0	4.73	14.5	1.43
522	5.22	0.07	96	44	24.8	29.0	13.8	967	27.71	0.00	248.5	3.03	15.5	1.43
523	-3.27	0.08	99	42	26.5	31.6	15.4	965	26.81	8.64	295.7	1.67	17.3	1.58

524	-10.86	0.06	100	62	26.2	29.7	17.9	961	22.59	17.53	243.2	2.64	20.6	1.18
525	0.54	0.08	100	55	25.7	30.2	16.3	957	24.62	4.83	215.4	1.18	19.7	0.88
526	5.32	0.12	99	53	22.5	26.5	15.9	960	21.76	0.25	253.1	3.93	16.6	0.75
527	-2.24	0.11	100	70	19.6	22.7	16.3	965	9.69	4.32	162.8	3.20	16.8	0.35
528	2.46	0.08	100	84	21.2	24.1	16.7	964	8.99	0.00	309.4	1.39	20.5	0.20
529	2.63	0.07	100	69	23.8	28.3	17.6	960	22.26	0.76	204.6	5.59	20.4	0.48
530	7.37	0.10	100	45	27.5	32.8	17.6	963	27.19	0.25	150.5	1.59	20.6	1.73
531	7.34	0.10	100	46	28.8	33.1	19.1	964	29.46	0.00	179.9	3.70	20.8	1.58
601	6.05	0.15	100	53	27.5	31.9	19.3	964	28.15	0.00	265.7	3.49	20.7	1.25
602	5.06	0.13	100	49	27.9	32.0	19.2	964	23.69	0.00	139.8	16.04	20.7	1.39
603	4.23	0.02	100	50	28.0	32.4	20.0	966	19.93	0.00	154.5	1.80	21.6	1.25
604	5.47	0.10	100	49	28.8	33.4	21.3	963	23.25	0.00	293.5	1.78	21.7	1.43
605	5.82	0.13	96	49	30.4	35.2	19.4	958	27.07	0.00	441.9	1.66	22.4	1.62
606	5.07	0.08	98	53	29.9	34.9	19.4	958	25.50	0.00	374.3	2.49	22.2	1.52
607	6.27	0.11	93	48	32.3	37.2	23.7	954	27.49	0.00	453.0	2.03	24.1	1.96
608	5.77	0.08	100	33	33.1	38.3	23.6	955	28.08	0.00	252.0	3.69	23.6	2.46
609	2.06	0.08	100	62	27.0	31.3	20.9	962	20.98	0.00	367.2	2.29	22.4	0.82
610	-4.08	0.13	100	56	24.8	29.8	18.5	964	17.47	6.60	222.3	4.04	20.6	0.83
611	-11.51	0.12	100	52	23.9	30.5	18.2	963	10.25	15.24	253.2	2.64	19.7	0.70
612	4.63	0.05	99	47	28.2	33.6	18.8	960	28.58	0.00	335.7	1.75	21.8	1.38
613	3.86	0.12	97	48	30.0	34.3	21.7	960	29.14	0.00	515.8	1.97	21.9	1.68
614	3.77	0.12	97	44	29.3	33.9	21.8	960	24.96	0.00	596.6	2.10	21.2	1.66
615	1.70	0.06	97	76	25.8	28.8	23.0	962	11.11	0.00	589.1	1.83	22.8	0.58
616	2.63	0.18	98	53	29.3	33.7	23.2	963	22.00	0.00	520.5	2.28	23.3	1.30
617	4.26	0.18	99	50	30.1	34.3	20.8	965	25.33	0.00	348.4	3.14	22.5	1.53
618	2.78	0.04	99	47	30.5	34.6	20.7	965	20.73	0.00	178.7	3.30	22.0	1.74
619	2.36	0.07	100	47	29.7	34.5	21.3	966	21.43	0.00	142.7	5.34	22.6	1.52
620	2.58	0.09	100	43	30.6	34.8	20.8	966	26.31	0.00	146.4	3.62	21.7	1.82
621	2.79	0.07	96	37	30.9	34.9	20.2	964	24.46	0.00	153.3	2.02	20.1	2.15
622	1.07	0.03	94	35	31.2	35.8	20.5	960	27.46	1.27	278.1	1.80	20.5	2.37
623	2.94	0.07	95	40	30.5	34.6	18.8	958	25.05	0.00	227.8	5.37	19.7	1.99
624	2.49	0.08	97	31	30.9	38.0	19.3	959	27.41	0.00	171.7	1.18	19.5	2.40
625	-2.10	0.09	97	24	34.2	41.8	20.2	958	28.52	4.57	317.7	2.05	20.8	3.19
626	4.46	0.13	82	34	34.6	39.2	24.1	958	28.76	0.00	256.1	1.65	21.7	3.11
627	3.57	0.11	91	23	36.3	44.1	23.5	956	28.48	0.00	345.0	2.88	22.0	3.86
628	2.19	0.07	93	47	31.8	36.3	24.0	961	21.74	0.00	283.9	4.95	22.6	2.05
629	-12.40	0.08	90	23	33.1	38.9	20.8	962	27.22	14.48	332.0	1.28	20.3	2.73
630	4.81	0.25	87	38	30.9	37.4	21.7	960	28.13	0.00	245.7	1.08	21.3	2.20
701	4.51	0.24	85	29	32.8	39.1	24.2	959	26.29	0.00	478.4	1.78	20.4	2.75
702	3.55	0.05	86	43	30.9	36.1	23.2	958	27.61	0.00	511.2	1.89	21.3	2.07
703	3.99	0.10	89	37	32.0	37.3	21.9	959	27.64	0.00	456.4	2.02	20.2	2.46
704	3.19	0.14	86	31	31.5	35.7	22.0	961	29.07	0.00	442.0	1.96	18.9	2.55
705	1.92	0.11	90	41	31.3	35.6	20.3	962	26.72	1.52	433.3	2.39	19.9	2.28
706	4.50	0.21	90	49	28.7	34.5	20.2	959	25.80	0.00	358.9	1.35	20.4	1.68
707	2.09	0.24	85	41	32.4	37.7	22.3	955	26.37	4.06	372.2	2.34	21.1	2.35
708	-41.97	3.30	95	35	27.0	31.9	21.3	966	24.27	46.48	252.2	2.76	17.3	1.83
709	-9.82	3.30	95	49	24.4	28.9	19.4	968	14.34	10.67	239.0	4.61	19.3	0.86
710	—	—	95	56	26.1	29.4	19.9	967	23.50	0.00	189.6	3.59	20.2	1.03
711	6.76	0.26	95	58	26.3	30.9	20.8	964	19.62	0.00	255.9	1.76	21.4	0.96
712	0.33	0.34	95	51	28.0	32.8	19.9	961	18.44	0.00	231.2	2.05	21.8	1.14
713	4.72	0.18	89	34	30.3	36.0	20.0	961	26.17	0.00	203.3	2.53	19.4	2.35
714	-5.83	0.18	93	48	28.3	33.4	19.0	964	23.76	10.41	253.8	2.74	20.0	1.44
715	-20.67	0.26	95	50	28.2	33.7	19.1	966	26.53	21.34	329.5	1.17	21.5	1.38
716	-1.66	0.34	91	47	28.9	34.5	19.6	967	26.41	0.00	256.8	1.67	21.9	1.53
717	8.26	0.32	86	40	30.6	36.1	23.2	967	26.62	0.00	261.0	1.50	21.0	2.05
718	6.53	0.26	83	31	32.3	37.2	23.2	964	28.24	0.00	319.7	1.57	19.3	2.77
719	7.06	0.17	81	27	31.8	36.5	22.6	961	28.20	0.00	453.2	1.67	17.7	2.86
720	5.91	0.14	85	36	31.6	36.3	23.8	963	27.36	0.25	404.3	2.17	20.2	2.49
721	2.79	0.10	94	51	27.3	30.7	19.3	966	17.89	0.51	173.9	10.23	19.7	1.27
722	3.35	0.23	94	31	30.7	36.4	20.0	964	26.68	0.00	276.9	1.81	18.4	2.41

723	4.24	0.25	76	38	31.7	37.3	23.3	963	20.95	0.25	296.7	2.91	19.3	2.53
724	4.61	0.16	77	31	33.6	38.6	23.9	962	22.54	0.25	281.2	1.95	18.5	3.22
725	-4.09	1.17	91	43	29.3	34.6	20.2	962	20.27	6.35	191.9	1.20	20.7	1.76
726	3.68	1.17	94	55	25.5	29.9	15.0	963	20.32	0.76	327.4	3.91	18.2	1.01
727	5.60	0.08	93	32	25.3	29.4	14.9	966	29.13	0.00	193.5	5.53	12.7	1.82
728	4.86	0.10	82	34	27.3	31.3	16.7	966	27.63	0.00	162.2	0.91	14.1	2.15
729	3.68	0.18	82	35	28.0	33.1	18.6	964	26.12	0.00	339.3	2.92	15.5	2.18
730	1.48	0.22	88	43	26.9	30.8	17.5	964	22.69	0.00	367.1	2.06	16.2	1.63
731	1.22	0.34	91	36	28.1	33.8	17.3	965	27.02	0.00	347.7	2.00	17.2	1.98
801	---	---	87	31	30.0	35.4	19.6	964	26.50	0.00	376.6	1.50	17.3	2.43
802	4.03	0.06	85	28	29.8	34.0	20.4	964	25.08	0.00	235.7	2.25	16.7	2.39
803	---	---	85	33	29.4	33.8	20.6	964	24.69	0.00	286.3	1.10	18.1	2.19
804	---	---	93	38	28.7	35.1	20.7	965	17.09	4.32	182.5	1.26	20.2	1.69
805	3.64	0.14	94	38	27.9	31.7	17.9	969	25.57	0.00	262.5	3.34	17.5	1.81
806	---	---	94	27	29.7	34.7	17.9	963	26.06	0.00	333.7	1.27	18.8	2.29
807	---	---	92	43	29.7	34.7	18.0	960	26.55	0.00	426.8	2.58	18.6	2.00
808	---	---	95	42	28.7	34.6	18.0	965	25.47	0.00	274.7	4.10	19.3	1.85
809	1.12	0.08	96	33	29.2	34.0	18.6	969	27.51	0.00	287.0	3.00	18.3	2.15
810	---	---	94	37	29.7	34.6	20.4	968	24.37	0.00	307.8	2.17	18.8	2.12
811	---	---	87	30	31.1	35.9	21.1	968	24.69	0.00	267.1	1.58	18.0	2.63
812	2.08	0.41	84	29	31.6	36.5	22.0	966	24.39	0.00	356.6	1.49	17.8	2.78
813	4.32	0.14	79	27	32.7	37.8	22.5	965	25.34	0.00	273.2	1.73	17.6	3.12
814	2.47	0.07	81	35	29.4	33.5	18.8	967	19.42	0.51	374.5	2.11	14.5	2.02
815	1.84	0.10	64	14	25.3	30.2	15.3	968	20.66	0.00	185.0	3.99	4.8	2.41
816	---	---	73	16	28.9	34.0	15.5	964	27.67	0.00	182.0	1.34	10.3	3.03
817	---	---	94	33	30.0	38.6	20.6	962	21.55	26.92	297.9	2.73	19.9	2.19
818	2.47	0.11	90	41	31.2	35.2	22.6	962	22.43	0.00	287.9	2.40	21.2	2.17
819	1.74	0.23	90	29	32.2	39.2	24.0	959	17.14	0.25	349.7	1.29	20.1	2.56
820	1.25	0.22	93	60	26.0	28.9	16.3	961	15.73	0.00	285.4	5.91	19.1	0.88
821	2.03	0.08	94	34	26.6	30.6	16.5	964	25.74	0.00	157.3	1.93	14.9	1.86
822	3.78	0.07	90	33	27.8	32.4	16.9	963	25.74	0.00	252.3	1.26	15.7	2.08
823	1.20	0.52	90	35	30.3	35.0	18.8	964	24.02	0.00	298.9	1.47	19.9	2.26
824	3.81	0.55	90	42	30.1	35.4	23.4	967	18.55	0.00	278.8	1.35	21.2	1.73
825	2.77	0.35	82	33	32.2	37.1	23.3	966	23.32	0.00	387.3	1.40	19.5	2.60
826	4.93	0.35	80	31	33.3	38.3	23.2	963	25.20	0.00	408.1	1.25	19.1	3.08
827	5.45	0.25	78	32	33.2	38.1	22.4	964	24.94	0.00	394.8	1.61	18.7	2.99
828	4.43	0.23	79	27	32.4	37.9	22.0	963	24.47	0.00	349.7	1.55	17.7	3.00
829	---	---	81	28	32.5	38.2	21.8	961	22.27	0.00	406.8	1.16	18.1	3.04
830	---	---	85	28	32.8	37.9	21.0	960	24.03	0.00	388.2	1.46	18.6	3.01
831	---	---	95	72	23.6	35.0	21.0	965	11.90	5.84	305.1	2.74	25.4	0.50
901	---	---	95	73	27.7	34.4	18.3	968	10.40	0.00	275.9	1.82	21.5	0.58
902	---	---	98	61	24.0	28.5	18.4	969	16.79	0.00	245.6	1.02	20.0	0.81
903	---	---	98	54	28.1	32.1	22.2	967	18.27	0.00	417.6	1.16	22.0	1.22
904	---	---	96	29	30.8	35.2	22.5	964	23.74	0.00	472.1	1.53	16.8	2.56
905	---	---	97	63	23.6	25.3	20.5	966	3.99	5.33	185.6	1.33	20.7	0.51
906	---	---	97	49	26.7	31.1	17.6	970	19.86	0.00	222.8	2.15	19.4	1.18
907	---	---	91	43	26.6	31.4	17.9	968	18.01	0.00	184.3	1.60	18.1	1.57
908	---	---	97	50	23.8	29.8	18.0	966	12.22	24.38	242.9	2.37	18.5	0.84
909	---	---	97	58	24.1	28.0	17.9	968	18.69	0.00	299.3	1.12	19.3	0.76
910	---	---	96	40	25.8	29.5	18.0	968	21.87	0.00	204.6	2.59	16.8	1.43
911	---	---	94	50	26.7	30.3	18.5	967	21.89	0.00	289.4	2.53	19.1	1.36
912	---	---	93	50	27.5	31.0	20.3	968	21.24	0.00	343.5	1.45	20.0	1.42
913	---	---	92	48	28.6	32.2	21.3	967	19.94	0.00	401.3	1.52	20.2	1.63
914	---	---	92	50	28.4	31.6	21.7	964	17.74	0.00	421.4	1.74	20.6	1.50
915	---	---	97	63	24.8	27.3	19.3	962	9.01	0.00	218.1	1.17	20.5	0.69
916	---	---	83	25	24.9	28.8	12.1	967	17.95	0.00	308.6	5.20	8.2	2.06
917	3.53	0.12	81	23	25.7	30.5	12.6	970	22.87	0.00	202.1	2.64	7.9	2.35
918	2.95	0.11	91	23	26.1	30.5	12.6	969	22.41	0.00	153.6	1.30	9.6	2.42
919	1.82	0.30	89	32	25.2	29.6	13.2	968	21.94	0.00	152.9	1.78	12.6	1.90
920	2.16	0.33	81	36	26.0	30.3	16.4	966	20.89	0.00	362.8	1.27	13.3	1.91

921	-22.83	0.20	95	34	27.1	32.4	9.5	961	18.83	21.08	488.4	0.84	13.7	2.06
922	6.63	0.19	88	30	15.2	19.5	7.9	968	16.17	0.00	282.3	3.42	4.3	0.88
923	2.37	0.11	90	29	15.3	21.7	5.5	958	11.69	0.51	316.4	1.74	5.6	0.86
924	2.09	0.07	91	35	15.2	20.6	5.4	965	21.13	0.00	242.2	3.15	6.2	0.91
925	1.75	0.08	87	36	21.3	25.7	11.4	965	20.35	0.00	301.2	1.04	13.4	1.30
926	2.09	0.09	87	21	24.8	29.5	14.8	959	21.46	0.00	237.7	1.66	9.7	2.07
927	1.91	0.11	92	34	26.1	32.3	14.8	960	20.64	0.00	159.4	2.35	14.8	1.95
928	2.40	0.09	90	21	29.7	35.8	16.0	962	20.14	0.00	185.6	1.02	13.9	2.88
929	2.80	0.08	87	20	29.5	36.0	16.1	961	20.49	0.00	323.0	1.14	13.5	2.77
930	3.28	0.09	85	18	27.9	32.6	16.9	961	20.58	0.00	386.5	1.43	11.8	2.58
1001	2.87	0.08	88	35	26.8	31.3	16.2	958	19.44	0.00	271.0	1.79	14.4	1.90
1002	2.47	0.04	84	39	27.4	32.9	17.3	953	18.60	0.00	369.9	2.05	15.7	1.86
1003	-1.55	0.03	89	36	28.1	33.1	17.3	958	19.15	3.81	277.3	2.44	17.2	2.06
1004	3.00	0.02	91	50	26.0	29.8	18.2	968	13.59	3.81	178.1	1.30	17.8	1.36
1005	2.62	0.07	80	33	27.2	31.5	20.5	962	14.81	0.00	534.1	0.69	15.2	1.82
1006	2.61	0.09	86	45	26.3	30.6	20.4	954	14.38	0.00	595.6	1.53	16.9	1.60
1007	-21.42	0.29	95	80	14.5	22.4	10.4	961	1.89	22.86	329.9	1.67	12.0	0.16
1008	2.44	0.29	94	33	17.1	20.3	5.8	968	19.63	0.00	333.2	3.07	6.3	0.92
1009	3.79	0.05	90	23	16.8	21.4	5.5	972	20.23	0.00	161.9	2.70	3.1	1.19
1010	0.26	0.06	86	31	17.0	20.9	5.5	971	19.84	0.00	122.1	1.13	4.2	1.18
1011	1.79	0.05	85	25	17.6	21.9	6.7	967	19.61	0.00	121.0	1.12	3.9	1.29
1012	1.84	0.05	96	28	18.7	23.0	6.6	964	19.50	0.00	115.7	1.90	9.2	1.28
1013	0.50	0.04	97	51	20.1	24.2	10.5	966	15.77	0.00	191.6	1.75	12.5	0.88
1014	-2.17	0.20	97	65	16.7	18.6	11.2	964	6.33	3.30	301.3	0.51	12.9	0.46
1015	-6.14	0.20	99	95	15.1	17.5	13.9	956	1.45	8.13	496.9	1.03	15.5	0.06
1016	-1.68	0.04	99	95	19.7	21.5	17.5	960	2.47	1.78	469.3	0.69	20.1	0.06
1017	-0.12	0.02	98	84	22.8	25.5	20.1	959	4.68	1.78	348.4	1.46	21.1	0.23
1018	-5.03	0.06	99	40	22.2	26.1	16.0	959	13.23	6.35	200.3	1.02	15.5	0.95
1019	1.85	0.08	99	38	22.5	27.3	15.7	963	16.61	0.00	182.8	1.79	15.4	1.08
1020	-34.03	0.11	99	57	22.3	27.6	16.3	964	12.90	33.78	216.4	0.44	18.4	0.61
1021	2.35	0.13	98	57	21.4	24.7	12.2	958	16.01	0.25	162.2	3.13	14.9	0.73
1022	1.29	0.11	93	19	23.5	29.2	12.0	960	16.92	0.00	183.9	0.39	10.4	1.78
1023	-13.83	0.65	92	42	20.9	25.6	12.4	966	16.33	14.48	284.3	1.36	12.4	1.24
1024	-7.20	0.65	94	52	18.8	20.9	7.8	966	4.98	9.40	400.5	0.75	11.0	0.37
1025	3.01	0.07	74	32	11.5	15.3	3.9	972	11.83	0.00	256.5	3.25	-0.3	0.77
1026	3.12	0.08	86	32	12.9	17.1	2.9	973	17.03	0.00	168.0	0.79	2.2	0.90
1027	3.13	0.10	85	42	14.7	18.4	7.5	967	12.38	0.00	287.6	1.63	5.0	0.85
1028	-0.25	0.11	93	65	15.5	18.2	11.7	962	8.44	0.00	427.5	1.00	11.0	0.46
1029	1.74	0.08	95	81	15.7	18.0	12.9	963	2.58	0.00	147.2	1.80	13.9	0.22
1030	-10.44	0.05	95	69	19.4	21.9	10.7	963	6.82	7.11	269.2	0.70	14.5	0.51
1031	4.16	0.05	93	54	12.2	14.9	5.2	967	12.35	0.25	332.9	2.06	5.6	0.47
1101	0.75	0.15	93	33	15.7	20.7	5.4	959	15.03	0.00	586.9	0.74	6.5	0.94
1102	1.58	0.16	89	53	18.8	24.8	12.3	953	9.69	0.00	503.0	1.41	14.6	0.77
1103	2.17	0.19	96	46	24.8	28.8	14.2	957	12.18	0.00	346.2	1.29	17.5	1.19
1104	-43.11	0.21	98	91	11.9	16.5	5.7	958	1.48	40.13	388.7	0.72	8.4	0.08
1105	6.32	0.16	96	56	10.8	14.8	5.1	960	13.20	0.00	161.7	3.67	5.9	0.40
1106	1.42	0.21	94	41	16.3	20.4	5.9	971	15.23	0.00	216.2	0.75	6.8	0.79
1107	0.30	0.22	87	53	16.8	21.2	8.9	967	13.35	0.00	485.6	0.77	11.4	0.69
1108	---	---	95	60	22.4	26.2	7.8	959	11.55	4.83	450.1	0.92	14.8	0.77
1109	---	---	96	61	9.1	11.8	1.2	968	8.42	0.00	336.2	2.65	3.1	0.35
1110	1.82	0.07	96	58	10.0	13.9	1.3	970	14.54	0.25	161.1	1.01	5.1	0.38
1111	-0.42	0.02	96	62	10.6	14.0	7.0	968	10.08	0.00	279.4	0.85	6.6	0.33
1112	---	---	96	79	10.7	14.4	7.7	964	4.11	0.25	509.8	0.68	9.6	0.18
1113	---	---	99	73	17.0	19.4	9.9	959	1.49	6.35	303.4	2.00	15.3	0.05
1114	---	---	86	68	11.8	15.1	4.8	968	8.54	0.00	358.0	0.98	6.2	0.34
1115	---	---	95	47	11.0	14.6	0.9	975	13.26	0.00	275.7	2.64	2.2	0.56
1116	---	---	98	33	11.2	15.4	0.8	968	13.76	0.00	325.4	0.35	4.9	0.69
1117	---	---	98	21	16.3	21.4	1.7	955	6.53	0.00	375.8	2.16	2.5	0.47
1118	---	---	98	33	12.5	16.0	2.5	967	7.58	14.48	214.1	0.50	6.0	0.80
1119	---	---	98	52	16.0	18.2	12.5	962	1.37	52.83	562.4	0.81	15.4	0.05

1120	---	---	76	34	12.2	14.3	4.6	949	10.48	0.00	533.5	1.81	0.6	0.82
1121	-1.67	0.12	93	43	11.9	15.4	3.2	968	13.43	0.00	300.4	0.77	3.1	0.68
1122	-0.35	0.07	92	60	6.1	7.8	-0.3	977	4.34	0.00	382.7	1.28	-0.3	0.24
1123	---	---	96	46	5.9	8.9	0.1	982	8.78	1.02	240.6	0.39	0.6	0.38
1124	---	---	98	82	7.9	10.1	2.9	969	2.63	0.00	322.9	1.73	5.5	0.11
1125	---	---	99	98	8.2	10.9	5.3	966	2.18	0.51	217.1	0.23	9.0	0.02
1126	---	---	99	52	13.0	16.4	10.0	957	5.19	0.00	378.7	0.74	12.5	0.06
1127	---	---	76	28	11.3	13.2	-1.0	956	12.93	0.00	276.1	3.96	-3.3	0.78
1128	-0.01	0.11	83	24	8.3	12.6	-0.9	961	13.13	0.00	237.6	1.72	-4.6	0.71
1129	1.49	0.11	86	20	8.5	12.7	-1.3	973	12.91	0.00	216.2	1.79	-5.9	0.74
1130	0.95	0.10	82	28	9.6	14.2	-1.1	974	12.81	0.00	311.3	1.39	-3.2	0.78
1201	1.42	0.08	82	32	11.2	16.5	-0.3	969	12.62	0.00	498.9	0.73	-0.2	0.82
1202	---	---	99	67	11.7	14.1	7.4	961	4.45	0.25	532.2	0.81	10.7	0.27
1203	---	---	99	69	16.4	19.5	11.6	962	6.71	0.25	280.0	0.61	13.5	0.32
1204	---	---	96	40	17.6	21.5	4.2	961	11.00	0.00	383.4	1.23	7.8	0.75
1205	---	---	98	85	4.5	7.1	3.5	969	3.80	0.76	212.3	1.54	3.9	0.08
1206	---	---	99	86	14.8	19.4	0.2	960	1.42	2.03	399.0	0.70	9.6	0.06
1207	---	---	98	60	4.1	7.4	-0.3	971	10.67	17.02	244.2	1.21	0.6	0.24
1208	---	---	97	80	2.3	3.0	-1.6	968	1.54	0.00	419.4	0.62	0.0	0.03
1209	---	---	90	46	3.5	6.6	-2.7	971	10.43	0.00	313.9	1.44	-3.4	0.32
1210	---	---	91	29	5.2	8.8	-3.5	976	12.25	0.00	233.1	3.15	-5.1	0.46
1211	2.49	0.10	90	38	2.1	5.7	-3.0	971	7.23	0.00	391.1	0.71	-5.8	0.32
1212	0.15	0.08	91	46	4.0	7.9	-3.3	968	8.71	0.00	127.3	4.01	-2.2	0.33
1213	---	---	98	61	4.5	6.6	2.0	969	3.18	0.51	222.3	0.39	1.7	0.26
1214	---	---	99	90	7.4	9.6	4.9	965	3.23	0.25	224.4	2.21	6.4	0.04
1215	---	---	99	84	7.1	8.2	5.2	969	3.29	4.57	193.8	0.88	6.4	0.11
1216	---	---	95	44	10.9	14.3	-0.2	968	10.04	0.25	118.8	2.98	2.1	0.42
1217	1.10	0.13	93	47	10.9	15.9	0.1	972	11.67	0.00	94.0	1.29	2.4	0.58
1218	-0.18	0.06	94	40	10.2	14.7	0.5	972	11.81	0.00	258.4	0.62	1.6	0.61
1219	1.59	0.08	95	52	13.7	17.2	3.5	962	10.76	0.00	359.7	1.98	6.2	0.65
1220	1.04	0.22	85	28	12.0	16.0	0.3	965	11.63	0.00	193.9	1.34	-2.3	0.85
1221	-0.14	0.21	95	47	8.4	12.8	-1.4	969	11.56	0.00	261.7	1.50	-0.1	0.49
1222	---	---	98	56	6.7	11.0	-1.7	975	11.71	0.00	138.8	1.67	1.0	0.31
1223	-0.11	0.25	98	51	8.2	13.5	-1.6	972	9.24	0.25	203.1	0.67	1.5	0.37
1224	---	---	98	42	3.7	9.8	-4.6	971	9.93	0.00	62.6	3.69	-1.9	0.26
1225	0.94	0.26	95	30	8.6	14.0	-2.8	971	12.10	0.00	53.9	2.50	-1.6	0.59
1226	0.75	0.14	87	38	10.4	14.5	0.9	970	11.79	0.00	236.8	0.97	0.8	0.63
1227	0.42	0.03	91	46	11.7	15.5	3.1	968	9.29	0.00	182.0	1.62	4.9	0.61
1228	-4.87	0.31	98	89	8.7	9.4	4.6	967	2.09	3.56	142.1	0.61	7.1	0.06
1229	1.68	0.32	99	64	9.3	12.7	-1.3	966	8.42	0.00	133.3	3.03	3.6	0.23
1230	-1.76	0.20	99	80	6.7	9.9	-1.0	966	4.89	0.51	131.8	0.20	5.8	0.13
1231	---	---	98	78	9.1	12.2	-6.1	964	2.53	0.00	435.0	0.37	1.0	0.09
101	---	---	88	47	-0.3	2.7	-6.1	979	11.78	0.00	186.3	2.91	-7.0	0.26
102	0.70	0.23	93	47	3.4	7.0	-4.6	974	8.56	0.00	192.8	1.15	-3.1	0.31
103	-1.79	0.12	90	61	-2.0	1.3	-7.8	977	2.75	0.00	407.5	1.15	-8.2	0.10
104	---	---	83	43	-3.4	-0.7	-7.9	981	10.39	0.00	246.9	1.18	-10.6	0.24
105	---	---	98	56	-0.6	3.9	-4.6	966	5.15	0.00	585.4	0.60	-2.7	0.18
106	---	---	98	60	5.0	7.2	-8.6	953	9.86	0.25	396.5	1.60	-4.8	0.25
107	0.33	0.16	87	43	-0.1	4.6	-9.0	968	12.45	0.00	324.5	0.38	-5.9	0.30
108	0.93	0.16	90	43	10.4	13.9	-2.6	965	11.86	0.00	235.3	2.01	-0.8	0.63
109	2.03	0.05	87	43	10.0	15.7	-2.2	966	12.21	0.00	280.9	0.61	3.1	0.63
110	-1.84	0.07	92	50	12.3	15.9	2.5	959	11.73	0.00	163.7	1.55	3.8	0.62
111	1.27	0.08	91	21	16.5	24.9	2.7	954	12.25	0.00	279.5	1.50	1.4	1.34
112	0.42	0.06	80	35	14.0	18.1	4.7	955	8.27	0.00	317.6	0.41	3.4	0.90
113	---	---	92	36	11.6	14.4	-0.1	959	11.57	0.00	376.6	1.90	0.9	0.67
114	0.81	0.08	90	31	9.9	14.5	0.0	963	13.06	0.00	206.7	1.42	-1.0	0.69
115	1.28	0.07	80	25	12.7	18.0	1.5	960	12.65	0.00	526.9	0.69	-0.6	0.98
116	0.07	0.06	91	26	13.2	16.5	2.1	952	6.05	0.00	410.3	2.18	4.2	0.48
117	-0.53	0.05	86	41	8.2	11.1	1.8	960	12.93	0.76	299.4	0.74	-1.2	0.55
118	-0.28	0.03	85	42	5.1	7.8	-1.9	963	5.42	0.00	297.0	2.09	-3.3	0.39

119	---	---	83	21	7.3	11.5	-2.1	967	13.71	0.00	191.6	15.09	-7.4	0.65
120	---	---	81	33	10.7	15.5	-1.9	968	12.96	0.00	155.5	1.29	-0.7	0.79
121	---	---	98	48	2.9	5.4	-0.6	970	7.19	0.51	289.8	1.03	-2.5	0.32
122	---	---	98	82	-0.2	0.4	-8.2	968	8.67	1.52	255.5	2.60	-3.7	0.05
123	---	---	91	53	-1.6	4.6	-8.7	972	14.10	2.79	206.7	0.54	-5.4	0.15
124	---	---	86	53	5.4	9.2	-1.7	971	12.09	6.60	242.0	1.02	-0.5	0.34
125	---	---	99	51	8.3	13.6	0.8	970	13.47	0.00	185.9	1.21	3.8	0.42
126	---	---	99	78	10.2	12.8	6.6	963	2.25	4.83	349.9	0.69	9.8	0.01
127	---	---	91	41	14.0	19.1	5.2	951	12.76	1.78	414.3	0.76	5.5	0.70
128	---	---	98	68	5.6	6.5	-0.2	964	3.65	0.00	492.2	0.93	0.5	0.22
129	---	---	98	81	0.8	2.2	-4.0	972	5.00	3.05	360.5	1.56	-1.5	0.06
130	---	---	94	35	6.3	11.3	-4.0	971	15.09	1.52	235.0	0.92	-2.7	0.51
131	---	---	87	33	10.5	16.0	-1.8	963	11.73	0.00	67.4	0.95	0.5	0.72
201	---	---	61	22	16.8	23.1	5.1	962	14.02	0.00	106.9	13.84	1.1	1.34
202	1.79	0.07	74	28	20.2	25.2	7.6	960	15.14	0.00	308.5	0.63	4.4	1.59
203	0.18	0.06	88	30	12.6	15.2	-1.2	972	15.33	0.00	384.6	3.82	-0.5	0.83
204	---	---	77	18	13.9	20.7	1.9	969	15.25	0.00	358.4	0.84	-1.2	1.12
205	---	---	80	39	7.9	11.3	1.7	973	15.74	0.00	244.0	1.85	-1.8	0.55
206	---	---	76	28	12.1	16.5	1.5	967	14.70	0.00	226.2	0.87	-0.4	0.86
207	---	---	88	24	6.9	9.8	-6.1	974	13.80	0.00	331.6	3.54	-7.4	0.66
208	---	---	83	33	5.5	9.2	-4.5	976	16.61	0.00	336.6	0.60	-6.5	0.55
209	---	---	98	34	10.5	15.6	2.8	961	12.15	0.00	182.0	4.04	0.1	0.77
210	---	---	99	32	10.1	13.3	1.0	957	15.50	0.00	500.8	0.86	-3.5	0.64
211	---	---	70	37	1.0	1.9	-5.1	967	5.32	0.00	469.2	1.46	-11.9	0.33
212	---	---	60	42	-2.9	-0.7	-5.2	970	4.39	0.00	302.0	1.15	-11.2	0.27
213	---	---	98	58	0.2	1.5	-2.1	969	3.86	0.00	270.5	0.76	-3.5	0.22
214	---	---	100	97	1.3	11.9	-0.5	959	2.66	1.52	472.9	0.73	5.1	0.01
215	---	---	100	53	5.1	11.1	-2.2	961	11.10	0.00	489.0	1.62	-3.3	0.26
216	-7.91	0.00	93	73	0.1	2.2	-5.6	970	3.86	4.57	74.1	15.59	-3.3	0.09
217	2.73	0.00	85	29	7.5	13.5	-4.9	976	18.27	4.57	170.2	0.46	-2.8	0.59
218	0.36	0.00	85	39	11.1	16.1	-0.9	968	14.39	0.00	333.3	1.51	1.4	0.73
219	2.12	0.00	77	21	14.6	19.0	5.3	973	17.97	0.00	266.9	2.41	-1.7	1.10
220	1.55	0.05	65	26	18.3	24.3	5.8	971	17.78	0.00	227.3	5.09	2.4	1.48
221	1.83	0.05	59	22	18.2	20.8	8.2	971	16.95	0.00	268.1	0.82	0.0	1.52
222	---	---	63	30	19.1	24.5	9.1	962	15.20	0.00	343.8	2.91	5.0	1.44
223	---	---	75	24	18.7	21.8	3.0	967	17.63	0.00	391.6	1.99	2.0	1.36
224	---	---	74	24	13.9	19.0	3.9	976	18.78	0.00	290.7	0.98	-0.7	1.13
225	---	---	98	52	15.9	20.2	7.5	967	13.06	0.00	479.3	1.05	10.3	0.70
226	---	---	99	44	19.6	24.8	10.8	958	13.36	0.00	423.8	1.89	13.3	0.81
227	---	---	99	75	11.7	13.4	0.7	963	7.66	0.00	570.0	0.77	6.5	0.15
228	---	---	93	72	0.8	2.4	-3.1	973	4.80	0.00	649.3	1.20	-3.4	0.11
301	---	---	92	69	-4.4	-3.2	-6.1	976	3.66	0.00	506.5	1.14	-7.1	0.08
302	---	---	93	87	-5.4	-4.7	-6.1	976	5.67	0.00	309.6	1.77	-6.7	0.04
303	---	---	98	71	-1.3	1.7	-5.4	972	11.65	7.87	198.2	0.55	-2.6	0.13
304	---	---	100	98	4.1	7.1	1.7	962	3.16	2.03	433.2	1.26	5.0	0.01
305	---	---	100	84	5.7	6.5	4.9	963	3.48	0.00	263.0	0.94	4.6	0.07
306	---	---	99	81	10.6	17.8	-7.9	954	4.13	17.53	536.1	0.64	2.5	0.07
307	---	---	83	54	-3.1	0.8	-9.2	951	21.19	0.76	537.6	1.71	-8.8	0.16
308	0.73	0.10	83	30	1.3	8.2	-9.1	978	21.44	0.00	223.8	1.12	-7.8	0.42
309	4.48	0.11	82	21	9.5	15.9	-3.7	974	21.86	0.00	462.0	1.32	-4.0	0.85
310	---	---	90	36	13.3	18.6	0.5	970	21.36	0.00	591.8	1.19	2.7	0.91
311	---	---	92	65	14.3	17.9	8.8	965	10.05	0.00	700.8	1.05	11.1	0.41
312	---	---	99	86	16.7	18.3	12.0	960	5.35	10.92	509.7	1.93	14.1	0.20
313	---	---	99	92	13.3	13.7	11.2	961	2.51	39.12	304.0	0.99	12.1	0.04
314	---	---	99	82	14.1	16.2	12.4	963	7.94	11.94	397.0	1.14	13.0	0.10
315	---	---	97	59	17.1	20.9	9.7	967	11.32	0.25	334.3	3.30	12.2	0.46
316	---	---	98	38	19.2	23.6	8.7	966	20.57	0.00	165.1	2.52	8.8	1.08
317	---	---	89	28	20.6	25.4	8.8	969	20.68	0.00	137.9	1.40	7.5	1.48
318	2.23	0.26	79	38	22.0	25.8	10.9	965	21.37	0.00	376.3	1.10	9.7	1.49
319	2.72	1.20	79	34	23.2	28.6	10.5	953	20.42	0.00	502.6	1.65	9.9	1.63

320	2.90	1.20	82	31	18.2	21.7	8.5	960	19.92	0.00	236.8	1.65	5.5	1.23
321	6.10	0.19	96	41	21.9	28.2	8.6	955	21.81	0.00	504.3	1.31	13.5	1.46
322	---	---	67	18	27.3	33.2	12.2	952	20.29	0.00	308.8	1.95	5.2	2.69
323	2.19	0.23	69	32	19.4	23.9	11.7	962	22.42	0.00	323.7	2.00	5.8	1.35
324	---	---	83	49	21.1	26.0	13.4	956	18.48	0.00	545.8	1.03	13.7	1.07
325	-9.90	0.24	99	64	18.2	20.8	9.9	953	6.43	12.95	528.5	1.81	15.5	0.27
326	2.06	0.23	92	28	16.3	19.8	1.0	961	22.17	0.00	366.7	1.71	2.0	1.15
327	0.10	0.15	92	33	12.4	17.0	1.2	970	24.08	0.00	261.6	2.10	1.4	0.84
328	-4.59	0.27	92	53	6.4	8.0	4.3	972	5.06	0.00	365.7	1.37	2.6	0.27
329	3.33	0.25	92	64	8.4	11.3	3.7	970	11.51	0.00	361.9	1.27	3.1	0.29
330	4.01	0.16	88	45	8.2	11.5	3.6	969	14.52	0.00	339.0	1.28	0.6	0.50
331	4.87	0.17	88	50	10.7	14.7	4.8	968	20.36	0.00	192.4	1.41	4.2	0.51
401	4.89	0.13	78	22	18.4	22.7	8.0	965	24.12	0.00	229.5	1.54	2.6	1.42
402	2.51	0.25	79	22	19.2	23.8	6.5	964	24.96	0.00	397.2	1.31	5.3	1.45
403	-7.52	0.41	99	70	14.2	16.0	7.9	963	3.19	7.11	156.1	2.98	11.5	0.17
404	5.46	0.37	100	55	15.5	19.8	8.8	967	17.08	0.00	229.6	2.84	10.0	0.41
405	0.44	0.17	98	66	16.4	19.0	9.0	961	13.00	0.00	262.5	1.00	11.6	0.48
406	2.62	0.16	99	60	17.3	22.5	11.7	959	18.79	0.00	343.0	1.03	13.1	0.53
407	3.87	0.14	99	51	21.7	27.0	13.6	955	21.55	0.00	511.1	1.40	15.6	0.92
408	6.18	0.27	89	20	25.4	31.8	15.2	950	25.57	0.00	447.4	1.65	11.6	1.88
409	-1.13	3.28	95	47	20.2	24.1	12.8	947	23.59	0.00	334.1	0.91	12.8	0.96
410	-5.81	3.27	98	58	8.5	14.1	-1.2	952	7.57	7.62	555.9	1.45	2.1	0.17
411	4.27	0.07	81	28	8.4	14.6	-1.4	961	26.89	0.00	329.4	2.68	-2.6	0.69
412	4.85	0.14	77	22	15.1	22.9	1.6	969	26.18	0.00	170.8	3.99	1.0	1.18
413	4.03	0.37	85	31	20.1	25.0	7.7	970	26.68	0.00	352.3	1.15	7.3	1.53
414	—	—	86	24	22.6	27.5	12.1	956	23.50	0.00	606.5	1.52	9.0	1.77
415	2.96	0.11	95	58	21.6	26.9	14.2	956	20.25	0.00	309.3	0.80	17.2	0.87
416	-18.42	5.32	98	73	23.3	26.7	11.9	956	7.91	4.32	330.9	1.44	17.8	0.47
417	-35.77	5.32	100	54	16.3	24.2	10.9	952	4.61	51.56	300.3	2.09	13.7	0.07
418	2.90	0.23	88	36	16.9	20.4	7.1	958	26.71	0.00	278.2	1.71	5.9	1.06
419	1.35	0.22	99	56	13.1	17.0	6.7	955	13.74	1.52	390.2	2.30	9.6	0.40
420	1.40	0.05	98	38	17.3	22.0	8.4	953	27.23	0.00	265.1	1.44	9.1	0.86
421	1.31	0.40	98	53	16.8	21.5	6.6	957	26.87	1.02	495.2	0.72	8.6	0.69
422	—	—	97	89	6.7	7.2	5.4	964	2.54	26.92	561.4	1.87	5.5	0.06
423	---	---	92	53	10.5	15.1	5.7	966	14.73	0.25	263.1	5.10	5.5	0.35
424	3.94	0.19	94	43	14.6	17.8	4.9	967	20.44	0.00	200.5	2.85	5.4	0.78
425	4.90	0.15	92	40	17.7	22.3	5.9	963	27.40	0.00	532.9	1.15	8.5	1.04
426	1.89	0.13	91	50	17.0	23.1	3.9	958	24.40	0.00	547.7	2.27	7.7	0.67
427	4.61	0.11	89	32	13.5	18.2	4.2	969	26.95	0.00	271.7	2.48	3.5	0.87
428	2.96	0.06	91	57	17.8	21.5	10.8	960	16.79	0.00	491.2	1.19	12.8	0.75
429	3.62	0.05	93	47	19.8	23.2	12.9	956	21.66	0.00	338.5	1.62	13.2	0.71
430	-0.10	0.11	—	---	---	---	—	—	—	—	—	—	---	---
501	2.25	0.12	---	---	---	---	---	---	---	---	---	---	---	---
502	1.75	0.07	—	—	—	—	—	—	—	—	—	—	—	—
503	0.59	0.06	97	74	15.9	20.4	9.6	955	10.85	0.25	307.8	4.80	13.1	0.28
504	4.25	0.05	96	44	17.4	21.5	9.6	967	28.36	0.00	290.5	2.49	8.6	0.92
505	-5.27	0.06	97	63	15.0	17.9	10.0	967	9.76	4.57	304.4	1.65	11.9	0.39
506	-22.25	0.08	96	84	17.3	19.8	15.1	959	7.13	28.19	438.0	1.07	16.5	0.18
507	-35.76	0.09	95	65	18.9	22.2	13.2	953	4.98	37.59	394.8	2.32	14.8	0.28
508	9.23	0.09	89	33	19.0	22.9	11.3	949	26.72	0.00	446.1	3.46	7.7	1.18
509	6.78	0.06	82	34	20.3	25.4	10.6	955	28.86	0.00	310.4	1.74	8.9	1.28
510	4.08	0.04	96	44	16.9	20.6	8.7	962	28.40	0.00	280.6	8.99	7.6	0.95
511	5.14	0.04	96	44	18.5	22.8	9.0	961	25.81	0.00	228.8	1.05	11.4	0.90
512	2.28	0.07	95	73	19.7	24.3	13.7	948	12.32	0.00	510.2	1.43	18.2	0.42
513	6.68	0.10	97	27	26.5	31.0	17.6	948	29.13	0.00	223.8	1.55	14.0	2.01
514	4.36	0.12	93	53	20.1	23.6	15.4	962	28.88	0.00	322.0	2.74	13.3	0.92
515	4.70	0.12	93	52	23.7	27.7	14.5	962	20.36	0.00	290.3	1.23	18.8	0.74
516	1.33	0.05	91	77	23.0	24.3	19.1	954	8.44	0.25	393.3	1.84	19.9	0.49
517	4.95	0.16	89	19	25.9	30.1	9.3	947	25.96	0.00	464.4	1.88	10.2	1.85
518	2.26	0.16	88	37	15.6	20.6	7.9	960	21.79	0.00	323.8	5.60	6.0	0.88

519	4.89	0.11	87	37	19.6	24.5	7.6	965	29.23	0.00	106.1	1.69	8.7	1.27
520	-1.68	0.20	95	39	21.4	25.5	11.2	963	26.03	6.86	278.0	2.68	11.9	1.32
521	2.30	0.18	94	43	21.8	26.4	14.6	963	23.52	2.79	265.8	2.85	14.0	1.13
522	6.78	0.07	92	47	24.3	28.1	15.6	961	25.42	0.00	507.0	1.46	16.7	1.30
523	-38.73	0.05	97	81	21.1	23.3	12.0	959	3.68	43.18	375.1	1.67	16.9	0.33
524	0.06	0.05	97	89	13.6	14.4	12.2	964	4.97	0.51	310.3	1.36	12.2	0.10
525	-21.31	2.80	97	89	13.7	16.3	12.4	967	5.81	21.08	337.3	1.88	13.3	0.13
526	-12.50	2.80	97	60	20.5	24.8	15.6	961	14.61	19.56	323.7	1.59	17.2	0.43
527	5.13	0.09	97	38	22.7	27.0	14.9	955	23.67	0.00	319.0	2.87	14.1	1.02
528	5.09	0.08	86	44	20.8	24.4	14.1	964	26.91	0.00	282.0	1.86	11.7	1.18
529	0.28	0.06	90	64	16.5	17.6	14.3	968	8.32	0.51	234.2	2.07	12.6	0.46
530	-10.33	0.09	97	60	19.4	23.4	12.8	965	13.67	13.72	147.9	1.16	15.4	0.50
531	1.86	0.07	96	48	20.5	26.2	13.0	961	20.11	1.02	125.8	3.46	15.0	0.80
601	5.02	0.19	96	34	24.3	29.6	14.6	960	27.10	0.00	214.9	1.88	15.4	1.41
602	4.12	0.14	96	58	24.9	28.7	15.7	960	19.66	0.00	262.6	1.34	18.9	1.01
603	—	—	97	59	23.1	26.9	12.9	960	13.92	88.65	395.1	1.62	17.7	0.68
604	---	—	94	73	19.1	22.7	15.0	963	4.35	19.05	275.9	1.58	15.9	0.34
605	—	—	95	58	23.8	27.5	16.1	957	18.62	0.00	242.1	1.86	17.7	0.93
606	---	---	94	56	27.1	32.0	19.6	950	26.71	0.00	438.9	1.95	21.4	1.18
607	3.07	0.47	95	63	28.5	32.1	22.6	953	24.39	0.00	417.3	2.41	22.9	1.09
608	2.15	1.84	94	59	27.6	30.9	21.2	957	17.57	0.00	427.3	1.73	22.1	1.00
609	—	—	97	70	23.2	27.7	17.7	960	3.69	16.51	305.6	2.49	20.5	0.41
610	---	---	97	81	18.0	20.0	13.3	964	3.97	6.86	364.4	1.47	15.4	0.17
611	—	—	96	44	19.1	22.2	12.0	969	28.35	0.00	295.3	7.16	10.3	0.97
612	---	---	88	36	22.4	26.7	13.0	968	29.75	0.00	159.1	2.14	11.9	1.49
613	—	—	87	46	24.5	28.7	15.3	965	29.09	0.00	368.2	1.79	15.1	1.47
614	---	---	84	37	26.7	32.0	18.0	962	28.55	0.00	480.8	1.93	16.2	1.82
615	—	—	85	39	25.9	30.2	18.1	964	29.70	0.00	452.2	2.04	16.0	1.62
616	---	---	94	39	25.7	29.3	17.6	968	29.65	0.00	341.5	4.59	16.2	1.58
617	—	—	94	42	25.3	28.9	16.7	970	25.56	0.00	285.4	3.77	15.7	1.47
618	---	---	91	34	25.6	29.3	16.9	969	28.07	0.00	247.1	3.51	14.8	1.75
619	—	—	88	37	26.2	29.9	17.6	967	24.46	0.00	248.7	3.19	15.9	1.66
620	---	---	88	38	26.7	30.8	17.6	964	28.48	0.00	225.5	3.66	16.1	1.75
621	—	—	89	36	27.7	31.6	17.9	962	26.37	0.00	210.7	3.30	16.4	1.99
622	---	---	90	35	28.2	32.3	17.8	962	25.61	0.00	211.2	3.47	16.2	2.12
623	—	—	92	38	27.2	31.1	18.8	963	27.42	1.02	286.1	2.22	17.1	1.78
624	---	---	90	42	24.3	28.6	15.6	961	25.38	0.00	328.9	1.73	15.7	1.24
625	—	—	88	36	24.5	29.0	15.5	962	29.29	0.00	268.1	7.50	13.0	1.62
626	---	---	81	32	26.3	30.8	15.6	963	29.19	0.00	188.9	1.98	13.1	2.05
627	—	—	94	40	25.8	30.9	16.7	962	23.99	0.00	245.4	1.54	16.2	1.58
628	---	---	94	34	28.5	34.2	17.1	960	26.86	0.00	248.6	1.92	18.6	1.99
629	—	—	91	64	23.6	26.2	17.6	964	20.97	0.25	369.1	1.59	17.1	0.84
630	---	---	89	44	21.2	24.4	13.8	968	17.61	0.00	289.1	7.45	13.5	0.90
701	—	—	86	31	23.7	27.5	14.2	967	29.31	0.00	249.9	1.76	11.0	1.74
702	---	---	85	51	24.1	29.0	18.6	961	18.21	0.00	309.4	1.59	17.2	1.08
703	—	—	86	41	29.1	34.2	18.9	952	26.43	0.00	532.7	1.69	19.2	2.01
704	---	---	87	22	29.7	33.5	18.8	952	29.08	0.00	314.0	5.94	13.8	2.56
705	—	—	93	23	29.0	33.6	18.5	963	29.99	0.00	153.6	2.18	14.0	2.70
706	---	---	93	25	29.9	35.2	19.6	969	29.85	0.00	257.1	1.58	17.3	2.40
707	—	—	95	34	30.1	34.8	20.3	969	30.03	0.00	286.4	2.81	18.3	2.27
708	---	---	86	31	31.5	36.1	20.8	966	29.51	0.00	324.6	2.05	17.2	2.75
709	—	—	78	20	34.1	39.4	22.2	964	29.14	0.00	233.7	3.69	18.0	3.61
710	---	---	75	19	33.9	39.4	22.3	964	29.20	0.00	209.5	1.62	17.3	3.49
711	—	—	72	23	34.6	39.2	22.6	964	29.15	0.00	234.1	2.02	15.5	3.95
712	4.23	0.19	82	21	33.5	38.4	22.2	963	28.84	0.00	255.3	2.02	16.9	3.55
713	1.24	0.23	82	31	32.4	36.7	22.9	963	28.53	0.00	202.4	8.02	18.7	2.78
714	---	---	86	47	29.5	31.4	21.9	962	0.78	0.00	121.1	0.41	19.7	1.97
715	—	---	91	35	29.8	34.0	19.8	964	26.60	0.00	238.9	3.00	18.2	2.19
716	---	---	91	37	29.3	34.1	20.7	964	24.68	0.00	183.0	3.56	18.8	2.02
717	—	—	91	47	28.1	32.8	20.6	965	19.40	0.00	174.5	4.09	19.6	1.59

718	---	---	97	42	29.1	33.2	20.2	964	22.62	0.25	226.6	2.90	19.5	1.88
719	---	---	97	50	26.8	32.1	20.6	963	19.36	0.25	271.6	1.42	20.7	1.13
720	---	---	91	45	29.1	34.5	20.7	961	23.25	0.00	164.3	2.68	20.3	1.69
721	---	---	91	43	30.4	34.7	21.2	961	28.01	1.27	283.9	1.86	20.3	1.98
722	---	---	93	40	29.4	35.0	20.6	960	25.35	8.89	337.2	1.63	19.7	1.95
723	---	---	95	42	27.0	33.2	19.1	959	16.18	11.68	296.0	0.93	19.4	1.44
724	---	---	97	52	26.5	31.2	19.6	961	26.05	2.29	164.5	2.23	20.9	1.14
725	---	---	96	39	30.0	34.7	20.6	961	27.92	0.00	336.9	1.57	19.7	2.05
726	---	---	85	41	31.2	36.1	23.1	961	27.92	0.00	454.8	2.12	20.9	2.15
727	---	---	79	25	33.2	39.6	22.5	959	28.63	0.00	375.0	2.30	18.7	3.11
728	---	---	92	25	33.8	38.2	22.3	961	28.42	0.00	319.9	1.75	20.5	3.26
729	---	---	93	43	31.0	34.4	22.6	964	25.61	0.00	344.2	3.62	21.5	1.91
730	---	---	87	44	28.7	32.0	22.8	965	22.42	0.00	314.5	2.10	19.9	1.71
731	---	---	94	64	25.0	27.2	22.2	963	9.92	1.52	297.4	1.44	21.1	0.69

MARENA

Date	ET lys mm	ET std dev mm	RH max %	RH min %	T air avg C	T air max C	T air min C	Atm pres kPa	Rs MJ/m^2	Rain mm	Wind run km	Wind day/night ratio	T dew avg C	Vap pres defct kPa
201	0.00	0.00	93	21	2.0	7.9	-9.9	985	12.58	0.00	285.2	2.4	-9.0	0.45
202	1.87	0.00	92	23	4.7	10.5	-10.2	982	14.84	0.00	168.8	5.3	-8.2	0.61
203	-2.22	0.20	99	24	9.3	15.3	-4.7	978	12.81	0.00	303.6	1.5	-2.8	0.82
204	-0.59	0.20	94	41	6.0	12.0	-3.0	980	14.00	0.00	198.6	1.1	-1.6	0.47
205	0.46	0.00	97	36	7.3	10.9	-2.6	979	14.74	0.00	141.4	2.9	-3.3	0.50
206	-0.70	0.39	98	40	11.1	16.4	-1.9	976	14.06	0.00	135.2	1.1	1.2	0.70
207	2.22	0.44	99	60	1.8	4.1	-5.8	976	6.43	0.00	292.8	1.0	-5.4	0.18
208	1.99	0.44	99	54	-5.2	-4.2	-13.1	972	2.80	0.00	410.3	0.3	-12.3	0.06
209	2.34	0.51	89	40	-9.0	-5.3	-12.9	986	9.61	0.00	249.2	3.4	-16.6	0.17
210	1.77	0.38	89	41	-2.4	3.6	-12.3	981	13.84	0.00	150.1	1.4	-9.6	0.26
211	-2.57	0.28	95	14	5.8	13.1	-7.2	976	13.14	0.00	331.8	0.6	-3.8	0.72
212	0.35	0.20	88	43	5.9	8.8	-8.6	980	14.11	0.00	349.5	3.3	-5.6	0.44
213	-0.94	0.32	87	19	6.2	12.6	-8.7	995	16.80	0.00	171.7	1.0	-9.1	0.70
214	-1.29	0.49	60	10	11.3	16.4	1.0	983	13.38	0.00	285.4	6.5	-9.0	1.12
215	0.00	0.53	79	19	12.5	17.9	0.8	986	16.37	0.00	79.3	5.5	-4.6	1.10
216	-3.05	0.42	81	33	15.2	20.9	1.2	986	15.92	0.00	301.0	1.4	2.9	1.01
217	-3.27	0.28	80	41	17.7	22.6	5.8	979	14.50	0.00	464.6	0.9	7.5	1.06
218	-2.22	0.38	89	43	17.0	19.5	13.4	970	8.94	0.00	660.2	0.9	11.2	0.80
219	-9.48	0.49	100	82	15.7	16.5	1.6	969	1.20	12.70	218.4	2.6	10.7	0.05
220	4.33	0.38	100	82	6.2	9.1	-1.1	979	6.35	0.00	269.7	1.2	2.3	0.09
221	-18.27	0.00	100	77	4.5	6.9	1.3	982	5.03	18.80	237.4	0.8	3.9	0.13
222	-4.69	0.38	100	89	5.5	6.2	-4.2	968	2.80	5.84	239.7	1.4	2.0	0.00
223	2.46	0.38	98	69	-2.7	-1.0	-8.2	970	11.09	0.25	249.8	8.5	-6.8	0.12
224	-0.94	0.00	97	39	8.7	16.6	-6.3	973	17.20	0.25	455.6	1.2	0.3	0.64
225	2.52	0.07	77	39	-2.0	-0.2	-9.2	986	18.28	0.00	486.7	1.7	-11.9	0.27
226	0.65	0.08	95	33	-1.2	3.9	-9.2	991	18.59	0.00	115.0	8.1	-10.0	0.33
227	0.41	0.05	95	37	2.7	7.2	-6.8	983	12.02	0.00	337.7	1.2	-5.0	0.40
228	-16.57	0.28	100	62	7.6	9.5	3.0	976	2.22	13.46	262.5	1.6	4.9	0.17
301	0.41	0.40	100	98	2.0	2.8	-3.7	980	1.59	1.78	214.1	5.4	0.6	0.00
302	-1.17	0.40	100	52	8.2	14.9	-3.3	982	18.63	0.25	120.1	6.6	3.4	0.39
303	-3.47	0.40	93	33	18.0	25.0	2.9	979	18.00	0.00	280.4	1.4	6.9	1.20
304	-0.81	0.40	87	29	20.4	25.8	7.5	974	19.41	0.00	109.4	3.3	5.8	1.58
305	-1.12	0.40	97	29	21.3	27.1	8.7	973	19.38	0.00	135.6	4.2	9.5	1.56
306	-3.52	0.28	98	66	18.1	23.6	10.5	973	11.79	0.00	263.1	0.8	13.6	0.38
307	---	---	100	61	12.4	15.1	2.9	980	9.73	22.10	428.6	1.0	5.9	0.43
308	---	---	100	99	0.0	2.5	-1.6	983	2.35	1.02	44.5	0.0	-0.7	0.00
309	---	---	99	61	1.5	2.9	-3.1	982	18.19	7.87	231.0	1.3	-2.5	0.16
310	---	---	92	56	4.7	10.0	-3.3	985	21.17	2.54	131.3	8.0	0.1	0.29
311	---	---	84	33	12.8	18.0	1.8	983	19.53	0.00	306.5	2.1	1.7	0.84
312	---	---	97	61	13.6	16.9	5.7	986	11.33	0.00	256.7	1.3	8.1	0.50
313	---	---	92	30	13.0	17.6	5.1	988	21.34	0.00	244.7	1.3	2.1	0.84
314	---	---	84	23	19.4	24.9	7.4	975	21.71	0.00	378.4	1.9	5.9	1.49
315	---	---	68	24	17.0	20.3	6.2	980	21.61	0.00	242.3	6.4	0.6	1.32
316	---	---	72	23	17.3	23.5	5.2	978	21.86	0.00	339.5	0.7	2.9	1.42
317	---	---	69	33	25.1	30.2	10.4	962	18.57	0.00	477.7	2.3	10.1	1.82
318	---	---	64	17	20.9	25.3	10.6	972	22.22	0.00	182.2	2.1	0.9	1.91
319	---	---	87	38	24.5	30.5	12.3	965	16.86	0.00	314.6	2.4	13.9	1.74
320	---	---	88	25	22.8	30.9	4.8	963	15.35	0.00	438.8	1.1	6.9	1.54
321	---	---	71	19	14.8	20.0	4.4	979	23.34	0.00	133.1	4.4	-1.3	1.23
322	---	---	89	14	20.4	25.5	6.1	972	21.74	0.00	465.8	1.1	4.2	1.94
323	---	---	90	17	25.1	30.3	9.9	964	20.53	0.00	430.3	1.1	6.1	1.97
324	---	---	85	45	8.7	10.2	0.3	980	8.06	0.00	297.1	9.1	-1.5	0.57

325	---	---	85	32	11.0	15.5	0.8	980	14.38	0.25	170.0	3.3	4.6	0.67
326	---	---	100	82	10.5	13.3	5.4	965	2.09	12.70	330.5	0.9	8.4	0.03
327	---	---	90	39	9.9	12.8	-0.9	974	18.99	0.00	421.9	1.7	-1.5	0.59
328	---	---	91	33	7.3	11.5	-1.1	982	23.43	0.00	234.2	1.7	-2.8	0.55
329	---	---	93	29	11.4	15.6	-1.0	984	22.94	0.00	372.6	1.5	-0.6	0.80
330	---	---	94	36	8.0	12.1	-1.0	992	23.61	0.00	161.0	1.8	-2.3	0.60
331	---	---	85	24	16.1	22.5	1.5	982	24.15	0.00	343.6	4.7	2.0	1.31
401	---	---	84	26	20.9	27.0	6.2	977	23.99	0.00	426.8	1.1	7.8	1.64
402	---	---	95	52	19.2	24.4	3.1	971	15.06	0.00	503.9	1.3	8.8	0.87
403	---	---	92	36	12.3	17.5	2.7	984	24.66	0.00	236.4	0.9	1.7	0.82
404	---	---	91	39	19.0	24.7	5.9	968	15.60	0.00	493.5	1.4	8.9	1.25
405	---	---	100	66	2.2	5.8	-1.0	973	2.89	0.25	527.1	1.6	-0.6	0.05
406	---	---	87	27	7.2	11.8	-1.3	982	25.10	0.00	181.7	7.2	-4.6	0.63
407	---	---	92	29	12.9	18.8	-0.8	980	24.89	0.00	516.1	1.2	1.8	0.96
408	---	---	100	49	18.3	22.3	12.1	974	16.73	12.70	276.9	2.2	11.5	0.91
409	---	---	98	79	19.4	23.5	13.1	967	9.68	0.00	408.9	1.8	17.8	0.25
410	---	---	100	96	12.0	13.3	11.4	971	2.66	53.34	307.4	1.7	11.7	0.03
411	---	---	100	71	14.0	18.0	5.8	971	8.88	7.87	413.9	0.9	8.8	0.11
412	---	---	95	32	12.7	17.5	2.9	975	20.51	0.00	394.4	12.2	3.4	0.70
413	---	---	95	21	22.3	29.5	2.7	970	26.26	0.00	437.2	1.5	8.4	1.99
414	---	---	81	23	27.5	33.3	11.6	962	23.82	0.00	567.0	1.4	15.2	1.90
415	---	---	85	31	15.9	19.0	7.0	980	24.05	0.00	309.9	11.8	3.5	1.02
416	---	---	78	26	21.5	27.3	7.8	987	26.71	0.00	185.3	7.4	6.8	1.76
417	---	---	68	23	25.2	29.5	12.5	984	26.39	0.00	358.1	2.1	5.8	2.35
418	---	---	89	20	24.8	29.9	13.2	978	26.21	0.00	318.9	3.9	8.3	2.29
419	---	---	93	31	25.2	30.4	12.9	980	25.70	0.00	146.3	1.3	12.4	1.82
420	---	---	95	45	24.9	29.9	13.7	980	22.56	0.00	148.6	1.8	15.6	1.54
421	---	---	100	41	26.4	30.9	16.4	975	24.07	4.06	232.7	2.5	16.5	1.66
422	---	---	100	85	16.9	19.2	13.7	979	9.18	0.00	192.0	4.1	15.4	0.12
423	---	---	100	55	22.9	27.6	13.8	975	23.67	0.00	333.5	1.7	17.0	0.97
424	---	---	94	47	25.6	29.1	17.8	969	22.27	0.00	491.9	1.6	18.0	1.32
425	---	---	97	81	22.0	23.6	15.6	963	6.24	5.84	384.9	2.3	19.2	0.29
426	---	---	95	24	25.3	29.3	9.4	967	26.98	0.00	286.8	0.7	8.7	2.08
427	---	---	100	58	7.9	10.6	5.0	977	5.18	8.13	373.9	2.0	5.5	0.22
428	---	---	100	58	17.6	20.8	6.9	979	17.81	1.27	312.3	0.9	15.1	0.50
429	---	---	100	70	20.8	20.8	20.8	981	3.56	32.51	385.0	1.4	19.6	0.26
430	---	---	98	77	14.5	20.8	4.0	984	6.90	0.00	129.7	9.8	9.1	0.21
501	---	---	100	53	12.2	17.1	4.3	983	28.06	0.25	40.1	5.1	7.2	0.53
502	---	---	100	97	9.9	10.8	8.6	979	3.04	15.75	79.3	25.3	9.4	0.01
503	---	---	100	60	15.4	20.5	9.2	979	21.66	0.00	1.4	0.0	11.7	0.45
504	---	---	100	65	18.2	20.9	11.5	980	13.12	0.00	4.3	0.0	14.0	0.48
505	---	---	100	54	22.7	26.9	12.4	980	24.99	0.00	154.8	0.8	16.7	0.96
506	---	---	100	66	25.9	29.6	13.8	972	19.87	4.57	277.0	1.3	20.3	0.83
507	---	---	100	65	14.8	17.8	9.0	979	11.96	0.00	236.0	20.3	11.1	0.28
508	---	---	100	68	16.9	21.1	8.9	975	22.46	0.00	139.6	4.2	14.4	0.43
509	---	---	100	69	19.9	24.0	14.1	977	13.43	0.25	93.0	114.6	17.1	0.32
510	---	---	100	55	22.0	25.6	13.4	982	21.99	0.00	92.2	66.4	16.8	0.77
511	---	---	100	74	23.7	27.1	16.0	978	16.49	1.52	109.7	ERR	20.5	0.48
512	---	---	100	69	25.2	28.1	18.4	975	21.50	0.00	116.1	6.6	21.2	0.57
513	---	---	100	68	24.1	27.4	17.0	969	17.84	0.00	158.9	4.5	20.4	0.53
514	---	---	100	65	22.0	25.6	14.4	968	17.07	0.25	209.4	1.4	17.8	0.51
515	---	---	100	42	23.4	27.7	13.1	978	29.14	0.00	142.2	ERR	14.3	1.29
516	---	---	100	54	25.0	29.1	14.2	977	27.70	0.00	183.7	2.5	18.4	1.18
517	---	---	100	61	25.3	28.2	16.5	979	25.20	0.00	195.7	11.8	19.7	0.83
518	---	---	100	49	24.5	28.1	14.7	981	28.02	0.00	114.5	10.8	16.2	1.23
519	---	---	94	43	23.6	28.2	13.5	979	24.62	0.00	103.7	5.1	13.7	1.26
520	---	---	95	44	23.1	27.3	12.7	978	29.17	0.00	166.8	11.6	13.7	1.32
521	---	---	96	48	21.7	27.6	12.5	979	20.83	0.00	---	---	14.2	1.07
522	---	---	---	---	---	---	---	---	---	---	---	---	---	---
523	---	---	100	48	28.1	29.8	17.7	975	4.91	6.60	90.8	1.0	18.4	1.82

524	3.23	0.20	100	55	25.4	30.2	18.0	974	25.39	0.25	38.0	1.1	20.1	0.97
525	-1.24	0.21	100	45	26.9	32.5	18.3	969	26.95	5.84	139.6	1.1	19.5	1.37
526	---	---	98	42	22.6	26.3	13.0	974	26.49	0.00	268.5	5.0	13.9	1.11
527	2.59	0.41	100	49	21.5	25.1	12.9	978	25.31	0.00	116.7	23.2	14.8	1.03
528	---	---	100	70	22.8	26.9	16.0	976	19.41	27.43	53.1	2.2	19.6	0.54
529	-1.36	3.00	100	58	24.4	30.0	17.7	972	24.69	1.52	42.5	1.6	20.4	0.73
530	4.27	0.14	100	49	28.2	32.7	17.3	975	28.49	0.00	42.5	1.6	22.1	1.24
531	-0.11	0.39	100	58	28.9	32.2	20.0	977	28.40	0.00	36.3	2.6	22.3	1.24
601	-0.36	0.53	100	55	27.8	31.0	19.6	976	28.88	0.00	210.4	5.0	21.7	1.12
602	8.54	0.38	100	56	28.1	31.3	19.5	977	25.41	0.00	90.7	16.6	21.8	1.22
603	1.05	0.39	100	72	26.3	29.8	19.6	979	22.56	0.00	157.0	12.1	22.1	0.70
604	5.14	0.48	100	59	28.4	31.9	19.6	975	25.49	0.00	206.6	2.2	22.9	1.03
605	0.45	0.32	100	63	29.6	33.1	18.9	971	28.07	6.60	366.7	2.4	22.7	1.16
606	---	---	100	65	25.3	29.9	19.5	972	23.11	1.02	164.2	1.3	22.1	0.70
607	---	---	98	65	31.2	34.8	22.5	967	28.67	0.00	386.5	1.7	26.1	1.21
608	---	---	99	65	30.5	33.8	20.9	968	26.04	0.00	268.9	1.4	24.7	0.99
609	---	---	100	82	22.5	27.0	19.2	976	14.44	7.11	218.0	1.9	21.1	0.21
610	4.93	0.10	100	68	24.3	27.9	19.7	978	19.91	1.02	137.3	6.8	21.3	0.52
611	1.04	0.33	100	73	25.0	29.2	19.1	976	17.58	0.00	165.9	5.4	22.3	0.41
612	1.24	0.36	100	54	28.3	32.6	19.1	973	28.92	0.00	284.5	2.6	22.9	1.26
613	6.82	0.22	97	51	30.4	33.4	22.9	971	29.27	0.00	466.9	1.9	23.3	1.49
614	4.19	0.55	86	49	29.2	31.8	23.9	947	27.77	0.00	603.6	2.0	19.9	1.63
615	5.50	0.54	90	58	26.0	27.8	23.1	955	19.87	0.00	539.8	2.3	20.7	1.03
616	---	---	96	57	28.1	31.4	22.2	950	18.22	0.00	412.8	2.6	21.9	1.19
617	---	---	97	45	29.1	32.8	20.2	947	28.88	0.00	247.3	6.5	21.1	1.56
618	---	---	99	44	29.4	33.8	19.9	946	28.37	0.00	126.7	4.6	20.3	1.79
619	---	---	97	51	28.3	32.4	20.8	948	20.96	0.00	72.0	17.6	21.9	1.27
620	7.01	0.10	99	45	30.0	34.0	20.7	947	25.02	0.00	89.7	5.4	21.4	1.83
621	5.13	0.17	95	38	30.5	34.7	21.0	943	26.90	0.00	77.4	10.8	20.7	2.00
622	---	---	94	37	30.4	34.5	20.8	942	28.09	0.00	252.7	1.7	19.9	2.22
623	2.76	0.11	91	37	29.5	33.7	18.8	941	27.59	1.27	249.4	5.7	18.3	2.00
624	3.82	0.12	91	36	29.6	34.8	19.0	944	26.16	0.00	114.4	2.7	18.4	2.24
625	-0.26	0.18	87	25	33.8	39.6	21.3	941	28.89	0.00	321.6	2.2	19.4	3.25
626	0.19	0.18	85	24	32.2	36.7	22.4	942	30.03	0.00	161.6	1.9	16.0	3.00
627	-0.87	0.13	97	37	33.3	39.0	22.3	939	28.75	0.00	215.1	4.2	22.9	2.70
628	-1.93	0.24	95	31	32.5	37.3	22.0	944	28.80	0.00	189.3	6.3	20.0	2.56
629	---	---	95	23	32.9	38.3	20.6	944	28.41	0.00	232.6	1.9	16.7	3.47
630	---	---	92	37	30.5	36.3	20.8	944	28.72	2.79	163.0	2.1	20.9	2.14
701	---	---	89	40	31.8	37.3	20.5	962	26.65	0.25	341.8	1.3	21.9	2.07
702	---	---	92	43	30.8	35.8	21.9	971	28.27	0.00	313.9	2.2	20.9	2.20
703	0.46	0.21	93	37	31.8	36.9	22.8	972	27.72	0.00	335.9	2.8	20.6	2.33
704	3.98	0.19	83	35	31.7	36.4	23.9	974	25.01	0.00	368.6	2.6	19.4	2.46
705	2.52	0.17	83	34	32.0	36.0	23.4	975	28.75	0.00	381.6	2.4	19.9	2.63
706	1.59	0.10	92	40	30.7	34.2	23.6	972	24.76	0.00	289.0	2.1	20.7	2.03
707	2.71	0.05	90	42	31.4	36.6	20.3	968	22.23	0.00	337.8	1.7	21.1	2.07
708	2.46	0.07	86	32	26.4	31.1	18.2	979	29.11	0.00	190.5	16.1	14.3	1.96
709	3.23	0.08	98	42	25.7	30.3	18.3	981	19.51	0.00	178.3	20.8	17.4	1.43
710	1.97	0.15	99	41	28.1	33.4	18.5	980	25.90	0.00	176.0	7.7	19.9	1.66
711	-0.01	0.14	99	46	28.1	32.7	20.3	977	22.82	0.00	202.4	6.2	20.1	1.54
712	---	---	100	56	27.6	31.2	20.9	975	21.33	0.00	257.0	2.2	21.0	1.24
713	---	---	100	45	28.6	33.2	22.2	974	19.74	0.00	182.4	1.2	21.8	1.47
714	---	---	100	41	25.2	34.7	18.2	977	13.06	37.34	208.6	1.5	20.2	0.84
715	---	---	100	55	25.2	29.8	18.0	980	23.55	13.46	208.6	1.5	20.4	0.89
716	---	---	99	50	27.9	33.8	19.6	980	26.10	0.51	208.6	1.5	21.9	1.37
717	---	---	98	46	27.5	33.8	21.7	980	19.72	0.00	208.6	1.5	22.4	1.17
718	---	---	98	34	32.8	36.8	23.1	976	27.36	0.00	208.6	1.5	20.4	2.75
719	3.52	0.51	81	33	32.5	35.9	25.2	973	28.65	0.00	317.8	2.8	19.1	2.86
720	---	---	99	42	31.0	35.3	20.6	976	24.50	24.89	208.6	1.5	21.2	2.07
721	---	---	100	48	25.2	30.9	19.9	979	16.69	0.76	130.7	6.8	20.6	0.80
722	5.79	0.36	94	37	30.0	34.9	21.0	976	26.65	0.00	180.0	2.1	20.3	2.05

723	6.83	0.35	97	35	32.0	37.8	21.8	975	27.11	0.00	203.5	2.6	22.3	2.35
724	-0.05	1.04	98	58	29.6	32.2	21.4	975	17.85	4.83	197.9	1.4	23.1	1.17
725	-8.67	1.05	99	62	26.2	30.2	20.7	975	19.86	15.24	208.6	1.5	22.6	0.75
726	2.00	0.82	99	63	24.0	27.7	16.3	975	17.91	0.00	208.6	1.5	18.6	0.65
727	4.34	0.81	88	39	24.3	27.9	16.1	979	28.26	0.00	148.3	3.5	14.1	1.50
728	3.32	0.11	93	42	25.1	28.7	15.0	979	28.09	0.00	140.1	8.7	14.5	1.57
729	5.45	0.24	90	47	25.2	29.5	15.8	979	25.90	0.00	188.7	2.4	16.7	1.45
730	2.00	0.24	97	55	26.0	29.0	18.7	978	26.75	0.00	275.9	2.3	18.7	1.24
731	3.78	0.14	97	42	27.7	32.8	19.0	978	27.22	0.00	208.6	1.5	18.7	1.67
801	4.96	0.25	92	36	29.4	34.0	19.5	979	24.98	0.00	244.3	2.2	18.6	2.13
802	2.40	0.29	88	46	28.0	31.9	20.2	979	18.68	0.00	141.1	4.9	19.0	1.59
803	2.44	0.22	88	37	29.0	33.2	20.7	979	24.03	0.25	239.3	1.7	18.6	2.00
804	---	---	98	41	28.5	35.0	20.4	979	22.90	13.21	167.4	3.5	20.6	1.47
805	---	---	96	49	25.2	28.4	16.3	979	25.61	0.00	159.8	6.4	17.7	1.12
806	---	---	100	48	26.4	32.5	16.1	979	23.81	0.00	301.1	1.2	21.2	1.22
807	---	---	100	49	25.3	29.6	18.1	979	19.35	0.00	298.0	3.1	18.7	1.18
808	---	---	100	51	27.0	31.8	18.1	979	25.72	0.00	176.6	10.8	20.4	1.32
809	---	---	100	46	28.4	32.4	19.8	978	24.93	0.00	182.2	4.4	19.9	1.58
810	---	---	97	39	29.5	34.0	19.7	977	24.33	0.00	225.4	3.4	19.7	2.01
811	---	---	89	35	31.1	35.7	21.7	977	23.86	0.00	218.1	2.2	19.4	2.40
812	---	---	90	32	31.5	36.4	21.6	977	25.42	0.00	274.2	2.2	19.6	2.54
813	---	---	90	29	32.8	38.2	22.0	977	24.67	0.00	232.8	2.0	19.5	2.94
814	---	---	87	36	26.3	30.2	11.4	976	18.31	0.00	278.7	3.4	14.6	1.26
815	---	---	85	22	24.8	30.2	12.1	974	27.56	0.00	123.2	22.6	10.1	2.05
816	---	---	91	25	28.1	33.5	16.2	972	26.63	0.00	125.9	6.4	13.1	2.55
817	---	---	92	31	27.0	34.3	15.7	970	16.55	0.00	181.8	3.8	17.3	1.84
818	---	---	94	43	30.6	36.9	19.6	968	23.18	0.00	258.5	2.0	22.1	2.09
819	---	---	100	33	31.0	37.8	21.9	966	15.29	24.89	250.4	1.1	22.4	2.00
820	---	---	100	49	24.6	28.0	16.7	965	15.66	2.79	163.7	4.8	18.4	0.79
821	---	---	95	43	24.9	28.5	16.4	965	26.06	0.00	106.1	30.0	15.6	1.43
822	---	---	94	42	26.2	30.4	16.9	964	25.37	0.00	172.2	1.6	16.8	1.58
823	---	---	98	40	27.9	32.8	17.8	962	25.39	0.00	174.3	3.5	19.1	1.75
824	---	---	98	44	30.1	34.9	21.4	960	23.78	0.00	203.6	2.5	21.7	1.78
825	---	---	98	42	31.2	35.8	22.8	959	23.68	0.00	330.6	1.3	21.7	2.00
826	3.66	0.55	86	38	30.9	37.3	23.9	959	22.22	0.00	336.2	1.9	21.7	1.98
827	9.74	0.37	85	31	33.5	38.1	23.6	958	24.74	0.00	371.5	1.5	19.8	2.98
828	---	---	74	30	33.3	38.1	23.8	959	24.24	0.00	280.2	1.9	18.6	3.03
829	---	---	78	26	32.8	38.0	23.3	961	23.87	0.00	309.7	1.0	18.9	2.98
830	---	---	100	28	31.9	38.6	20.2	965	19.64	18.29	326.1	2.8	20.0	2.65
831	---	---	100	86	22.4	24.0	17.8	975	4.65	4.57	214.3	0.7	20.0	0.15
901	---	---	100	84	18.5	19.8	17.1	972	4.80	1.27	133.0	23.3	18.0	0.16
902	---	---	100	71	22.1	25.5	19.0	974	12.88	0.76	162.8	0.9	20.1	0.34
903	---	---	99	82	23.6	25.8	20.7	973	8.95	0.00	301.7	1.0	21.9	0.34
904	---	---	97	42	29.4	33.2	22.4	952	22.92	2.03	365.3	1.9	20.2	1.82
905	-12.49	0.28	100	71	23.9	26.5	20.1	979	11.38	17.78	155.8	2.7	21.3	0.40
906	1.95	0.23	100	39	25.8	29.5	16.0	984	22.30	0.00	117.8	7.9	16.6	1.27
907	5.79	0.22	96	44	24.8	28.9	16.4	982	21.00	0.00	122.4	2.0	16.9	1.33
908	-1.89	0.27	100	60	23.6	28.0	15.1	980	11.60	0.00	133.8	6.8	18.6	0.64
909	4.75	0.33	100	63	23.8	27.7	15.2	981	18.61	0.25	136.1	4.7	19.0	0.80
910	-1.90	0.36	100	42	25.1	29.0	17.0	981	21.48	0.00	162.4	4.0	17.1	1.27
911	7.44	0.36	97	51	26.0	30.2	17.0	981	20.91	0.00	202.3	4.6	19.1	1.23
912	2.52	0.23	96	54	27.1	30.5	19.4	981	19.10	0.00	223.8	3.0	20.2	1.28
913	3.67	0.22	97	51	28.3	31.7	20.3	979	18.17	0.00	289.0	2.0	20.7	1.45
914	1.52	0.21	91	52	28.6	31.4	22.1	977	20.08	0.00	340.2	1.9	20.7	1.53
915	-1.07	0.11	100	53	25.1	27.9	17.9	975	8.89	0.51	164.1	1.6	20.7	0.55
916	-5.09	0.12	70	23	24.7	28.9	13.9	980	18.07	0.00	224.4	3.1	8.1	2.06
917	0.20	0.28	86	21	24.9	29.4	12.0	982	22.90	0.00	174.8	8.3	7.9	2.25
918	-0.95	0.28	97	36	23.5	27.7	11.5	982	22.70	0.00	98.7	4.1	12.1	1.61
919	-1.19	0.14	99	36	24.5	28.7	13.7	982	22.29	0.00	103.1	7.3	14.0	1.59
920	---	---	96	40	25.5	29.4	14.4	979	20.38	0.00	154.1	2.5	14.9	1.66

921	---	---	99	39	25.7	30.5	9.8	973	12.15	11.43	433.0	0.9	14.0	1.69
922	---	---	93	30	15.5	19.3	6.7	979	17.57	0.25	243.5	3.7	5.0	0.89
923	---	---	94	43	13.1	17.7	6.8	970	11.59	0.00	316.3	1.6	6.0	0.61
924	---	---	91	38	15.6	20.6	7.2	976	18.02	0.00	231.4	2.6	6.7	0.89
925	---	---	87	30	21.8	27.0	12.0	977	16.45	0.00	246.9	3.5	9.4	1.37
926	---	---	87	34	23.4	28.0	12.3	971	21.00	0.00	116.6	2.3	10.6	1.69
927	---	---	98	36	24.1	29.2	12.5	973	20.22	0.00	140.9	7.9	13.6	1.69
928	---	---	100	29	27.5	33.3	16.1	975	19.91	0.00	114.3	3.6	16.1	2.11
929	---	---	99	21	29.3	35.7	16.2	974	20.35	0.00	268.5	1.1	14.2	2.57
930	---	---	90	22	28.8	32.8	15.8	973	20.18	0.00	352.4	2.7	12.9	2.72
1001	---	---	94	34	27.3	32.0	15.0	970	19.70	0.00	192.3	5.5	14.8	2.02
1002	---	---	95	40	26.4	30.8	16.7	967	16.12	2.29	223.2	1.5	16.3	1.74
1003	---	---	97	52	26.5	30.1	18.0	972	16.23	7.11	247.0	1.6	18.6	1.30
1004	1.04	0.10	99	44	25.8	29.9	17.9	981	16.12	0.00	130.3	1.1	18.3	1.38
1005	0.45	0.09	99	60	22.9	27.2	19.0	976	10.55	1.27	330.1	0.6	17.7	0.57
1006	3.00	0.08	79	41	26.4	29.4	21.0	967	15.14	0.00	510.4	1.5	16.5	1.70
1007	-14.85	0.13	99	55	15.4	22.9	12.2	974	2.34	14.48	279.2	1.2	12.4	0.39
1008	1.93	0.18	98	30	17.6	20.8	7.6	981	17.72	0.00	301.2	3.1	5.5	0.97
1009	-0.11	0.14	97	22	17.8	21.8	6.9	985	19.83	0.00	123.2	4.6	2.8	1.38
1010	-2.76	0.08	91	26	17.5	21.4	6.8	985	19.35	0.00	111.6	2.4	3.5	1.26
1011	0.17	0.08	93	26	17.3	22.1	6.5	981	19.19	0.00	107.6	1.8	4.2	1.24
1012	1.40	0.05	100	47	18.8	23.6	6.3	977	18.28	0.00	117.6	1.5	10.4	0.98
1013	0.52	0.05	100	48	19.5	24.2	10.4	980	17.00	0.00	147.8	4.4	13.1	0.84
1014	-2.74	0.18	100	61	16.9	19.9	11.2	978	8.47	4.06	202.5	0.8	13.4	0.44
1015	-1.74	0.18	100	94	15.2	16.7	14.4	970	2.09	2.03	375.7	1.2	15.3	0.05
1016	0.32	0.06	100	92	19.3	21.3	16.7	974	3.85	0.25	362.9	0.9	19.6	0.08
1017	-1.25	0.06	100	91	21.1	21.9	19.3	972	2.83	1.52	321.6	1.4	20.3	0.14
1018	-5.05	0.05	100	50	21.8	25.0	10.6	972	10.13	4.32	129.4	2.5	14.6	0.57
1019	1.26	0.09	100	66	19.2	23.8	12.3	976	10.23	0.00	132.0	0.9	16.2	0.43
1020	0.14	0.09	100	63	21.0	25.0	17.1	977	9.53	1.02	103.2	0.5	18.3	0.44
1021	-0.64	0.05	100	64	21.1	24.8	12.2	970	8.52	0.25	85.5	1.6	16.0	0.47
1022	1.57	0.09	98	21	22.7	28.0	7.7	973	16.86	0.00	163.5	1.5	9.3	1.67
1023	1.14	0.12	95	24	20.5	25.2	8.6	979	16.56	0.00	141.0	5.0	8.4	1.56
1024	2.40	0.13	96	30	19.1	22.0	7.3	981	9.94	0.00	291.5	1.0	4.4	1.06
1025	0.33	0.10	84	21	12.4	15.6	2.1	986	15.99	0.00	169.9	5.3	-3.0	1.04
1026	0.33	0.05	85	26	13.2	17.7	2.0	986	16.31	0.00	57.2	0.0	-0.8	1.03
1027	1.86	0.05	88	27	15.6	20.9	1.3	980	15.91	0.00	235.5	1.4	2.9	1.19
1028	0.18	0.11	94	52	15.2	19.9	7.1	975	8.52	0.00	337.6	1.3	8.9	0.66
1029	0.77	0.11	94	66	15.5	18.6	10.6	977	4.16	0.00	111.4	1.5	12.0	0.47
1030	-12.19	0.10	99	70	17.5	19.8	10.3	977	4.44	12.95	165.0	0.5	13.8	0.41
1031	-0.60	0.11	96	52	11.8	14.8	4.6	979	10.33	0.00	257.9	5.4	5.4	0.45
1101	1.83	0.07	91	26	15.8	21.1	6.0	972	12.14	0.25	428.9	1.0	4.7	1.05
1102	2.96	0.08	74	48	18.9	24.1	13.2	965	9.86	0.00	488.8	1.0	13.6	0.91
1103	-1.76	0.08	99	50	24.8	28.2	9.5	970	12.20	4.06	293.1	2.2	14.2	1.22
1104	-25.55	1.66	100	92	9.6	10.6	5.8	972	1.72	25.65	328.7	0.7	7.5	0.04
1105	-8.02	1.66	99	64	8.9	13.0	2.6	972	5.48	10.16	182.4	4.3	5.7	0.20
1106	3.65	0.07	99	29	16.6	21.9	3.2	984	14.80	0.25	91.4	2.2	5.7	1.05
1107	4.36	0.11	92	46	17.9	22.5	6.0	980	13.20	0.00	406.2	0.9	10.9	0.88
1108	-28.25	0.12	98	55	22.8	26.5	7.8	971	10.62	24.13	361.5	1.1	13.7	0.92
1109	-2.13	0.07	94	72	8.1	9.8	3.7	981	3.71	0.00	296.9	2.4	4.3	0.25
1110	1.46	0.08	98	54	11.1	14.4	4.4	984	12.51	0.00	117.8	2.9	5.5	0.45
1111	-0.58	0.10	97	51	12.6	16.4	5.6	981	11.64	0.00	235.2	0.8	5.9	0.55
1112	2.83	0.10	94	64	11.6	16.3	6.6	977	8.70	0.00	429.1	0.7	8.7	0.34
1113	-4.75	0.07	100	82	16.9	18.1	9.3	972	1.25	4.32	274.3	1.9	15.4	0.12
1114	-0.54	0.15	100	69	11.8	14.7	5.3	981	5.50	0.00	273.8	1.0	7.8	0.21
1115	-0.99	0.16	92	42	11.3	15.2	0.9	988	12.06	0.00	230.0	2.9	2.6	0.56
1116	1.86	0.05	94	35	11.7	16.7	1.2	982	13.63	0.00	257.9	0.5	4.6	0.74
1117	-2.11	0.08	96	50	13.8	16.2	1.6	968	2.71	0.00	301.2	2.5	6.9	0.17
1118	1.17	0.16	99	29	14.0	18.6	1.9	981	12.69	2.54	200.6	0.6	4.8	1.03
1119	---	---	100	94	11.6	14.7	10.9	978	0.50	65.28	316.3	0.8	12.0	0.01

1120	---	---	98	28	12.6	15.8	4.3	960	8.18	0.00	475.4	1.4	1.9	0.74
1121	—	—	86	45	11.6	14.9	2.8	981	12.85	0.00	230.5	1.1	1.8	0.67
1122	-0.69	0.02	97	44	5.1	6.3	-1.9	993	2.20	0.00	261.3	1.6	-3.1	0.42
1123	0.73	0.07	96	45	6.3	9.9	-1.6	996	11.07	0.00	130.8	0.6	-0.7	0.42
1124	2.21	0.09	91	67	9.8	11.9	5.8	982	5.20	0.00	286.9	1.7	5.9	0.29
1125	0.17	0.05	100	82	9.4	11.0	7.5	980	2.60	0.51	154.8	0.4	8.4	0.15
1126	0.98	0.33	100	65	12.3	19.6	9.9	970	2.97	0.25	382.7	0.5	13.0	0.07
1127	-2.19	0.33	80	33	11.0	12.9	-1.0	966	12.25	0.00	293.0	2.5	-2.1	0.70
1128	-0.32	0.06	85	18	9.1	14.8	-1.1	973	12.58	0.00	208.7	1.7	-3.7	0.75
1129	-0.62	0.04	81	34	7.4	10.9	-2.1	986	12.11	0.00	139.2	4.8	-4.0	0.59
1130	0.49	0.14	76	23	10.6	15.3	-1.3	986	12.20	0.00	258.4	2.2	-4.0	0.90
1201	2.02	0.14	60	24	13.5	18.1	3.5	982	12.20	0.00	368.4	1.3	-2.1	1.10
1202	1.36	0.08	98	55	13.8	17.6	7.2	973	7.23	0.51	432.1	1.1	10.2	0.56
1203	0.62	0.13	100	82	14.8	16.3	13.4	975	2.41	0.00	140.7	0.5	13.6	0.16
1204	-1.34	0.11	100	50	18.0	21.3	2.7	974	9.83	0.00	333.5	0.9	9.9	0.64
1205	-1.83	0.06	100	98	3.0	4.9	2.5	983	2.08	1.52	154.6	2.0	3.7	0.01
1206	-5.94	0.06	100	89	7.4	11.4	-1.5	973	0.80	4.32	240.5	0.4	4.6	0.00
1207	-2.02	0.06	99	64	1.8	4.5	-1.7	985	9.69	2.54	189.8	1.2	-1.4	0.18
1208	-1.49	0.05	99	79	1.6	2.2	-2.6	982	1.56	0.00	352.8	0.6	-0.8	0.05
1209	0.45	0.12	97	46	3.1	7.1	-3.9	985	10.36	0.00	210.9	1.6	-3.0	0.31
1210	-0.91	0.14	97	43	4.0	7.7	-5.6	989	11.67	0.00	195.7	3.4	-5.1	0.35
1211	-0.55	0.09	84	35	0.2	4.3	-5.0	986	6.82	0.00	273.6	0.6	-8.0	0.32
1212	0.12	0.04	92	51	3.9	7.4	-2.9	981	9.87	0.00	112.3	2.0	-2.6	0.32
1213	0.80	0.04	100	59	3.4	5.4	-0.1	983	3.81	0.00	121.5	0.3	0.7	0.23
1214	0.18	0.05	100	89	6.5	8.4	2.7	978	1.34	0.51	191.4	1.6	5.6	0.01
1215	-2.65	0.07	100	93	5.5	6.8	2.9	983	1.93	1.27	124.7	1.0	5.8	0.01
1216	-2.51	0.07	100	39	9.8	13.9	0.0	981	8.88	0.00	104.4	7.7	2.1	0.39
1217	0.11	0.05	88	28	10.9	16.6	0.0	984	11.31	0.00	167.3	2.0	1.0	0.73
1218	1.24	0.11	82	30	9.2	14.4	1.2	986	11.39	0.00	216.2	0.6	-1.2	0.65
1219	0.68	0.11	98	40	13.9	19.1	4.2	974	9.53	0.00	223.2	11.4	4.8	0.83
1220	-0.35	0.06	95	33	11.5	15.1	1.0	977	10.64	0.00	145.7	4.5	0.6	0.75
1221	-0.27	0.12	97	63	5.5	8.0	-0.4	982	5.20	0.00	240.1	0.9	0.8	0.23
1222	0.27	0.11	99	66	5.2	9.3	-3.9	988	7.83	0.00	140.6	1.3	0.4	0.17
1223	0.69	0.06	100	94	0.3	2.3	-1.9	987	3.14	0.00	137.2	1.1	0.1	0.00
1224	-0.44	0.06	100	56	3.4	8.4	-6.4	986	8.65	0.00	63.0	0.6	-1.4	0.23
1225	0.65	0.06	100	36	7.1	13.8	-5.1	985	11.47	0.25	51.3	1.3	0.0	0.48
1226	1.06	0.07	99	29	10.2	16.3	-2.7	984	11.59	0.00	97.6	5.3	-0.2	0.72
1227	2.59	0.09	88	35	12.8	18.1	1.0	981	10.79	0.00	87.8	13.3	3.0	0.83
1228	0.38	0.07	94	64	9.8	12.4	5.4	980	2.54	0.00	76.0	0.3	5.8	0.27
1229	0.41	0.07	95	82	6.0	6.8	4.6	980	2.32	0.00	85.5	3.4	3.9	0.13
1230	0.93	0.30	93	67	8.2	10.1	3.8	980	4.57	0.25	47.5	0.9	4.7	0.27
1231	-6.68	0.30	100	75	6.1	7.5	-6.8	978	0.77	4.32	331.4	0.3	-1.3	0.02
101	-0.08	0.07	91	49	-1.5	1.9	-6.7	992	11.68	0.00	139.4	6.1	-7.9	0.24
102	1.08	0.16	94	34	2.6	7.4	-5.5	988	8.50	0.00	89.6	0.4	-5.1	0.35
103	-1.39	0.17	95	56	-3.6	-2.1	-11.3	992	6.64	0.00	236.0	2.4	-10.0	0.11
104	0.41	0.08	89	50	-4.5	-1.2	-11.1	995	8.59	0.25	59.9	3.4	-10.9	0.19
105	-0.27	0.10	96	48	-2.0	3.6	-9.2	980	4.88	1.27	383.5	0.7	-3.9	0.19
106	-0.45	0.10	96	67	2.9	5.0	-9.3	965	2.67	0.00	358.0	1.1	-5.4	0.12
107	1.71	0.05	89	39	-0.7	5.3	-9.1	981	11.91	0.00	188.8	0.8	-7.0	0.30
108	0.63	0.11	97	53	4.5	6.3	-4.8	978	10.10	0.00	142.1	10.2	-3.1	0.33
109	1.89	0.12	99	38	8.8	15.7	-3.2	980	11.02	0.00	163.7	0.9	2.2	0.61
110	0.49	0.09	100	66	8.9	11.1	-0.2	972	11.15	0.00	122.4	1.3	3.4	0.25
111	2.39	0.09	100	20	14.2	23.0	0.2	965	11.80	0.25	207.9	1.5	1.2	1.13
112	0.72	0.09	93	52	9.7	13.6	3.9	968	5.68	0.00	247.7	0.4	4.7	0.41
113	-1.08	0.08	98	56	8.9	11.5	-0.9	971	7.94	0.00	387.4	1.3	2.2	0.37
114	-0.21	0.09	99	46	6.5	11.5	-2.2	976	11.12	0.00	120.8	6.3	0.5	0.37
115	2.85	0.09	97	22	12.1	18.1	-1.9	973	12.47	0.00	352.9	0.8	-1.5	0.98
116	-4.56	0.12	96	44	14.0	16.3	1.3	965	5.12	4.57	420.8	1.2	5.7	0.68
117	0.72	0.13	87	44	6.9	9.8	0.6	974	12.43	0.00	205.6	0.8	-2.1	0.47
118	-2.01	0.09	94	52	4.0	4.8	-2.6	977	2.60	0.00	205.2	2.5	-3.1	0.36

119	0.38	0.08	90	34	6.2	10.4	-2.2	979	13.07	0.00	176.7	20.5	-4.6	0.49
120	0.84	0.12	92	38	9.0	13.4	-3.0	981	12.67	0.00	163.1	1.0	-1.1	0.65
121	-9.25	0.12	100	44	1.9	5.1	-2.3	984	12.69	0.00	175.2	2.3	-4.0	0.33
122	-1.81	0.17	99	71	0.0	0.8	-7.0	983	7.42	4.83	168.0	1.2	-4.0	0.09
123	0.68	0.16	95	54	0.2	4.8	-7.3	985	13.79	4.32	158.7	0.8	-4.2	0.19
124	1.59	0.03	87	39	8.6	13.6	0.2	984	13.45	2.29	171.5	7.3	-0.8	0.59
125	2.31	0.02	100	32	11.4	16.3	1.9	984	13.24	0.00	50.8	6.0	1.4	0.79
126	-2.24	0.07	100	91	8.4	12.7	5.9	977	1.24	4.06	346.7	0.6	10.1	0.00
127	0.35	0.07	96	54	12.6	15.6	3.7	962	10.70	0.51	475.1	0.9	5.4	0.52
128	-1.58	0.05	97	79	3.3	4.0	0.7	976	1.41	0.25	412.2	0.9	0.6	0.11
129	-1.23	0.15	97	67	1.9	3.7	-4.7	985	4.66	0.25	311.4	1.7	-2.0	0.13
130	0.63	0.15	98	38	5.9	11.7	-4.9	983	14.13	0.00	164.5	1.1	-2.1	0.47
131	1.71	0.11	84	28	11.4	17.0	0.7	975	13.11	0.00	132.9	2.7	-0.2	0.85
201	2.35	0.11	84	26	16.8	23.7	3.5	973	14.46	0.00	150.7	5.2	4.2	1.29
202	2.08	0.07	78	21	19.4	26.6	7.3	972	13.36	0.00	317.3	0.4	5.1	1.48
203	-1.89	0.07	89	42	10.7	13.0	-2.9	984	11.75	0.00	340.0	4.6	0.1	0.59
204	0.58	0.10	87	24	10.9	19.1	-2.6	981	15.01	0.00	334.3	0.8	-1.5	0.89
205	0.27	0.14	85	45	6.4	9.6	-0.3	986	14.53	0.00	188.7	1.1	-1.7	0.45
206	0.35	0.17	79	30	10.4	14.0	0.8	980	12.96	0.00	119.9	1.8	-2.5	0.74
207	-1.79	0.13	83	32	5.5	7.6	-6.6	987	14.83	0.00	293.0	3.4	-8.0	0.55
208	1.15	0.06	74	23	3.6	8.7	-6.5	990	15.83	0.00	162.6	0.6	-10.5	0.57
209	0.67	0.09	89	32	11.1	15.3	0.1	973	15.42	0.00	192.6	14.8	-2.1	0.86
210	0.57	0.08	87	28	9.1	12.2	0.3	971	15.60	0.00	361.1	1.2	-6.7	0.73
211	-1.23	0.08	65	28	0.3	2.2	-6.7	982	9.46	0.00	310.5	2.1	-14.9	0.38
212	-0.94	0.08	88	42	-5.7	-3.5	-7.3	985	2.98	0.00	220.5	1.2	-11.0	0.16
213	-1.68	0.08	95	52	-1.2	0.9	-3.8	984	4.18	0.25	189.8	0.9	-6.4	0.20
214	1.29	0.12	100	88	0.9	12.3	-0.8	972	1.68	2.29	377.7	0.7	4.4	0.01
215	-1.17	0.13	86	54	2.9	5.3	-3.7	976	6.80	0.00	367.0	2.0	-4.6	0.22
216	-0.80	0.10	79	37	2.1	7.1	-3.8	984	7.36	0.00	204.9	2.7	-6.4	0.36
217	1.75	0.08	81	16	9.4	15.1	-4.2	989	17.77	0.00	56.8	25.6	-7.1	0.90
218	0.99	0.06	87	23	12.6	18.6	0.1	981	15.78	0.00	233.4	2.6	-1.4	1.04
219	1.66	0.08	85	25	13.0	18.5	2.3	986	17.26	0.00	217.7	2.5	-1.2	0.95
220	1.23	0.10	57	19	17.9	22.9	4.0	983	17.68	0.00	225.7	6.6	-1.0	1.47
221	2.22	0.08	60	16	16.6	22.8	4.2	984	17.73	0.00	222.7	1.0	-2.4	1.51
222	1.78	0.05	87	20	22.0	26.8	7.7	973	14.96	0.00	333.7	2.4	4.1	2.01
223	-1.11	0.11	88	18	17.9	22.4	1.5	981	18.18	0.00	282.4	2.8	-1.9	1.49
224	1.02	0.12	60	16	12.4	17.8	1.3	990	18.37	0.00	193.7	1.5	-5.4	1.18
225	2.98	0.05	90	41	18.8	23.2	8.1	978	17.28	0.00	474.8	1.3	9.7	1.16
226	-11.78	0.07	100	56	18.4	22.7	12.1	971	8.06	12.45	298.7	2.0	13.9	0.56
227	-2.85	0.09	100	89	9.9	13.4	0.9	977	4.39	0.25	418.6	0.8	5.8	0.08
228	-1.69	0.10	93	69	0.8	1.8	-4.5	988	2.83	0.00	468.4	1.0	-3.9	0.11
301	-5.45	0.12	95	55	-4.6	-3.9	-6.4	992	3.32	0.00	361.5	1.3	-7.5	0.11
302	-6.67	0.10	96	91	-5.4	-4.4	-6.6	991	4.87	0.00	183.5	2.5	-6.1	0.03
303	1.25	0.08	100	84	-1.9	0.6	-5.5	986	12.66	8.89	127.8	0.6	-1.9	0.04
304	0.52	0.06	100	98	2.8	4.5	0.6	976	2.34	1.52	205.6	4.2	3.5	0.00
305	1.44	0.03	100	74	5.7	6.7	3.6	976	4.47	0.00	164.5	1.4	3.3	0.14
306	---	---	100	81	9.4	15.4	-9.2	968	2.60	10.92	378.6	0.4	1.4	0.11
307	---	---	89	81	-6.2	-2.8	-10.2	987	17.31	0.00	393.5	1.6	-9.1	0.06
308	---	---	84	34	-1.4	5.2	-10.3	994	20.98	3.05	138.9	2.1	-8.7	0.31
309	---	---	83	19	9.9	16.4	-3.8	987	21.25	0.00	378.2	1.8	-5.0	0.94
310	3.12	0.12	78	24	14.4	19.2	3.8	983	21.22	0.00	444.2	1.7	-0.5	1.18
311	4.12	0.08	82	52	15.8	20.0	8.7	978	15.27	0.00	589.8	1.1	10.2	0.69
312	---	---	100	68	17.8	19.9	12.5	974	5.23	32.77	392.3	2.4	14.1	0.42
313	---	---	100	97	14.1	15.1	12.8	974	3.27	23.11	222.6	0.9	13.6	0.01
314	---	---	100	72	15.3	17.9	12.8	978	8.14	1.78	277.7	1.3	13.1	0.22
315	---	---	94	40	19.4	23.2	9.7	980	16.50	0.00	277.5	1.9	9.9	0.99
316	---	---	92	27	20.5	24.7	9.4	979	20.39	0.00	176.9	1.4	7.8	1.50
317	---	---	88	24	21.0	25.5	9.7	982	20.81	0.00	121.6	2.4	6.8	1.63
318	1.01	0.07	80	33	22.2	26.9	11.3	978	20.73	0.00	206.4	5.5	9.3	1.62
319	1.83	0.11	77	26	25.2	30.4	11.6	965	20.10	0.00	453.6	1.7	9.4	2.15

320	0.05	0.12	80	27	18.3	22.4	8.7	972	21.76	0.00	154.3	30.7	4.8	1.25
321	4.00	0.10	84	28	23.9	30.0	9.2	967	20.75	0.00	446.2	1.5	12.0	2.03
322	-0.02	0.09	71	12	28.2	33.4	10.1	962	21.00	0.00	337.0	3.3	4.7	3.00
323	0.44	0.05	79	24	19.5	23.8	9.9	975	22.88	0.00	235.6	2.4	3.6	1.52
324	2.54	0.05	80	42	19.8	25.1	10.0	970	19.00	0.00	441.6	1.4	10.0	1.20
325	---	---	100	60	17.5	21.6	15.4	968	5.08	19.05	387.7	1.3	14.4	0.47
326	---	---	100	30	17.0	20.5	2.5	973	22.19	0.00	351.5	2.4	2.9	1.06
327	---	---	89	36	11.7	15.7	1.7	982	23.36	0.00	244.6	3.6	0.8	0.77
328	-0.73	0.20	95	46	7.7	9.7	2.8	986	9.96	0.00	234.9	1.9	2.2	0.43
329	-0.64	0.08	92	54	7.8	9.7	0.9	984	9.29	0.00	245.6	1.7	1.3	0.35
330	1.40	0.74	92	35	7.7	11.4	0.6	984	12.15	0.00	190.1	1.5	-0.4	0.58
331	1.95	0.09	95	41	11.1	14.9	3.7	981	23.82	0.00	120.0	5.0	2.7	0.67
401	2.26	0.14	92	23	17.6	22.1	5.7	977	24.22	0.00	164.7	22.4	2.4	1.36
402	1.44	0.75	96	18	20.9	25.3	8.5	976	24.37	2.54	435.3	1.4	4.0	1.80
403	-1.55	0.75	100	68	15.9	17.9	7.8	976	9.31	1.78	138.6	4.9	11.3	0.38
404	1.15	0.10	94	36	15.1	18.3	5.1	981	23.57	0.00	165.4	204.6	3.4	0.87
405	3.23	0.09	97	42	17.6	22.8	5.7	974	23.37	0.00	303.8	1.6	9.7	0.97
406	1.99	0.08	100	49	18.2	23.8	11.5	972	19.22	0.00	187.1	2.2	11.9	0.74
407	3.32	0.10	100	43	22.4	27.6	12.3	968	23.93	0.00	382.6	3.1	14.5	1.21
408	4.62	0.13	98	29	26.1	31.7	14.1	961	25.28	0.00	446.0	1.1	14.4	2.00
409	0.94	0.30	97	68	14.3	17.6	10.6	960	17.18	0.00	262.4	2.0	10.9	0.34
410	-11.44	0.29	100	76	7.5	13.3	-1.0	964	0.78	6.10	411.7	1.2	3.8	0.05
411	1.90	0.04	87	30	7.7	13.5	-1.4	973	24.28	0.00	372.0	2.8	-3.3	0.64
412	3.40	0.07	78	21	14.1	20.7	1.1	981	25.73	0.00	215.4	19.7	-0.8	1.12
413	4.46	0.06	84	22	19.0	24.7	5.0	983	24.67	0.00	283.3	1.0	4.7	1.55
414	4.08	0.05	83	28	23.7	28.3	13.9	968	22.05	0.00	529.3	1.7	9.6	1.84
415	3.44	0.06	97	53	21.3	24.5	14.1	970	19.13	0.00	215.4	0.8	15.7	1.00
416	-2.96	0.05	97	65	24.8	27.5	12.5	969	11.52	4.32	355.0	1.3	17.3	0.78
417	---	---	100	59	14.1	20.5	11.5	967	2.16	26.16	313.9	0.9	13.4	0.01
418	---	---	91	37	15.7	19.4	5.5	970	27.23	0.00	321.1	3.9	4.7	0.98
419	---	---	100	52	12.0	17.1	5.3	971	16.70	3.05	284.4	1.8	9.4	0.37
420	---	---	94	46	16.8	20.5	7.4	965	27.05	0.00	295.2	2.4	8.4	0.81
421	---	---	86	47	14.5	18.3	7.0	972	26.84	0.51	384.1	1.4	5.7	0.74
422	---	---	99	85	7.1	7.6	6.2	979	2.22	34.80	385.3	1.1	6.3	0.07
423	---	---	97	50	11.3	15.3	3.8	978	17.18	0.00	249.9	24.8	5.2	0.44
424	---	---	97	47	11.1	17.4	4.5	979	8.34	1.02	84.4	103.9	6.3	0.39
425	4.62	0.03	93	38	17.9	22.4	6.0	976	25.12	0.00	456.9	1.1	7.9	1.11
426	0.00	0.14	95	49	16.4	22.0	2.9	970	16.28	0.00	471.1	3.3	7.4	0.68
427	3.40	0.14	95	32	13.1	17.6	2.9	983	27.10	0.00	135.7	92.7	2.3	0.88
428	-8.96	1.38	99	54	16.0	20.9	7.1	974	12.78	11.43	361.6	1.0	11.1	0.67
429	---	---	100	60	17.9	21.4	13.0	970	16.35	7.37	203.1	2.1	13.8	0.46
430	---	---	---	---	---	---	---	---	---	---	---	---	---	---
501	---	---	---	---	---	---	---	---	---	---	---	---	---	---
502	---	---	---	---	---	---	---	---	---	---	---	---	---	---
503	-5.73	0.14	100	92	13.4	15.1	10.4	970	2.25	6.35	181.9	3.8	13.1	0.03
504	5.90	0.12	100	53	16.4	20.8	9.1	980	27.10	0.00	209.4	8.8	10.2	0.62
505	---	---	100	53	16.5	20.0	10.1	982	17.49	5.84	220.3	1.4	12.1	0.58
506	---	---	100	75	17.6	22.4	14.1	973	11.59	32.77	331.1	1.7	16.5	0.21
507	---	---	100	85	19.1	21.4	15.2	967	2.39	33.78	315.0	1.7	16.9	0.10
508	---	---	95	33	19.9	24.1	11.3	961	24.21	0.00	491.7	2.8	11.1	1.05
509	---	---	87	39	20.6	25.4	10.9	966	28.22	0.00	344.9	2.2	10.1	1.18
510	-1.02	0.17	100	59	15.8	18.5	9.2	974	22.02	0.00	207.3	41.6	9.7	0.64
511	2.55	0.05	100	47	18.8	23.2	9.2	974	24.49	0.00	114.8	1.1	11.5	0.89
512	2.90	0.04	95	74	19.5	24.4	13.1	961	8.71	0.00	481.2	1.3	18.6	0.37
513	5.92	0.07	91	28	28.4	32.2	16.8	960	29.29	0.00	187.5	2.6	13.8	2.24
514	2.44	0.11	91	52	20.5	24.7	15.3	975	22.64	0.25	232.8	9.1	13.3	0.97
515	4.55	0.09	96	62	24.2	29.7	15.0	975	23.59	0.00	209.9	1.9	20.6	0.93
516	---	---	97	78	24.8	26.0	21.8	966	11.00	0.00	365.4	1.4	21.9	0.51
517	0.05	0.17	99	25	24.0	29.2	12.6	959	10.60	2.03	226.7	0.9	16.8	0.76
518	1.01	0.05	96	48	15.5	19.9	8.2	971	15.00	0.00	250.4	47.6	9.2	0.62

519	3.94	0.04	95	38	19.4	24.3	9.4	978	29.91	0.00	52.8	0.0	9.8	1.15
520	4.86	0.04	92	37	22.3	27.2	11.4	976	25.76	0.00	195.0	1.9	13.3	1.29
521	2.67	0.06	93	48	23.2	28.1	16.1	976	22.82	0.00	95.8	1.2	16.2	1.05
522	4.70	0.07	90	49	24.1	28.6	16.7	975	21.93	0.00	324.1	1.6	17.4	1.03
523	-18.29	1.00	100	77	22.8	24.7	12.8	972	4.02	18.29	314.4	1.9	18.4	0.34
524	-8.62	1.00	100	95	14.4	15.4	13.1	977	3.50	8.64	226.1	1.6	14.0	0.02
525	-1.89	16.92	100	87	14.7	16.8	13.2	981	6.32	12.95	198.0	1.3	14.5	0.09
526	---	---	100	79	20.0	23.5	16.8	975	12.86	25.15	262.8	1.1	18.9	0.18
527	---	---	100	58	23.0	26.8	14.3	967	19.24	0.00	273.5	4.2	16.5	0.69
528	---	---	97	48	21.4	25.2	12.1	977	28.39	0.00	188.3	14.2	12.7	1.12
529	-1.44	0.18	97	57	18.1	20.4	12.5	982	16.16	5.08	177.0	2.5	13.2	0.65
530	2.82	0.23	100	86	18.5	20.6	15.3	978	5.77	1.52	108.1	2.6	17.9	0.13
531	4.33	0.16	100	52	22.3	26.4	15.6	974	23.14	0.00	93.6	1.5	17.1	0.81
601	6.95	0.12	100	50	23.5	28.1	15.6	973	25.88	0.00	60.7	3.6	17.4	0.99
602	2.04	0.55	100	51	23.8	31.2	16.2	973	23.64	2.79	184.3	1.3	18.6	0.85
603	---	1.44	100	68	22.9	26.4	17.1	975	17.20	62.48	248.2	1.8	19.8	0.43
604	---	1.63	100	64	22.7	27.5	14.9	976	14.48	10.92	207.2	1.8	18.3	0.52
605	---	1.03	100	68	21.5	26.6	15.0	970	17.19	22.35	216.8	2.0	19.0	0.36
606	---	1.04	99	66	26.1	30.4	18.0	963	24.25	0.00	289.1	1.8	22.9	0.75
607	---	0.95	95	60	30.1	33.5	24.0	965	28.38	0.00	285.2	5.1	24.1	1.24
608	---	2.90	94	71	25.2	29.7	18.0	970	12.11	49.28	363.7	1.6	20.1	0.61
609	---	2.91	95	82	21.8	25.3	18.3	974	8.80	53.34	318.1	3.3	20.0	0.29
610	---	0.93	92	70	19.0	20.6	14.8	978	7.57	2.79	255.9	2.9	15.0	0.43
611	---	1.70	88	40	20.1	23.5	13.3	982	28.99	0.00	197.8	135.6	10.9	1.11
612	---	1.44	89	30	23.0	27.1	13.9	981	29.26	0.00	62.0	0.0	10.8	1.65
613	---	0.23	85	43	24.3	28.0	14.9	978	28.90	0.00	250.2	1.9	14.8	1.49
614	6.92	0.07	81	42	27.5	31.5	19.8	974	29.26	0.00	394.7	2.7	17.1	1.82
615	6.57	0.06	84	45	26.8	30.5	19.4	976	28.99	0.00	376.2	2.4	16.6	1.63
616	6.92	0.11	91	48	26.3	29.5	18.9	981	29.19	0.00	216.1	12.0	18.0	1.44
617	5.76	0.11	90	44	26.1	29.4	17.7	983	27.29	0.00	145.7	328.2	17.0	1.44
618	4.51	0.08	92	38	25.9	29.6	17.4	983	26.46	0.00	129.9	0.0	16.1	1.62
619	6.35	0.15	93	41	26.7	30.4	17.4	980	28.48	0.00	126.7	0.0	17.1	1.63
620	6.33	0.15	91	41	27.3	31.2	17.4	977	28.80	0.00	103.1	0.0	17.5	1.75
621	5.60	0.09	90	38	27.9	32.0	19.0	975	26.91	0.00	72.9	0.0	17.7	1.85
622	6.66	0.09	91	40	28.7	32.8	20.2	975	27.61	0.00	84.4	103.9	18.8	1.89
623	1.11	0.76	94	44	24.4	31.5	18.2	976	15.10	0.00	119.6	3.9	18.2	0.96
624	0.82	0.75	91	51	23.0	28.1	19.1	973	19.43	4.57	253.3	1.1	17.7	0.72
625	4.64	0.14	77	35	24.5	28.8	17.1	973	25.47	0.00	251.0	5.6	12.9	1.55
626	8.47	0.14	82	29	25.9	30.3	15.5	975	30.17	0.00	160.8	0.0	12.8	2.02
627	5.29	0.06	89	40	27.6	31.3	18.5	974	28.56	0.00	141.6	2.6	16.9	1.91
628	-25.98	4.04	93	43	27.6	31.5	18.4	973	21.46	18.29	132.0	1.1	19.4	1.60
629	-5.43	4.04	91	68	22.4	25.1	19.2	977	11.44	1.52	224.1	1.3	18.2	0.55
630	4.05	0.06	83	46	22.2	25.4	14.1	981	16.67	0.00	166.8	13.8	14.2	1.01
701	6.51	0.06	83	40	22.5	26.1	14.2	980	28.27	0.00	95.8	4.0	12.8	1.38
702	0.56	0.09	90	61	23.5	27.8	17.8	975	19.07	3.30	255.9	1.6	18.5	0.80
703	10.03	0.12	89	50	28.2	32.5	19.1	965	26.93	0.00	460.3	1.3	20.7	1.50
704	6.15	0.19	84	32	30.0	33.5	17.9	964	28.12	0.00	317.5	19.6	16.5	2.21
705	6.78	0.16	88	29	28.1	33.1	16.8	975	29.31	0.00	153.9	6.8	14.5	2.31
706	7.82	0.06	86	35	30.0	35.0	17.3	981	28.16	0.00	182.0	1.4	19.1	2.16
707	7.70	0.04	86	29	31.5	36.0	22.0	981	29.74	0.00	281.8	2.9	17.9	2.68
708	7.52	0.37	74	36	32.5	36.6	23.7	978	29.27	0.00	319.3	2.4	18.7	2.77
709	7.76	0.38	82	35	31.9	36.4	22.3	977	29.03	0.00	99.1	5.0	19.9	2.55
710	7.08	0.20	89	39	31.4	36.2	21.5	977	28.88	0.00	125.6	4.8	20.2	2.36
711	5.66	0.20	91	28	33.5	39.3	21.0	976	28.77	0.00	179.9	3.3	19.6	3.07
712	5.32	0.09	89	29	33.3	38.3	23.0	976	28.37	0.00	164.2	3.6	20.5	3.00
713	3.63	0.02	88	35	32.2	36.3	23.7	976	27.69	0.00	133.1	0.0	21.1	2.40
714	2.89	0.15	89	50	30.5	32.5	22.1	975	0.69	0.00	50.6	0.4	20.2	2.05
715	1.33	0.15	93	38	30.4	34.2	20.5	977	26.90	0.00	121.7	36.3	20.0	2.10
716	2.68	0.10	93	40	29.7	34.6	20.8	977	25.16	0.25	132.0	4.6	20.4	1.92
717	2.60	0.21	93	47	28.4	33.0	22.0	977	20.29	0.76	103.5	6.9	20.8	1.47

718	2.85	0.19	88	31	29.8	34.1	21.0	977	27.50	0.00	137.5	13.6	16.8	2.36
719	-36.85	9.95	95	44	29.2	33.5	20.9	975	23.99	24.89	261.1	1.6	20.8	1.80
720	1.29	9.95	96	52	26.8	30.5	21.6	974	18.33	14.99	62.8	7.4	21.2	1.11
721	-3.31	0.07	94	51	29.7	34.2	21.5	974	23.54	6.10	193.1	1.4	22.8	1.41
722	6.43	0.13	94	38	28.9	34.1	21.4	972	25.55	0.00	239.9	1.9	20.6	1.45
723	-12.64	0.29	94	44	29.5	33.4	19.1	972	25.63	12.70	188.8	2.1	19.5	1.95
724	6.10	0.26	95	48	26.5	30.9	19.1	974	28.66	0.00	76.4	0.0	20.1	1.31
725	-8.07	0.07	95	43	30.1	34.2	18.6	973	27.97	12.95	226.8	1.9	20.7	1.73
726	13.90	0.07	93	55	29.7	33.7	19.5	973	27.65	0.00	282.0	2.2	22.9	1.56
727	1.86	0.12	92	40	32.6	36.7	22.2	971	28.29	0.00	207.5	49.1	22.3	2.37
728	6.50	0.10	91	48	31.1	34.7	22.1	975	28.05	0.00	160.5	2.5	22.0	1.88
729	4.49	0.06	91	52	29.5	32.9	22.6	978	25.30	0.00	137.8	20.1	21.3	1.63
730	5.87	0.08	91	49	29.3	32.3	22.8	979	25.28	0.00	157.2	4.6	21.2	1.58
731			93	58	28.0	30.4	22.4	976	20.36	0.00	163.2	3.9	21.8	1.25

WISTER

Date	ET lys mm	ET std dev mm	RH max %	RH min %	T air avg C	T air max C	T air min C	Atm pres kPa	Rs MJ/m^2	Rain mm	Wind run km	Wind day/night ratio	T dew avg C	Vap pres defct kPa
201	---	---	98	30	0.9	6.2	-11.3	1010	13.53	0.00	170.7	1.6	-8.0	0.38
202	---	---	100	23	3.6	10.0	-8.9	1008	15.49	0.00	107.7	6.4	-7.5	0.51
203	---	---	100	26	8.3	14.2	-7.1	1005	13.69	0.00	228.1	1.0	-1.1	0.73
204	---	---	100	0	11.2	12.8	3.4	1000	4.68	1.52	84.4	2.0	-2.0	0.32
205	---	---	100	0	10.5	13.7	-4.3	1000	13.91	0.00	99.0	10.9	-33.5	0.61
206	---	---	100	0	11.7	19.5	-3.9	1000	14.50	0.00	47.1	4.4	-29.0	0.66
207	---	---	100	0	12.6	20.4	-2.6	998	6.68	0.00	92.0	0.7	-5.2	0.55
208	---	---	100	59	6.7	11.5	-7.6	993	8.97	0.00	266.7	0.4	-0.4	0.26
209	---	---	94	78	-7.9	-5.2	-8.8	1007	2.16	0.00	248.6	1.6	-8.9	0.04
210	---	---	100	67	-2.6	0.2	-9.5	1004	6.86	0.00	103.9	7.8	-6.5	0.12
211	---	---	100	40	4.0	10.8	-9.0	1001	15.68	7.11	107.9	0.8	-0.3	0.40
212	---	---	98	56	8.5	11.1	-3.7	1000	4.46	2.03	200.9	1.2	0.8	0.19
213	---	---	100	30	5.0	10.2	-8.7	1018	17.28	0.00	78.9	7.0	-5.7	0.49
214	---	---	100	21	8.4	15.4	-8.9	1010	16.31	0.00	138.7	3.0	-2.4	0.79
215	---	---	100	0	14.3	18.7	-4.1	1009	16.01	0.00	56.8	4.1	-5.1	1.05
216	---	---	100	0	12.4	19.7	-4.4	1011	16.99	0.00	52.9	3.7	-1.4	0.95
217	---	---	100	37	14.1	20.5	-3.5	1005	15.13	0.00	114.1	1.9	3.9	0.93
218	---	---	77	48	17.7	20.4	14.2	998	9.44	0.00	385.5	1.3	9.9	0.91
219	---	---	100	0	17.8	19.2	8.3	995	2.87	18.80	280.0	1.9	-12.7	0.36
220	---	---	100	0	16.7	22.0	6.7	1000	14.09	0.00	159.6	0.4	-9.9	1.00
221	---	---	100	0	9.8	12.0	6.8	1005	4.61	30.23	197.6	0.4	-23.3	0.07
222	---	---	100	0	9.8	11.6	2.7	989	4.38	1.02	187.9	0.4	-5.7	0.11
223	---	---	100	65	1.5	2.8	-7.9	1000	6.01	0.00	265.5	3.5	-4.6	0.16
224	---	---	100	35	6.2	13.8	-7.6	999	18.85	0.00	208.2	1.1	-1.3	0.52
225	---	---	72	43	6.2	10.9	-7.5	1003	18.16	0.00	344.7	1.7	-6.7	0.40
226	---	---	100	36	0.1	5.5	-7.4	1014	19.02	0.00	126.9	9.0	-7.9	0.35
227	---	---	99	33	4.8	9.4	-6.7	1008	13.37	0.00	168.6	1.1	-4.6	0.49
228	---	---	100	49	8.0	10.8	4.4	1001	3.13	30.73	158.4	1.1	4.1	0.37
301	---	---	100	94	6.3	7.5	2.2	999	1.98	14.73	249.3	0.7	4.5	0.00
302	---	---	100	59	6.5	10.0	-2.7	1004	15.94	0.00	203.6	4.0	1.0	0.28
303	---	---	100	39	13.3	21.4	-2.7	1004	19.02	0.00	89.4	15.8	4.8	0.78
304	---	---	100	30	19.4	26.5	1.6	996	19.27	0.00	83.0	65.5	7.1	1.37
305	---	---	100	30	19.8	26.9	2.2	996	19.73	0.00	67.5	5.2	7.6	1.44
306	---	---	100	51	20.3	25.7	7.5	996	15.89	0.00	157.2	1.8	14.9	0.82
307	---	---	100	88	15.7	19.6	6.2	1000	5.12	12.45	232.0	0.4	12.5	0.09
308	---	---	100	96	4.0	5.9	-0.5	1002	1.74	19.81	408.1	1.3	1.8	0.01
309	---	---	100	60	1.9	4.2	-4.0	1002	9.57	9.65	197.2	5.9	-2.1	0.13
310	---	---	100	36	9.2	15.8	-4.1	1008	21.52	2.03	118.0	18.2	-0.1	0.65
311	---	---	100	33	13.0	19.2	-3.0	1009	21.28	0.00	118.6	2.9	2.4	0.88
312	---	---	100	40	13.4	18.3	1.4	1010	11.78	0.51	82.9	2.8	6.3	0.76
313	---	---	100	35	13.8	17.5	-1.3	1008	14.44	0.25	116.5	9.3	4.8	0.48
314	---	---	100	25	16.6	23.5	-1.2	1000	22.34	0.00	162.3	7.5	4.5	1.27
315	---	---	100	21	18.6	23.1	3.9	999	21.86	0.00	188.6	2.2	2.6	1.37
316	---	---	100	29	16.2	22.0	2.4	1002	22.51	0.00	94.4	5.2	3.4	1.21
317	---	---	100	43	20.5	25.5	4.4	990	19.41	0.00	420.6	1.4	11.6	1.18
318	---	---	100	19	22.6	26.5	4.2	992	22.32	0.00	124.5	24.6	5.8	1.80
319	---	---	100	53	21.8	27.3	5.3	990	19.63	0.00	209.3	2.7	15.2	1.13
320	---	---	99	57	22.5	26.2	10.1	987	9.00	4.57	246.2	0.9	14.4	0.80
321	---	---	100	25	15.9	19.7	-1.4	999	23.66	0.00	168.8	20.1	1.2	1.20
322	---	---	100	21	17.6	24.7	-1.0	997	23.77	0.00	179.5	1.9	3.9	1.52
323	---	---	100	58	22.6	26.1	15.2	988	14.60	0.00	209.9	5.7	17.1	0.79
324	---	---	100	38	16.7	18.9	4.9	997	7.30	0.00	260.2	2.9	5.4	0.95

325	---	---	93	45	13.8	18.8	5.3	1002	22.27	0.00	154.7	1.4	6.2	0.73
326	---	---	100	82	11.5	15.4	8.6	986	0.89	15.75	177.3	1.0	10.6	0.04
327	---	---	91	41	10.4	12.3	1.9	993	9.56	0.00	303.5	2.0	0.7	0.45
328	---	---	100	37	8.4	11.2	-3.2	1004	24.40	0.00	184.8	18.5	-2.1	0.60
329	---	---	100	33	13.5	19.7	-3.2	1005	24.38	0.00	252.4	1.8	1.4	0.96
330	---	---	100	33	8.8	12.3	-4.3	1014	21.01	0.00	191.4	7.6	-2.3	0.59
331	---	---	100	32	12.5	18.9	-4.4	1008	24.46	0.00	113.5	7.0	1.2	0.95
401	5.80	0.12	100	37	18.0	23.9	0.0	1002	22.57	0.00	228.8	2.7	7.3	1.20
402	-1.72	0.09	100	50	20.1	23.2	7.6	997	22.31	5.08	398.4	1.7	10.9	1.04
403	4.92	0.17	100	38	12.3	16.3	0.1	1005	25.87	0.00	139.6	24.7	2.4	0.70
404	---	---	100	36	16.0	22.4	0.6	994	19.16	0.25	231.0	1.2	10.0	0.97
405	---	---	100	85	13.8	21.0	1.3	989	3.91	3.81	355.6	1.0	7.9	0.14
406	---	---	100	62	4.3	7.8	-5.0	1004	12.65	0.00	158.2	37.6	-1.0	0.21
407	0.85	0.12	100	30	11.4	18.8	-5.3	1006	25.95	0.25	174.6	1.8	1.5	0.82
408	3.79	0.12	100	42	17.5	22.5	9.3	1000	24.73	0.25	219.5	4.5	10.4	0.95
409	8.44	0.06	100	79	18.8	22.6	14.4	994	4.94	0.25	302.7	0.8	18.2	0.18
410	5.38	0.09	88	62	24.4	27.5	21.7	993	10.15	0.00	275.7	1.1	19.3	0.80
411	-26.99	0.13	100	63	22.9	25.6	5.3	993	9.45	21.59	317.1	3.6	14.7	0.64
412	2.43	0.13	100	44	14.1	18.9	2.2	998	25.82	0.00	241.0	15.6	5.3	0.74
413	5.75	0.19	100	29	20.8	27.9	2.4	995	26.61	0.00	212.8	1.7	9.4	1.58
414	5.98	0.20	87	68	23.4	26.5	17.2	989	19.19	0.00	396.9	1.3	19.2	0.73
415	---	---	100	32	18.5	20.8	1.8	998	21.81	0.00	281.7	5.1	5.8	0.99
416	---	---	100	25	18.1	25.0	1.5	1010	26.95	0.00	83.4	17.2	5.8	1.35
417	---	---	100	27	21.3	28.3	4.0	1007	26.90	0.00	60.9	7.6	8.8	1.57
418	---	---	100	35	21.5	27.7	4.9	1002	25.07	0.00	83.4	81.9	10.7	1.43
419	---	---	100	49	23.4	29.1	8.9	1002	25.56	0.00	59.9	5.0	16.3	1.12
420	---	---	100	52	24.3	28.7	11.6	1002	24.18	0.00	54.3	9.8	17.0	1.00
421	---	---	100	50	23.8	28.4	11.9	998	19.53	0.00	43.6	1.9	16.9	1.00
422	---	---	100	58	22.3	25.6	11.5	998	25.12	0.00	148.8	3.7	15.4	0.80
423	---	---	100	51	21.1	25.4	10.5	999	20.17	0.00	81.5	11.1	12.9	1.06
424	---	---	100	57	23.2	26.9	10.7	995	22.85	0.00	232.7	2.1	17.7	0.92
425	---	---	100	77	22.2	24.1	17.0	989	7.78	10.67	224.8	3.2	19.3	0.44
426	---	---	100	37	23.7	27.2	17.3	990	14.55	7.11	228.9	2.2	18.7	0.49
427	---	---	100	82	22.9	27.0	16.4	996	7.47	0.00	117.7	0.6	20.0	0.34
428	---	---	100	67	19.4	24.5	10.6	1000	19.56	28.96	205.4	2.5	14.2	0.47
429	---	---	100	95	13.3	15.7	10.1	1003	3.52	38.10	154.7	1.2	13.6	0.00
430	---	---	100	75	10.5	11.8	6.5	1003	6.36	0.25	230.1	1.8	7.6	0.14
501	---	---	100	64	12.5	16.0	5.4	1006	17.97	0.00	116.7	3.2	7.7	0.40
502	---	---	100	85	8.2	9.4	7.5	1003	3.48	32.51	159.6	1.2	8.0	0.03
503	---	---	100	74	13.5	17.7	6.2	1001	15.47	0.00	59.0	21.2	10.1	0.20
504	---	---	100	54	18.1	24.0	8.1	1002	26.17	0.00	34.1	7.7	12.8	0.59
505	---	---	100	54	21.8	26.0	10.8	1003	25.37	0.00	49.0	6.1	14.5	0.91
506	---	---	100	73	22.5	26.4	10.7	997	18.29	0.00	146.1	4.1	19.9	0.51
507	---	---	100	81	18.3	22.5	7.3	997	5.98	34.80	182.7	3.2	14.3	0.12
508	---	---	100	67	17.6	22.5	6.9	998	21.87	0.00	68.1	6.3	13.8	0.48
509	---	---	100	76	19.8	22.8	13.8	999	15.30	0.00	40.4	15.5	17.3	0.32
510	---	---	100	62	21.7	26.2	14.6	1003	21.59	0.00	61.1	9.9	17.4	0.56
511	---	---	100	75	23.0	27.7	15.1	1000	15.59	0.00	26.6	9.3	20.4	0.41
512	---	---	100	81	22.9	26.0	18.2	997	8.94	2.29	43.0	43.5	20.9	0.18
513	---	---	100	67	23.3	27.7	17.3	991	18.56	13.97	92.2	7.2	20.2	0.47
514	---	---	100	72	23.0	26.6	16.0	990	18.22	0.00	109.2	26.1	19.1	0.52
515	---	---	100	67	23.0	26.2	13.9	998	17.80	0.25	77.1	82.3	17.9	0.57
516	---	---	100	64	24.0	28.1	13.2	999	27.06	0.00	97.4	4.4	19.1	0.78
517	---	---	100	55	23.8	27.4	9.2	1001	27.71	0.00	85.1	19.0	15.2	1.08
518	---	---	100	51	21.5	27.3	9.2	1002	30.11	0.00	60.7	25.5	14.1	0.98
519	2.67	0.55	100	42	21.4	25.4	8.1	1001	29.93	0.00	59.6	20.8	12.5	1.09
520	---	---	100	50	20.7	25.0	8.1	1001	30.00	0.00	67.4	5.4	12.8	0.96
521	7.06	0.33	100	47	22.1	27.2	8.2	1002	29.67	0.00	38.7	49.7	14.1	1.08
522	11.17	0.30	100	51	23.1	28.1	10.1	1003	26.21	0.00	24.7	67.1	15.8	1.04
523	---	---	100	49	23.8	28.5	11.3	1001	27.67	0.00	49.4	75.8	16.5	1.07

524	---	---	100	59	24.0	28.7	13.0	997	22.26	0.00	59.9	30.7	19.7	0.80
525	---	---	100	54	26.7	30.0	18.4	991	25.95	11.94	81.1	2.9	21.2	0.97
526	---	---	100	65	23.3	26.2	13.8	993	18.38	0.00	114.9	5.0	18.0	0.58
527	---	---	100	68	21.0	23.9	14.9	1000	19.01	0.00	88.4	9.1	16.9	0.58
528	---	---	100	63	22.5	25.9	14.2	1000	24.42	0.00	74.8	30.0	16.6	0.77
529	---	---	100	72	20.9	26.1	14.4	995	11.17	13.46	52.1	0.0	18.8	0.28
530	---	---	100	59	25.7	30.6	15.2	997	23.63	0.00	20.7	24.8	20.2	0.76
531	---	---	100	64	25.4	29.4	15.1	999	25.88	0.25	58.3	180.1	20.3	0.74
601	9.97	0.35	100	56	26.5	31.1	16.0	999	26.87	0.00	31.4	0.0	20.7	0.90
602	---	---	100	61	27.1	31.2	16.4	999	28.09	0.00	32.8	0.0	21.8	0.90
603	13.39	0.22	100	64	26.2	30.9	18.0	1000	21.10	1.52	39.8	37.0	21.8	0.60
604	-21.15	0.08	100	81	23.9	29.1	17.5	998	12.92	4.06	55.8	14.3	21.8	0.20
605	7.09	0.16	100	70	27.5	31.6	17.4	995	24.35	5.84	93.2	1.8	23.1	0.70
606	---	---	100	60	26.9	30.7	18.8	993	28.06	0.00	78.1	106.9	21.5	0.97
607	7.94	0.25	100	65	29.3	33.2	19.1	990	28.75	0.00	84.6	4.2	24.6	0.97
608	5.00	0.21	100	74	29.1	31.8	22.8	991	13.86	1.02	113.8	10.3	25.3	0.68
609	-9.35	0.18	100	79	22.6	26.2	18.9	996	10.89	15.75	110.8	16.4	21.0	0.23
610	6.82	0.19	100	76	24.1	27.4	17.7	999	13.06	1.52	27.2	0.0	21.6	0.28
611	7.35	0.15	100	68	26.3	30.5	17.5	998	24.83	0.00	16.5	57.7	21.9	0.68
612	8.25	0.19	100	63	28.4	31.9	18.5	996	28.55	0.00	92.0	6.1	23.4	0.98
613	7.07	0.16	100	64	28.8	32.0	22.5	997	28.42	0.00	216.2	2.6	23.6	1.01
614	10.51	0.08	89	60	28.9	31.9	24.9	998	24.31	0.00	235.9	2.6	23.5	1.07
615	3.98	0.08	100	59	27.7	29.8	22.4	1000	19.36	1.02	157.0	5.8	23.2	0.88
616	7.07	0.10	100	61	28.7	32.5	17.6	1001	26.66	0.25	119.6	30.6	22.1	1.04
617	6.07	0.10	100	57	29.2	34.0	17.9	1001	25.37	0.00	28.9	20.8	23.2	1.17
618	4.64	0.06	100	58	29.1	32.8	19.7	1000	27.28	0.00	64.9	7.8	23.2	1.09
619	4.73	0.08	100	55	29.0	32.9	19.1	1000	25.81	0.00	41.0	77.3	23.1	1.09
620	5.07	0.10	100	58	29.1	33.3	18.8	1000	24.62	0.00	39.2	14.5	22.7	1.16
621	4.47	0.08	100	50	29.3	34.0	18.2	998	26.87	0.51	63.4	3.7	22.6	1.30
622	4.69	0.10	100	53	29.1	33.6	19.5	995	26.01	0.00	40.6	21.4	23.0	1.18
623	3.74	0.11	100	59	27.7	33.3	16.3	990	22.79	3.81	95.3	7.3	22.9	0.77
624	4.39	0.18	100	47	27.0	30.9	15.7	992	29.32	0.00	113.5	0.0	19.0	1.41
625	8.94	0.19	100	49	30.3	35.7	15.8	992	29.30	0.00	223.9	1.2	23.1	1.74
626	5.06	0.08	100	53	32.2	35.4	22.0	992	25.59	0.00	171.3	162.8	25.0	1.62
627	7.21	0.11	100	56	31.9	35.5	20.8	992	27.36	0.00	127.3	78.1	24.9	1.53
628	7.44	0.13	100	55	31.4	36.7	20.5	995	27.14	0.00	69.3	44.3	25.3	1.52
629	4.17	0.10	100	21	33.1	38.2	22.7	996	28.25	0.00	95.5	4.6	21.1	2.79
630	---	---	100	46	29.6	35.7	20.3	992	23.19	29.46	136.2	12.8	22.9	1.27
701	---	---	100	51	29.9	34.5	20.3	995	27.09	0.25	157.9	2.9	23.2	1.37
702	6.78	0.61	100	54	29.5	33.5	20.3	994	25.05	0.00	84.4	37.9	22.4	1.47
703	5.94	0.61	100	49	30.6	34.8	20.1	996	26.42	0.00	106.5	6.1	23.9	1.50
704	11.59	0.90	100	49	30.8	34.4	20.2	998	27.94	0.00	157.2	10.8	22.8	1.65
705	5.33	0.97	100	46	30.5	34.0	20.2	999	27.88	0.00	165.2	5.4	22.7	1.75
706	-10.44	0.43	100	52	29.7	33.2	22.4	995	22.83	18.03	220.9	4.5	22.9	1.42
707	---	---	100	61	29.7	33.3	22.6	992	24.95	0.00	213.6	4.3	24.3	1.10
708	3.87	1.06	100	56	27.4	30.6	19.9	999	18.07	0.00	112.1	20.9	21.3	1.07
709	3.53	1.05	100	73	24.9	28.4	17.1	1003	15.06	1.78	86.3	39.5	21.4	0.38
710	9.48	0.54	100	51	27.2	31.3	16.9	1002	23.20	0.00	80.5	7.6	20.5	1.19
711	-1.76	0.54	100	73	24.8	29.2	17.8	1000	12.70	3.56	50.4	22.7	21.8	0.30
712	6.13	0.26	100	60	27.7	31.8	17.9	997	21.57	0.25	83.9	4.6	23.4	0.98
713	-10.76	0.64	100	75	27.4	31.1	21.3	996	14.66	1.52	103.1	6.3	23.8	0.51
714	---	---	100	72	26.9	31.6	20.7	999	17.86	1.52	142.5	4.2	23.4	0.53
715	-0.99	0.51	100	67	26.0	30.1	19.9	1002	16.98	3.05	43.6	66.8	22.4	0.54
716	4.51	0.52	100	53	27.3	33.3	19.2	1001	13.48	0.00	59.0	12.7	22.3	0.82
717	5.77	0.52	100	55	29.2	34.8	19.0	1001	24.45	0.00	99.3	14.5	23.1	1.18
718	2.87	0.10	100	47	30.8	35.5	19.9	999	25.57	0.00	113.4	6.3	23.5	1.60
719	---	---	100	46	31.1	35.0	19.9	998	28.62	0.00	149.6	14.2	22.9	1.80
720	3.60	0.81	100	54	30.7	34.2	20.7	999	23.06	0.00	132.2	19.2	23.3	1.53
721	-10.47	0.82	100	74	24.9	30.2	20.6	1000	12.03	14.73	88.0	18.7	23.0	0.24
722	-10.75	0.22	100	40	28.8	33.8	19.8	998	26.93	0.00	58.4	180.5	21.4	1.54

723	4.31	0.22	100	42	30.9	35.5	19.9	998	28.51	0.00	106.5	14.2	22.9	1.90
724	-6.71	0.22	100	47	30.2	34.3	22.9	997	19.42	4.83	132.5	3.7	24.4	1.40
725	5.58	0.18	100	81	25.3	28.2	19.7	998	8.89	3.05	25.2	33.8	22.9	0.24
726	-0.40	0.30	100	62	24.5	31.7	15.8	994	14.28	19.05	147.2	1.4	20.5	0.37
727	7.09	0.90	98	48	24.5	27.8	14.9	999	26.90	0.00	127.9	26.4	16.2	1.30
728	6.23	1.72	98	43	24.9	29.0	12.7	999	26.05	0.00	108.0	71.5	15.5	1.36
729	-3.91	2.49	99	37	24.9	29.6	12.8	1001	26.01	0.00	45.3	6.2	16.6	1.41
730	---	---	99	46	25.9	29.8	14.9	1001	25.05	0.00	112.0	12.3	17.8	1.26
731	---	---	99	46	26.4	31.6	14.6	1001	24.52	0.00	59.2	18.1	18.4	1.42
801	---	---	99	44	28.2	32.6	16.6	1000	25.48	0.00	72.7	12.4	19.1	1.68
802	---	---	98	41	28.2	32.1	17.0	1000	19.19	0.00	54.1	12.2	19.2	1.61
803	---	---	99	43	28.4	33.1	17.0	1000	22.53	0.00	90.6	5.7	20.0	1.70
804	-5.37	0.19	98	49	27.1	32.9	20.3	999	16.91	8.64	98.4	3.6	21.8	0.98
805	-0.07	0.16	99	60	26.3	30.4	19.6	1002	22.25	0.00	129.1	6.4	21.1	0.86
806	5.84	0.24	98	53	27.8	31.5	19.3	1000	21.93	0.00	123.6	5.0	21.4	1.27
807	---	---	99	75	23.4	26.2	16.5	997	5.84	8.64	90.3	9.4	19.8	0.36
808	2.80	0.09	99	49	27.2	33.0	16.3	1000	22.55	1.27	72.0	62.9	20.8	1.21
809	2.07	0.11	99	29	28.6	33.9	17.4	1004	24.54	0.00	59.3	13.7	18.7	1.82
810	3.40	0.10	99	45	28.8	34.2	17.4	1004	22.95	1.52	50.4	32.0	20.8	1.59
811	5.43	0.04	99	42	29.5	34.5	18.2	1003	24.68	0.00	64.4	10.8	21.0	1.78
812	4.58	0.11	99	42	30.0	34.6	18.7	1002	20.61	0.00	60.9	12.4	20.6	1.88
813	2.65	0.14	99	41	30.4	34.9	18.2	1000	24.41	0.00	86.7	17.7	20.3	2.01
814	---	---	99	50	27.9	33.8	18.4	1000	16.53	0.25	156.7	0.8	20.6	1.23
815	---	---	98	30	25.6	29.7	10.7	1001	23.40	0.00	133.2	32.5	13.1	1.82
816	---	---	99	30	25.8	31.2	10.5	999	27.47	0.00	88.8	14.2	12.6	1.98
817	---	---	98	21	27.7	34.0	11.4	998	26.31	0.00	69.6	4.4	14.0	2.42
818	---	---	97	40	30.2	35.8	16.9	998	23.26	0.00	90.5	13.0	20.6	2.21
819	---	---	97	50	27.4	34.8	21.3	996	12.51	4.83	165.7	2.8	21.7	0.99
820	-14.23	0.19	99	91	22.3	23.8	14.4	996	4.74	20.07	48.0	12.4	19.9	0.12
821	3.38	0.26	99	43	24.4	28.9	14.3	998	21.81	0.00	58.3	159.9	16.0	1.28
822	0.34	0.25	99	41	25.6	30.1	14.4	998	18.15	0.00	49.6	11.5	16.5	1.47
823	1.33	0.28	99	51	27.5	32.1	15.7	1000	19.90	0.00	77.2	4.7	19.7	1.49
824	3.40	0.40	98	48	29.1	33.5	17.6	1003	22.18	0.00	59.3	7.0	20.9	1.64
825	4.91	0.39	99	51	28.1	33.8	19.3	1002	18.60	0.76	61.9	8.2	21.9	1.14
826	1.02	0.26	98	50	28.5	33.6	20.0	1000	16.27	0.00	81.7	9.7	22.2	1.23
827	5.04	0.39	98	46	30.5	34.6	19.1	1000	22.16	0.00	98.0	9.5	21.6	1.82
828	6.82	0.92	99	40	30.7	35.4	18.3	999	24.92	0.00	121.3	5.6	20.1	2.13
829	0.52	0.88	98	38	30.2	35.0	18.0	997	19.60	0.00	96.5	5.6	19.3	2.12
830	1.17	0.24	94	41	31.1	36.2	19.4	995	21.89	0.51	148.9	2.3	21.4	2.09
831	-12.81	0.47	98	56	26.4	32.4	21.1	998	16.66	18.54	132.0	5.4	21.5	0.89
901	-3.75	0.45	98	83	22.3	24.9	18.8	1002	5.61	8.13	122.8	0.8	19.5	0.20
902	-2.40	0.38	99	67	22.9	26.3	16.7	1005	13.05	0.00	48.7	604.5	18.4	0.67
903	-2.98	0.45	99	58	24.9	30.0	18.4	1004	13.89	0.00	47.7	6.1	19.9	0.84
904	4.37	0.52	98	54	28.1	32.5	18.0	1001	20.31	0.00	118.6	15.5	21.2	1.35
905	-0.11	0.57	98	48	28.4	32.7	19.4	1001	13.35	0.25	154.9	1.1	21.2	1.34
906	7.98	1.04	99	60	26.4	29.8	15.2	1004	18.94	0.00	80.5	11.3	19.2	1.03
907	-0.38	0.99	99	47	26.1	30.8	15.2	1003	18.16	0.00	51.8	9.4	19.0	1.19
908	---	---	99	48	26.8	31.3	16.9	1002	18.99	0.25	63.4	5.0	19.2	1.34
909	2.07	0.12	99	42	26.3	30.6	11.2	1002	19.18	0.25	62.4	8.4	16.4	1.40
910	4.02	0.26	99	43	24.9	29.8	11.3	1003	20.68	0.00	64.3	11.0	16.3	1.44
911	1.32	0.25	99	45	27.4	32.3	15.1	1003	21.67	0.00	89.8	11.9	17.8	1.64
912	3.73	0.45	99	41	28.4	33.6	15.2	1003	19.07	0.00	93.2	11.8	19.2	1.77
913	2.20	0.46	99	42	29.4	33.8	16.7	1003	21.65	0.00	116.8	11.6	19.0	1.94
914	2.21	0.36	97	41	29.6	33.8	17.6	1001	18.85	0.00	130.9	11.3	19.4	1.93
915	-1.03	0.40	96	47	29.4	32.8	18.4	998	17.26	0.00	129.7	11.8	20.0	1.69
916	2.54	0.28	97	37	26.9	30.8	15.3	999	18.19	0.00	163.3	3.1	16.3	1.48
917	1.50	0.35	98	28	25.1	29.5	8.2	1002	20.58	0.00	147.4	8.5	10.8	1.89
918	2.19	0.34	98	35	23.7	29.0	8.2	1003	22.20	0.00	98.6	3.8	12.1	1.66
919	1.34	0.35	98	32	24.4	29.6	9.5	1003	22.41	0.00	63.8	7.6	11.8	1.77
920	-1.69	0.39	98	32	24.6	30.5	9.4	1001	21.82	0.00	58.0	7.0	12.3	1.84

921	-0.12	1.50	98	37	25.8	30.6	11.3	998	20.11	0.76	148.8	2.0	15.8	1.74
922	-5.95	1.49	99	39	14.6	18.9	3.5	1000	8.96	10.92	134.9	50.6	7.8	0.46
923	0.41	0.25	99	38	15.5	19.1	3.7	991	12.81	0.00	141.8	5.7	6.8	0.89
924	1.30	0.25	99	59	13.9	16.9	5.4	997	6.20	0.00	121.6	7.9	8.1	0.46
925	-3.49	0.25	99	49	18.0	22.4	8.7	998	10.10	0.00	111.6	32.0	11.3	0.77
926	-1.13	0.24	98	38	23.9	28.6	7.9	992	21.06	0.00	171.5	4.8	10.9	1.67
927	2.98	0.13	98	32	23.9	31.2	7.6	996	20.43	0.00	56.6	8.9	12.2	1.76
928	2.20	0.08	98	30	27.3	33.7	10.6	996	20.32	0.00	52.4	6.5	13.9	2.19
929	0.70	0.08	98	20	29.0	36.0	11.3	997	20.56	0.00	84.7	5.8	14.0	2.67
930	1.27	0.21	97	28	28.5	34.0	12.6	996	18.86	0.00	105.6	14.2	14.7	2.50
1001	-2.46	0.21	97	36	27.5	32.3	12.9	993	15.79	0.00	80.5	5.5	15.7	1.94
1002	1.89	0.08	98	30	26.8	32.4	12.3	989	19.27	0.00	69.8	5.0	15.8	1.92
1003	-1.06	0.10	97	37	27.2	31.2	14.2	995	11.92	0.00	105.0	4.5	15.4	1.96
1004	-0.07	0.28	98	41	26.6	30.8	13.3	1003	13.99	0.00	95.8	4.1	15.6	1.73
1005	-0.37	0.28	98	40	25.5	29.9	13.2	999	13.34	0.00	141.0	1.1	15.2	1.64
1006	3.13	0.09	76	34	28.1	32.1	20.8	993	18.20	0.00	374.0	1.4	15.8	2.19
1007	-32.21	2.29	99	66	24.6	26.8	15.6	995	5.78	25.40	225.0	1.9	18.9	0.79
1008	-9.80	2.32	98	52	16.3	19.0	5.2	1000	4.34	17.53	193.4	1.6	9.9	0.35
1009	7.43	0.63	98	29	17.3	21.8	2.7	1006	19.99	0.00	138.7	2.7	5.1	1.16
1010	5.39	0.49	99	27	16.1	20.7	1.3	1006	19.85	0.00	80.6	21.8	4.3	1.09
1011	-20.50	0.45	99	32	15.3	21.0	1.4	1003	19.68	0.25	119.0	1.5	8.1	1.00
1012	3.17	0.55	93	72	16.6	18.2	14.0	999	5.43	0.00	134.0	2.0	13.1	0.37
1013	-1.33	0.36	98	75	16.8	18.0	12.5	1001	4.92	0.00	41.9	3.1	13.7	0.37
1014	5.10	0.24	98	58	18.3	20.8	14.5	1000	8.69	1.02	113.2	1.3	13.5	0.61
1015	-0.45	0.43	96	60	18.6	22.1	15.4	996	7.40	8.13	191.9	1.3	15.4	0.47
1016	0.40	0.46	91	74	21.6	24.3	18.6	999	4.61	0.25	194.8	1.2	18.3	0.42
1017	1.82	0.25	93	77	20.7	22.6	19.3	998	2.66	0.51	130.9	1.8	18.6	0.38
1018	-5.48	0.06	99	72	22.7	25.8	11.9	995	4.93	1.52	93.1	0.0	17.7	0.42
1019	2.18	0.03	99	57	22.2	27.8	12.1	998	15.46	0.25	35.2	7.0	17.0	0.68
1020	-3.29	0.07	99	69	22.4	26.1	14.4	999	8.06	4.32	58.3	6.1	17.8	0.50
1021	---	---	99	64	22.7	25.7	14.0	992	12.07	0.00	77.2	10.0	17.3	0.66
1022	---	---	99	40	22.2	26.9	7.5	994	14.32	0.00	64.9	6.9	12.8	1.01
1023	---	---	98	35	20.2	25.2	6.6	1002	17.14	0.00	52.8	5.1	9.9	1.26
1024	---	---	97	55	18.7	21.6	10.2	1002	9.02	1.78	147.6	0.7	11.0	0.69
1025	---	---	98	36	11.9	15.0	-2.2	1007	8.10	0.76	104.8	1.6	1.0	0.62
1026	---	---	98	29	10.2	15.7	-2.7	1009	16.88	0.00	39.4	24.8	-0.8	0.75
1027	---	---	98	27	12.8	18.7	-2.5	1005	17.10	0.00	49.9	7.7	1.0	0.91
1028	---	---	98	30	15.1	21.4	-1.0	1001	16.52	0.00	90.0	4.8	3.8	1.01
1029	---	---	98	42	18.7	24.3	2.9	1000	15.94	0.00	48.0	8.2	8.1	1.15
1030	---	---	98	48	18.1	24.9	5.1	1000	14.44	0.00	41.2	1.1	11.9	0.88
1031	---	---	99	73	13.5	17.5	0.1	998	3.20	3.56	162.4	6.7	6.1	0.25
1101	0.78	0.15	99	39	13.1	18.2	0.7	998	13.41	0.00	185.9	0.8	5.5	0.69
1102	-7.69	0.16	88	68	19.2	24.5	13.9	993	6.36	0.76	331.7	1.0	16.9	0.60
1103	---	---	99	69	21.8	26.7	18.3	995	4.81	26.92	177.9	2.0	19.1	0.46
1104	-93.62	0.09	99	79	21.9	25.5	12.8	992	3.35	78.74	200.0	1.7	18.0	0.32
1105	-7.77	0.16	100	85	10.9	13.7	3.3	992	4.00	4.83	180.0	8.3	7.4	0.13
1106	-4.02	0.50	100	44	14.6	21.0	3.0	1007	14.85	0.00	46.0	3.4	6.7	0.66
1107	-0.09	0.48	100	39	17.5	22.4	4.9	1005	14.58	0.00	145.1	1.3	8.6	1.04
1108	-15.74	0.04	97	72	22.4	25.2	16.3	997	9.94	14.22	217.0	1.5	18.8	0.65
1109	---	---	98	85	11.9	16.3	9.0	999	1.02	16.00	240.8	1.2	8.8	0.10
1110	---	---	91	79	10.9	11.6	9.8	1005	3.04	0.00	131.3	1.7	7.8	0.23
1111	---	---	92	75	10.9	11.9	9.9	1006	2.49	0.00	70.1	0.6	7.9	0.24
1112	---	---	84	54	14.7	17.7	10.2	1003	11.70	0.00	163.9	0.8	9.4	0.61
1113	---	---	99	64	18.8	21.4	15.1	998	7.21	23.11	182.1	2.0	14.8	0.59
1114	---	---	99	96	16.5	17.0	12.6	1002	1.43	41.91	123.2	0.4	15.4	0.02
1115	---	---	99	83	12.7	13.7	4.5	1007	2.25	0.00	191.2	2.7	9.9	0.09
1116	---	---	100	67	12.1	17.0	2.1	1005	9.23	0.25	22.5	3.7	6.7	0.28
1117	---	---	100	71	11.9	14.3	2.3	995	6.97	0.00	131.8	2.8	8.6	0.27
1118	---	---	99	65	12.9	17.5	7.3	1004	7.16	0.00	115.8	0.5	10.5	0.24
1119	---	---	94	52	15.2	16.6	12.1	1003	2.39	2.79	172.0	1.1	9.4	0.61

1120	---	---	95	37	14.8	16.8	4.8	988	3.09	6.35	323.3	0.7	7.0	0.35
1121	---	---	99	53	13.6	16.9	1.1	1002	13.09	0.00	76.0	10.2	4.6	0.62
1122	---	---	99	43	9.4	11.7	-0.6	1013	7.31	0.00	165.2	2.5	-0.1	0.48
1123	---	---	98	42	8.4	11.7	-0.1	1018	11.23	0.00	36.0	13.9	0.4	0.52
1124	---	---	98	54	9.4	12.4	0.1	1008	6.52	0.00	145.1	1.4	4.2	0.46
1125	---	---	97	73	12.3	13.8	8.6	1003	5.77	0.00	77.3	1.0	9.0	0.31
1126	---	---	98	76	12.5	23.4	8.5	995	2.28	9.91	212.3	0.2	14.3	0.16
1127	---	---	97	31	19.7	22.2	-1.9	986	11.99	0.00	269.1	3.2	2.2	1.25
1128	---	---	97	25	10.6	15.6	-3.0	998	12.96	0.00	115.5	4.4	-1.3	0.81
1129	---	---	96	22	9.1	14.1	-4.8	1007	12.56	0.00	85.7	4.0	-3.6	0.73
1130	---	---	97	22	8.6	14.7	-5.2	1012	12.73	0.00	64.8	14.6	-3.2	0.75
1201	---	---	96	26	11.3	16.3	-3.7	1009	12.52	0.00	142.8	1.8	-1.8	0.89
1202	---	---	85	32	13.4	16.1	4.1	1002	7.74	0.00	145.1	1.6	5.3	0.87
1203	---	---	99	67	17.9	21.4	6.8	999	7.09	0.00	73.5	1.2	11.3	0.55
1204	---	---	99	75	14.5	18.9	3.7	999	7.06	0.00	45.5	6.1	9.0	0.19
1205	---	---	99	77	13.5	17.3	6.3	1003	6.02	0.25	39.5	2.5	10.0	0.17
1206	---	---	97	68	17.7	21.0	5.9	999	5.95	0.00	249.5	0.5	12.5	0.45
1207	---	---	92	53	9.2	12.6	5.3	1006	9.43	2.29	99.6	1.4	4.2	0.42
1208	---	---	98	94	7.9	9.2	3.1	1003	2.07	49.53	218.1	0.5	5.8	0.04
1209	---	---	96	86	3.8	4.6	2.9	1007	1.57	4.83	156.0	1.1	2.8	0.08
1210	---	---	87	47	5.2	7.3	-5.0	1009	10.67	0.00	241.4	1.6	-3.9	0.31
1211	---	---	92	50	0.3	3.6	-5.4	1011	7.60	0.00	72.4	1.1	-5.6	0.25
1212	---	---	98	53	4.2	8.0	-3.7	1006	9.17	0.00	67.7	4.4	-1.3	0.31
1213	---	---	98	71	4.2	6.4	0.2	1007	3.48	3.05	65.9	0.5	2.8	0.14
1214	---	---	98	83	8.0	10.9	5.0	1004	3.26	0.00	126.3	1.2	6.7	0.11
1215	---	---	98	82	9.5	11.3	6.6	1006	3.67	8.64	133.8	1.4	8.3	0.14
1216	---	---	100	73	11.0	12.5	0.0	1002	3.54	0.25	78.5	2.9	4.8	0.17
1217	---	---	100	43	8.1	15.6	-2.7	1007	9.39	0.00	50.7	2.6	1.6	0.36
1218	---	---	98	36	8.9	14.1	-3.0	1009	11.69	0.00	45.7	10.1	-0.7	0.57
1219	---	---	97	32	9.8	15.1	-3.3	1003	11.05	11.43	152.1	1.7	1.6	0.70
1220	---	---	99	90	8.6	9.3	3.5	1000	1.54	2.29	51.9	1.5	6.8	0.07
1221	---	---	99	72	7.4	10.2	3.3	1004	3.48	0.00	164.6	0.4	3.8	0.12
1222	---	---	93	63	11.0	14.0	3.6	1008	8.74	0.00	183.5	1.2	5.5	0.36
1223	---	---	99	76	6.4	8.2	-3.3	1008	8.43	0.00	166.6	1.9	1.3	0.16
1224	---	---	99	82	2.1	4.9	-4.1	1008	4.11	0.25	46.4	7.8	-1.2	0.06
1225	---	---	100	98	0.6	3.1	-3.0	1008	4.33	0.00	44.3	1.0	-0.4	0.01
1226	---	---	99	62	4.1	11.2	-4.2	1008	9.67	0.25	45.0	4.3	-0.6	0.16
1227	---	---	97	28	9.8	16.8	-4.4	1005	11.77	0.00	37.8	1.5	2.2	0.67
1228	---	---	98	58	9.0	12.0	4.5	1002	3.53	4.32	51.2	1.1	5.8	0.29
1229	---	---	99	63	9.7	12.6	-1.9	1001	6.58	0.25	80.5	7.8	2.9	0.28
1230	---	---	99	60	7.2	12.1	-1.8	1003	7.80	0.25	24.4	1.9	4.2	0.26
1231	---	---	98	76	9.5	12.1	-0.3	1001	3.80	1.52	159.8	0.1	4.9	0.19
101	---	---	95	52	0.0	1.8	-8.6	1013	7.85	0.00	157.1	9.6	-6.7	0.18
102	---	---	98	43	2.9	8.2	-8.3	1012	10.53	0.00	75.1	3.9	-2.6	0.35
103	---	---	98	67	0.7	2.3	-6.9	1012	2.60	3.05	173.9	0.8	-4.9	0.06
104	---	---	94	41	-3.0	0.5	-9.4	1018	11.36	0.00	115.7	2.9	-10.5	0.25
105	---	---	97	23	-0.2	4.8	-9.0	1008	9.06	6.35	181.3	0.8	-6.5	0.35
106	---	---	98	77	4.9	6.7	-4.3	986	2.45	0.00	255.5	0.4	-0.2	0.06
107	---	---	96	47	1.2	5.7	-5.3	1005	11.66	0.00	68.7	2.4	-4.9	0.27
108	---	---	97	47	11.6	15.0	-4.7	1000	10.89	0.00	144.3	3.4	-0.1	0.67
109	---	---	96	47	9.4	16.6	-4.4	1005	12.02	0.00	70.2	1.9	3.1	0.55
110	---	---	99	64	18.8	22.3	3.4	995	6.34	0.00	145.3	12.2	10.5	0.56
111	---	---	99	42	19.2	24.6	3.0	990	11.71	0.00	288.1	0.8	13.4	1.03
112	---	---	99	62	21.9	23.3	10.4	990	7.86	24.89	244.7	1.9	14.3	0.84
113	---	---	96	85	8.8	11.0	5.5	986	0.97	73.15	495.4	0.8	5.8	0.09
114	---	---	98	67	7.7	10.9	-2.5	995	10.43	0.00	226.9	4.2	2.2	0.22
115	---	---	98	24	10.1	17.0	-2.5	999	12.78	0.00	29.5	2.0	1.2	0.67
116	---	---	96	40	13.2	16.6	2.7	994	7.80	0.00	259.4	0.8	5.4	0.76
117	---	---	99	80	12.2	15.2	3.7	995	3.18	0.25	56.5	2.7	8.1	0.19
118	---	---	99	79	7.3	9.4	0.9	993	1.41	15.75	351.4	0.6	2.9	0.05

119	---	---	95	55	5.9	9.1	-3.0	1000	12.78	0.00	166.4	5.1	-0.2	0.34
120	---	---	97	36	8.3	12.3	-2.7	1003	13.07	0.00	87.9	5.9	-1.4	0.57
121	---	---	98	48	5.1	6.9	-0.7	1005	12.83	0.00	161.4	1.7	-2.1	0.33
122	---	---	98	83	0.6	2.1	-7.7	1004	3.54	2.03	107.5	1.6	-3.6	0.05
123	---	---	97	54	0.7	4.7	-9.5	1008	13.77	6.10	93.6	6.4	-5.4	0.21
124	---	---	97	43	5.1	11.7	-6.4	1009	13.03	5.08	48.0	7.2	-0.6	0.39
125	---	---	98	45	9.6	14.3	-1.1	1008	8.88	0.00	26.4	2.9	1.8	0.52
126	---	---	98	84	7.5	13.1	4.6	1003	1.94	1.02	154.6	1.0	8.1	0.11
127	---	---	96	43	17.1	20.0	3.7	987	10.83	2.03	242.1	2.5	7.4	0.74
128	---	---	94	79	5.9	7.7	2.8	995	1.43	0.25	309.4	1.1	2.5	0.15
129	---	---	94	81	2.7	3.1	-1.8	1005	2.09	2.54	233.8	0.8	-0.4	0.07
130	---	---	97	69	1.3	4.1	-5.7	1007	5.40	0.00	52.6	25.1	-3.1	0.13
131	---	---	98	38	9.2	16.1	-5.5	1000	14.66	0.00	73.4	7.3	0.3	0.60
201	---	---	98	36	13.9	20.9	-2.0	996	14.72	0.00	84.4	7.6	4.1	0.88
202	---	---	92	28	19.4	26.9	2.9	995	14.27	0.00	150.3	0.5	6.0	1.47
203	---	---	81	56	9.7	11.5	-0.3	1003	5.50	0.00	314.2	2.9	0.8	0.42
204	---	---	93	26	7.5	13.0	-0.1	1006	15.49	0.00	161.9	1.4	-2.8	0.65
205	---	---	95	41	5.4	8.0	-4.3	1008	15.74	0.00	165.9	4.2	-4.2	0.46
206	---	---	95	39	8.2	14.3	-3.1	1002	10.37	0.00	140.0	1.4	-1.0	0.53
207	---	---	78	36	5.8	8.3	-4.5	1008	13.10	0.00	263.8	2.7	-7.6	0.54
208	---	---	92	19	3.0	7.6	-5.3	1014	16.56	0.00	65.7	2.9	-9.0	0.56
209	---	---	100	42	9.3	11.5	-1.2	1000	10.01	0.00	224.4	5.6	0.4	0.60
210	---	---	96	36	11.6	15.4	3.8	991	12.15	0.00	255.5	0.4	0.1	0.46
211	---	---	80	43	2.4	3.9	-4.9	1002	4.29	0.00	322.5	1.3	-8.3	0.29
212	---	---	51	36	-1.7	-0.1	-5.0	1009	6.24	0.00	190.4	1.2	-12.8	0.31
213	---	---	86	45	0.0	1.1	-1.8	1008	3.90	0.00	155.7	1.0	-6.5	0.30
214	---	---	98	88	1.4	17.1	-0.6	999	1.35	1.27	99.9	0.9	5.4	0.04
215	---	---	98	87	13.2	17.7	3.6	994	1.30	0.76	227.2	1.5	7.8	0.15
216	---	---	98	84	5.5	6.8	-5.4	1004	3.04	0.25	143.3	1.5	1.2	0.07
217	---	---	97	26	7.2	13.5	-6.5	1012	17.81	0.00	49.6	4.3	-3.7	0.61
218	---	---	96	22	10.8	17.8	-6.3	1006	16.62	0.00	63.9	5.6	-1.1	0.87
219	---	---	97	32	13.3	19.4	-2.4	1006	17.09	0.00	93.7	2.3	0.6	0.98
220	-0.28	0.17	97	26	16.3	23.1	-1.6	1003	17.75	0.00	258.7	1.1	2.6	0.40
221	1.39	0.10	97	12	14.8	22.0	-1.8	1007	18.07	0.00	44.7	5.8	2.6	0.40
222	1.81	0.09	96	26	16.9	22.6	0.1	1000	12.71	0.00	196.7	1.7	2.6	0.40
223	0.35	0.09	89	26	19.7	23.7	4.8	1000	16.06	0.00	239.3	0.9	2.6	0.40
224	1.81	0.07	96	19	12.9	17.1	-1.5	1013	18.75	0.00	98.4	10.8	2.6	0.40
225	2.60	0.09	95	23	15.8	21.8	-1.4	1004	17.47	0.25	149.5	4.8	2.6	0.40
226	-5.71	0.08	99	76	14.8	17.9	11.2	999	4.95	9.65	180.9	1.6	2.6	0.40
227	0.37	0.06	98	64	17.7	21.3	7.8	996	12.12	0.00	258.6	0.6	2.6	0.40
228	1.24	0.09	91	78	6.4	7.7	1.7	1006	2.53	0.00	302.5	1.0	2.6	0.40
301	2.12	0.16	93	58	3.4	4.6	-0.7	1011	5.07	0.00	276.4	1.0	-2.1	0.22
302	-0.97	0.21	96	65	1.2	2.5	-0.7	1012	4.62	0.00	160.6	2.1	-2.1	0.18
303	-0.70	0.18	96	73	2.7	4.4	0.2	1010	5.37	0.76	96.8	0.8	0.3	0.15
304	-0.35	0.16	98	84	4.4	8.6	2.2	1003	2.76	0.00	163.1	1.3	4.0	0.10
305	-1.41	0,21	99	74	8.5	10.6	4.5	997	3.43	0.00	84.2	1.5	6.3	0.15
306	---	---	98	74	16.0	20.3	1.3	992	6.48	24.64	258.4	0.5	11.6	0.32
307	---	---	91	74	-1.0	0.9	-5.7	1004	7.10	0.00	340.6	1.9	-5.2	0.11
308	---	---	96	34	2.0	7.9	-6.0	1016	21.25	0.00	128.7	3.8	-6.1	0.38
309	---	---	96	25	9.6	16.4	-6.1	1013	21.62	0.00	84.6	3.0	-2.6	0.81
310	---	---	96	24	12.7	18.3	-3.4	1010	21.75	0.00	167.3	3.8	-0.2	1.00
311	---	---	80	44	16.9	21.3	4.1	1005	20.08	0.00	339.6	1.3	8.9	0.93
312	---	---	80	68	17.9	19.8	15.1	1002	4.78	0.00	342.4	0.7	13.8	0.49
313	---	---	96	72	17.3	19.0	14.1	997	2.89	7.11	246.5	2.1	13.7	0.34
314	---	---	96	82	15.8	17.2	14.2	1000	6.09	0.25	248.7	1.6	13.5	0.23
315	---	---	99	64	17.6	20.6	7.9	1000	9.01	0.00	115.8	9.3	12.1	0.48
316	---	---	99	45	18.9	24.0	5.8	1000	20.20	0.00	109.9	6.6	10.5	0.86
317	---	---	99	29	20.0	25.9	6.4	1003	20.57	0.25	49.8	8.2	9.8	1.21
318	---	---	98	29	21.0	26.5	6.6	1000	21.05	0.00	63.5	14.6	8.8	1.48
319	4.35	0.09	97	34	22.8	27.6	7.5	992	21.39	0.00	313.4	1.3	11.2	1.60

320	2.78	0.13	98	32	20.6	22.6	2.8	992	22.08	0.00	147.8	17.6	7.2	1.32
321	5.87	0.11	98	30	21.2	27.1	2.5	992	21.42	0.00	234.3	1.7	12.2	1.60
322	3.14	0.11	98	43	26.1	30.5	11.5	985	16.11	0.00	162.0	68.4	15.8	1.42
323	4.43	0.21	91	32	22.2	26.1	7.2	995	23.22	0.00	74.1	10.5	7.9	1.60
324	3.27	0.22	76	50	17.2	20.3	10.7	996	12.77	0.00	128.0	2.2	8.4	0.86
325	-8.97	0.13	99	45	20.5	24.8	11.6	994	11.52	13.46	120.8	2.8	11.1	1.18
326	0.50	0.10	100	35	21.1	25.3	3.5	994	7.64	0.25	98.8	1.5	10.4	0.57
327	3.87	0.08	93	36	13.4	17.6	2.5	1003	24.93	0.00	104.0	7.7	2.6	0.85
328	2.78	0.07	90	43	11.0	13.7	2.3	1006	13.58	0.00	67.7	8.8	1.8	0.65
329	1.07	0.12	90	46	12.9	15.6	2.3	1004	17.58	0.00	91.6	2.5	3.1	0.69
330	2.80	0.10	91	45	11.7	15.4	2.2	1004	20.12	0.00	68.5	4.3	2.9	0.64
331	---	---	98	43	11.5	14.9	-0.2	1003	15.69	0.00	47.0	583.0	2.4	0.58
401	5.28	0.09	99	29	15.7	21.7	0.1	1000	23.14	0.00	78.1	0.0	3.9	1.05
402	3.99	0.12	99	28	18.3	24.1	1.4	1000	25.39	0.00	75.8	36.7	5.6	1.33
403	-9.11	0.12	99	56	13.7	16.6	6.7	1000	5.22	10.92	40.8	2.6	11.5	0.26
404	1.54	0.10	99	52	17.3	21.3	4.5	1001	17.69	0.00	59.3	0.0	10.2	0.58
405	3.22	0.16	99	41	15.4	20.4	4.2	997	16.29	0.00	56.4	106.8	8.3	0.72
406	2.77	0.15	99	50	19.3	24.5	7.0	995	23.68	0.00	18.0	0.0	11.3	0.88
407	4.80	0.12	99	47	21.2	26.0	6.9	993	23.40	0.00	155.9	3.4	13.9	1.06
408	6.31	0.10	93	51	23.7	26.8	14.7	988	24.76	0.00	212.2	1.8	15.8	1.16
409	8.41	0.05	73	50	25.8	28.6	19.5	982	24.57	0.00	334.9	1.4	15.8	1.44
410	-24.33	0.07	97	67	19.8	22.6	5.3	986	3.04	31.50	92.4	0.8	11.3	0.50
411	4.05	0.08	98	39	9.3	13.6	1.6	995	21.34	0.76	82.4	106.7	2.2	0.48
412	4.61	0.06	99	37	14.3	19.1	1.3	1003	25.72	0.25	94.7	391.3	3.7	0.91
413	3.06	0.21	99	34	16.2	23.0	1.4	1006	26.44	0.00	10.5	42.3	6.4	0.97
414	5.18	0.24	99	39	19.9	25.4	3.4	996	24.63	0.00	136.6	3.2	9.8	1.28
415	2.43	0.13	97	65	20.8	23.2	16.8	993	9.90	0.00	74.4	2.9	16.9	0.61
416	-1.27	0.09	98	77	22.5	25.3	17.0	994	7.86	2.79	83.9	3.3	18.8	0.47
417	-4.22	0.07	97	72	21.9	25.7	16.6	991	10.51	6.35	215.9	0.9	18.2	0.42
418	5.14	0.07	99	31	21.8	24.2	3.6	991	26.33	0.00	139.0	40.6	7.3	1.54
419	-33.63	0.15	99	63	12.6	17.1	3.8	994	6.73	39.62	107.7	1.8	10.9	0.25
420	3.71	0.21	100	55	18.1	21.7	6.6	988	16.16	0.25	50.0	64.4	11.5	0.58
421	5.89	0.18	100	37	21.0	26.5	6.5	992	26.74	0.00	153.7	1.4	11.0	1.22
422	-2.06	0.08	96	60	13.2	15.7	9.1	999	11.89	4.57	217.3	3.2	8.5	0.41
423	1.20	0.08	98	78	9.2	10.1	3.3	997	5.06	0.00	126.4	784.7	6.2	0.15
424	3.31	0.39	99	56	16.6	18.7	3.1	999	0.27	0.25	8.4	0.1	6.2	0.68
425	4.85	0.48	99	39	17.1	22.3	3.2	1001	25.29	0.00	79.5	3.1	8.1	0.97
426	4.42	0.31	90	49	20.4	24.3	9.4	994	22.90	1.27	245.8	1.6	10.3	1.10
427	2.30	0.15	99	38	15.1	18.7	5.8	1004	27.17	0.00	115.7	150.3	6.6	0.78
428	2.34	0.04	99	51	17.3	22.5	8.3	999	18.97	0.00	89.4	2.5	10.6	0.79
429	-11.18	0.04	100	66	16.7	19.4	9.4	991	4.36	11.18	94.1	44.0	13.4	0.22
430	-13.41	0.11	---	---	---	---	---	---	---	---	---	---	---	---
501	0.26	0.15	---	---	---	---	---	---	---	---	---	---	---	---
502	4.05	0.12	---	---	---	---	---	---	---	---	---	---	---	---
503	0.76	0.06	98	68	16.0	19.4	12.2	994	11.53	2.03	90.7	5.6	13.1	0.42
504	3.54	0.35	99	56	19.7	22.7	7.0	1000	21.64	0.25	107.6	9.9	12.4	0.64
505	1.97	0.35	99	56	18.7	23.6	6.9	1004	24.31	0.76	112.6	1.2	13.6	0.67
506	---	---	99	82	16.5	18.5	14.3	998	4.29	21.08	68.5	4.5	15.1	0.16
507	---	---	99	69	21.8	25.3	15.2	993	7.89	41.91	156.8	1.5	18.4	0.40
508	---	---	100	65	18.8	23.1	14.8	988	15.67	6.86	163.1	3.1	15.2	0.45
509	---	---	99	38	23.6	27.1	12.6	988	28.90	0.00	155.7	17.9	13.9	1.31
510	---	---	99	58	18.8	21.5	9.2	994	27.16	0.00	127.2	42.9	11.2	0.83
511	---	---	99	52	18.7	23.1	9.5	996	19.78	0.00	49.4	203.8	12.2	0.72
512	---	---	100	64	20.4	24.8	10.2	987	12.00	0.00	186.9	1.2	18.0	0.59
513	---	---	99	64	28.4	31.1	20.7	983	22.78	0.00	150.3	46.3	22.7	1.03
514	-3.67	0.08	99	67	28.6	31.8	20.4	994	24.63	0.00	102.1	4.9	22.3	0.97
515	4.46	0.05	98	61	27.9	33.6	19.8	997	22.92	0.25	50.9	1.4	23.5	0.95
516	3.65	0.04	84	66	27.3	29.4	23.3	990	17.68	0.00	206.5	1.2	21.7	0.92
517	-3.25	0.10	99	65	24.9	26.2	17.9	984	6.06	5.59	227.2	4.0	20.3	0.63
518	1.60	0.10	95	67	17.7	21.7	9.9	991	13.54	0.00	169.1	11.6	11.6	0.57

519	---	---	99	50	19.0	23.3	9.0	999	30.10	0.00	83.2	515.8	11.4	0.86
520	8.80	1.38	99	49	21.5	27.1	9.2	999	26.56	0.00	18.0	12.2	15.2	0.96
521	-3.98	1.73	99	49	21.4	27.0	12.9	999	15.91	0.00	25.4	157.0	16.6	0.66
522	0.19	1.56	99	49	24.9	29.5	12.6	999	26.74	0.00	100.8	2.2	17.4	1.24
523	7.76	1.05	98	55	26.2	29.6	17.8	996	25.86	1.52	167.3	3.9	18.9	1.20
524	-0.37	1.09	99	71	23.4	28.5	18.0	997	11.02	1.52	77.4	2.0	20.1	0.46
525	-2.53	0.31	98	80	20.8	24.3	17.6	1001	12.68	0.76	69.7	3.4	18.8	0.31
526	3.36	0.13	97	74	23.9	28.1	19.2	998	16.37	0.25	110.5	3.4	20.7	0.46
527	4.12	0.21	99	64	26.4	28.9	16.2	991	18.83	0.00	153.2	15.3	19.9	0.92
528	6.98	0.46	97	48	24.6	28.6	14.1	998	29.44	0.00	69.4	5.9	15.9	1.28
529	1.23	0.43	99	59	18.9	22.2	13.6	1003	11.59	0.25	78.6	46.7	15.1	0.55
530	-1.97	0.18	98	79	20.2	21.7	16.0	1001	7.64	4.06	54.0	13.1	18.0	0.26
531	-10.76	0.16	100	85	19.1	21.8	14.3	997	8.09	11.18	52.8	130.3	16.8	0.16
601	5.74	0.20	100	56	22.9	27.7	15.0	995	22.65	0.00	46.4	51.4	18.0	0.72
602	-22.87	0.30	100	68	19.6	25.8	14.3	997	7.13	24.64	53.9	4.3	17.3	0.15
603	3.65	0.22	100	65	25.4	30.8	14.2	997	22.16	0.00	47.3	10.0	21.0	0.73
604	2.97	0.11	98	56	27.0	32.0	18.6	998	25.31	1.52	74.1	1.9	21.2	0.99
605	-18.68	0.47	100	62	23.9	30.8	16.1	993	20.70	27.94	47.4	15.8	18.9	0.68
606	4.10	0.46	100	64	25.7	31.3	16.1	987	23.14	0.00	84.6	38.7	21.8	0.77
607	2.52	0.12	99	74	27.6	30.6	20.7	990	18.58	0.00	113.8	9.4	23.8	0.69
608	2.96	0.13	95	69	28.4	31.3	21.8	994	14.68	0.00	116.2	1.9	23.6	0.86
609	5.95	0.16	93	64	28.4	32.1	21.5	998	20.80	0.00	143.7	3.7	23.2	1.09
610	-2.90	0.60	99	72	23.4	30.2	19.2	999	7.66	24.38	88.5	5.6	20.6	0.36
611	—	0.68	98	60	19.0	22.2	12.3	1001	14.68	2.29	142.7	16.0	14.6	0.44
612	---	0.36	99	46	21.9	25.5	10.9	1002	26.17	0.00	82.4	126.9	13.6	1.10
613	7.93	0.90	99	42	22.8	28.1	10.8	1001	30.67	0.00	23.1	43.2	14.8	1.21
614	3.49	0.90	100	49	25.4	29.3	13.6	1000	29.64	0.00	114.6	283.8	17.3	1.34
615	5.27	0.12	100	53	26.7	30.3	15.7	1001	28.75	0.00	100.1	112.0	19.1	1.32
616	5.78	0.23	100	50	27.1	31.4	15.9	1005	25.30	0.00	59.1	46.4	19.1	1.33
617	4.96	0.32	100	47	26.4	30.2	15.3	1006	23.92	0.00	45.8	161.6	17.9	1.44
618	2.85	0.25	100	45	26.4	30.9	14.6	1005	23.53	0.00	43.9	181.0	17.8	1.41
619	4.35	0.14	100	41	26.4	31.5	14.4	1002	28.73	0.00	20.3	32.6	18.2	1.45
620	4.53	0.13	100	46	27.2	31.8	16.1	998	26.37	0.00	22.9	70.3	19.2	1.41
621	4.41	0.10	100	45	27.7	32.3	16.0	996	28.68	0.00	36.2	14.0	20.3	1.49
622	3.06	0.10	99	55	27.7	32.4	19.1	997	21.07	0.00	25.4	27.7	21.6	1.11
623	2.25	0.14	100	61	26.1	32.0	16.7	997	18.37	0.76	50.0	12.1	20.7	0.80
624	3.94	0.14	100	55	25.9	30.6	18.3	994	25.08	0.25	56.1	9.9	20.6	0.95
625	0.85	0.12	100	55	23.5	26.6	13.7	993	13.67	0.25	114.3	188.3	17.8	0.71
626	5.88	0.15	100	43	25.0	28.5	13.4	995	30.27	0.00	122.9	178.7	15.8	1.41
627	0.61	0.15	100	53	24.0	29.6	13.2	997	14.69	1.52	22.9	70.3	19.0	0.77
628	8.95	0.10	100	51	28.2	32.9	17.0	996	28.13	0.00	58.4	32.0	21.0	1.37
629	2.96	0.21	100	63	25.1	30.1	19.0	997	15.37	0.00	61.5	8.6	21.3	0.64
630	-24.75	0.24	98	71	23.6	28.0	20.0	1000	10.35	30.99	58.1	41.5	20.6	0.33
701	3.41	0.21	99	50	25.5	28.5	16.6	1000	24.17	0.00	46.8	104.8	18.3	1.14
702	2.50	0.18	100	59	24.6	28.8	17.4	998	16.77	0.00	59.4	2.9	20.2	0.79
703	5.49	0.10	88	59	29.3	32.8	22.8	990	22.63	0.00	282.1	1.1	22.8	1.29
704	-5.75	0.28	97	42	29.7	31.7	17.2	989	23.51	13.21	331.1	4.6	20.7	1.50
705	-2.77	0.31	99	61	25.2	29.3	18.2	997	22.40	0.00	80.1	6.6	20.2	0.84
706	6.69	0.25	99	37	28.8	33.5	18.3	1003	28.73	0.00	81.2	105.3	20.5	1.56
707	4.83	0.99	100	45	30.3	34.9	18.6	1004	28.64	0.00	44.4	51.5	21.9	1.78
708	1.69	0.99	100	44	30.8	34.7	19.4	1001	29.40	0.00	75.5	17.4	21.3	1.96
709	3.30	0.18	100	49	31.6	35.9	20.1	998	29.06	0.00	93.5	35.3	22.7	1.92
710	10.19	0.11	100	50	30.5	34.9	19.8	998	28.87	0.00	43.7	30.9	22.3	1.69
711	4.57	0.14	100	42	32.4	37.2	19.6	998	28.59	0.00	25.3	10.3	23.8	2.13
712	8.02	0.10	99	49	32.8	36.9	21.6	998	27.58	0.00	40.7	10.0	24.7	1.87
713	9.17	0.09	100	43	31.6	35.5	21.4	998	27.55	0.00	66.9	25.0	23.6	1.84
714	5.16	0.11	98	62	28.9	30.4	20.9	998	0.25	0.00	8.9	1.1	21.4	1.38
715	3.56	0.07	99	55	29.7	33.7	20.8	999	22.07	0.00	49.0	8.3	23.0	1.39
716	8.28	0.44	99	50	30.4	34.0	21.8	999	25.02	0.00	44.2	34.4	22.8	1.64
717	-12.53	0.44	100	59	27.2	32.5	20.8	998	17.50	14.73	61.3	23.2	22.7	0.79

718	4.56	0.08	100	50	29.2	33.0	19.7	998	25.64	0.25	77.9	7.1	21.9	1.34
719	5.37	0.12	98	45	29.7	34.9	19.4	998	24.88	0.00	50.9	27.1	21.4	1.81
720	-30.49	0.21	99	68	27.4	31.9	21.3	996	15.68	39.88	117.5	4.8	23.2	0.71
721	4.90	0.21	99	55	29.2	33.7	22.1	997	25.61	0.76	111.0	16.7	23.6	1.23
722	-6.29	0.17	100	64	28.7	33.8	21.9	995	18.85	9.91	71.0	54.2	23.8	0.93
723	-19.50	0.36	100	61	29.2	32.4	20.9	994	22.49	25.91	111.2	3.2	24.1	1.02
724	3.52	0.39	99	63	26.8	30.4	20.6	995	19.66	0.25	77.7	174.6	22.3	0.87
725	-0.36	0.24	99	58	30.9	34.1	18.5	996	27.47	7.62	125.8	2.0	23.3	1.48
726	0.76	0.18	100	60	25.2	30.6	18.8	997	16.66	2.54	67.1	150.7	21.5	0.63
727	6.58	0.25	100	55	31.8	35.8	20.5	995	27.74	0.00	86.2	81.4	24.4	1.67
728	3.90	0.26	100	51	33.4	38.3	22.0	996	26.35	0.00	56.3	0.6	25.7	1.99
729	7.06	0.15	98	56	30.4	32.7	21.9	1000	27.00	0.00	144.5	4.4	23.2	1.42
730	6.08	0.11	98	59	30.0	33.2	21.9	999	26.53	0.00	127.3	4.2	23.4	1.28
731			98	74	27.0	29.2	22.8	997	13.55	2.54	122.9	5.5	23.2	0.67

APPENDIX E

SUMMARY OF MISSING MESONET WEATHER DATA

GOODWELL

Year	Month	Day	Times
1994	May	4	1645
		10	0830, 0900-0930, 1200-1515
		11	1300
			TB10 erratic all month
	June		TB10 erratic all month
	July		none
	August		none
	September	10	1315
	October		none
	November		none
	December		none
1995	January		none
	February	2	0400-0645
		13	1545
	March	1	2200-2215
	April	18	0715, 0745-0800
	May	1	all
		2	all
	June		none
	July	4	1845
		14	all

APACHE

Year	Month	Day	Times
1994	January	16	2100, 2215-2230, 2315, 0030, 0100, 0215-0245, 0315-0345, 0415
		23	0230
		24	0300, 0615
		30	1645
		31	0030-1745
		2-31	RAIN, PRES, TA9M, WS2M, TS30
		2-25	TB05
		25-31	TS10
	February	1	0500-1015, 1615, 1645-1745
		2	0115-0945, 1215-1245, 1345-1830
		10	0915-0930
		1-28	TA9M, TS10, TS30
		1-2	RAIN
		1-3	PRES
	March	1-23	TA9M
		1-23	TS10
		1-29	TS30
	April		none
	May	5	1900
	June		none
	July		none
	August		none
	September		none
	October		none
	November		none
	December	31	1745
1995	January	20	2300-2345, 0015-0345, 0815
	February	9	1415-1615
		21	2300-2345, 0000-0900
		23	2330-2345, 0000-0815
	March	6	1445-1745
		21	1300
	April	5	1845
		23	1445, 1645
	May	1	all
		2	all
	June	5	0345, 0845-0915, 0945-1030, 1145-1200, 1845
	July	14	all

MARENA

Year	Month	Day	Times
1994	January		none
	February	10	0800, 1230
	March		none
	April		none
	May	21	1545-2345
		22	0000-2345
		23	0000-1600
	June		none
	July		none
	August	11	0915
	September		none
	October	12	1800
		31	0345-0545
	November		none
	December	31	2345
1995	January	20	2300-2345, 0015-0545, 0615-0715, 745
	February	2	0900
	March	1	1600-1615
		6	1445-1745
	April	5	1845
		18	0745-0800
		24	1200-1845
	May	1	all
		2	all
	June		none
	July	14	all

WISTER

Year	Month	Day	Times
1994	January	1-11	TA9M
	February	10	1200-1230
	March		none
	April	1	1145, 1745
		13	1845-1900
		14	0945
		27	1330-1845
	May	6	0900
	June		none
	July	16	1215-1515, 1630
	August		none
	September		none
	October	12	1800
		31	1745
	November		none
	December	31	1445-2345
1995	January	20	2300-2345, 0015-0445, 0530-0545, 0630-0715, 0745
	February	2	0415-0700, 1215
	March	1	1600-1615
	April	10	1245-1845
		18	0300-0330, 0400, 0430, 0715, 0745-0800, 0830, 0900, 0930
		24	0145-1845, 2045-2200
	May	1	all
		2	all
	June		none
	July	4	1845
		14	all

APPENDIX F

SUNRISE AND SUNSET TIMES

Rounded to nearest 15 minutes to coincide with Mesonet readings

GOODWELL

(Latitude 36° 37', Longitude 101° 37')

Sunrise

Year	Local time	Dates mmdd
1994	800	0101 - 0126
	745	0127 - 0212
	730	0213 - 0225
	715	0226 - 0308
	700	0309 - 0318
	645	0319 - 0328
	630	0329 - 0402
	730	0403 - 0404
	715	0405 - 0419
	700	0420 - 0501
	645	0502 - 0517
	630	0518 - 0712
	645	0713 - 0801
	700	0802 - 0819
	715	0820 - 0907
	730	0908 - 0926
	745	0927 - 1013
	800	1014 - 1029
	715	1030 - 1113
	730	1114 - 1128
	745	1129 - 1216
	800	1217 - 0126
1995	745	0127 - 0212
	730	0213 - 0225
	715	0226 - 0308
	700	0309 - 0318
	645	0319 - 0328
	630	0329 - 0401
	730	0402 - 0404
	715	0404 - 0419
	700	0420 - 0501
	645	0502 - 0517
	630	0518 - 0712
	645	0713 - 0801
	700	0802 - 0819

Sunset

Year	Local time	Dates mmdd
1994	545	0101 - 0112
	600	0113 - 0127
	615	0128 - 0210
	630	0211 - 0225
	645	0226 - 0313
	700	0314 - 0330
	715	0331 - 0401
	815	0402 - 0417
	830	0418 - 0504
	845	0505 - 0522
	900	0523 - 0617
	915	0618 - 0708
	900	0709 - 0801
	845	0802 - 0815
	830	0816 - 0826
	815	0827 - 0906
	800	0907 - 0916
	745	0917 - 0926
	730	0927 - 1006
	715	1007 - 1017
	700	1018 - 1029
	545	1030 - 1115
	530	1116 - 1226
	545	1127 - 0112
1995	600	0113 - 0127
	615	0128 - 0210
	630	0211 - 0225
	645	0226 - 0313
	700	0314 - 0330
	715	0331 - 0402
	815	0404 - 0417
	830	0418 - 0504
	845	0505 - 0522
	900	0523 - 0617
	915	0618 - 0708
	900	0709 - 0801
	845	0802 - 0815

APACHE

(Latitude 34° 55', Longitude 98° 18')

Sunrise

Year	Local time	Dates mmdd
1994	745	0101 - 0123
	730	0124 - 0211
	715	0212 - 0225
	700	0226 - 0308
	645	0309 - 0319
	630	0320 - 0330
	615	0331 - 0402
	715	0403 - 0410
	700	0411 - 0422
	645	0423 - 0506
	630	0507 - 0527
	615	0528 - 0629
	630	0630 - 0725
	645	0726 - 0814
	700	0815 - 0903
	715	0904 - 0924
	730	0925 - 1013
	745	1014 - 1029
	645	1030
	700	1031 - 1115
	715	1116 - 1130
	730	1201 - 1221
	745	1222 - 0123
1995	730	0124 - 0211
	715	0212 - 0225
	700	0226 - 0308
	645	0309 - 0319
	630	0320 - 0330
	615	0331 - 0401
	715	0402 - 0410
	700	0411 - 0422
	645	0423 - 0506
	630	0507 - 0527
	615	0528 - 0629
	630	0630 - 0725
	645	0726 - 0814

Sunset

Year	Local time	Dates mmdd
1994	530	0101 - 0106
	545	0107 - 0122
	600	0123 - 0206
	615	0207 - 0221
	630	0222 - 0311
	645	0312 - 0329
	700	0330 - 0402
	800	0403 - 0417
	815	0418 - 0506
	830	0507 - 0525
	845	0526 - 0730
	830	0731 - 0814
	815	0815 - 0826
	800	0827 - 0906
	745	0907 - 0916
	730	0917 - 0927
	715	0928 - 1008
	700	1009 - 1019
	645	1020 - 1029
	545	1030 - 1102
	530	1103 - 1127
	515	1128 - 1212
	530	1213 - 0106
1995	545	0107 - 0122
	600	0123 - 0206
	615	0207 - 0221
	630	0222 - 0311
	645	0312 - 0329
	700	0330 - 0402
	800	0403 - 0417
	815	0418 - 0506
	830	0507 - 0525
	845	0526 - 0730
	830	0731 - 0814

MARENA

(Latitude 36° 04', Longitude 97° 13')

Sunrise

Year	Local time	Dates mmdd
1994	745	0101 - 0119
	730	0120 - 0209
	715	0210 - 0222
	700	0223 - 0306
	645	0307 - 0320
	630	0321 - 0327
	615	0328 - 0402
	715	0403 - 0406
	700	0407 - 0417
	645	0418 - 0430
	630	0501 - 0515
	615	0516 - 0713
	630	0714 - 0803
	645	0804 - 0821
	700	0822 - 0910
	715	0911 - 0929
	730	0930 - 1017
	745	1018 - 1029
	645	1030 - 1102
	700	1101 - 1117
	715	1118 - 1202
	730	1203 - 1224
	745	1225 - 0119
1995	730	0120 - 0209
	715	0210 - 0222
	700	0223 - 0306
	645	0307 - 0320
	630	0321 - 0327
	615	0328 - 0401
	715	0402 - 0406
	700	0407 - 0417
	645	0418 - 0430
	630	0501 - 0515
	615	0516 - 0713
	630	0714 - 0803

Sunset

Year	Local time	Dates mmdd
1994	530	0101 - 0114
	545	0115 - 0128
	600	0129 - 0212
	615	0213 - 0227
	630	0228 - 0316
	645	0317 - 0402
	745	0403
	800	0404 - 0420
	815	0421 - 0508
	830	0509 - 0527
	845	0528 - 0728
	830	0729 - 0812
	815	0813 - 0824
	800	0825 - 0904
	745	0905 - 0914
	730	0915 - 0924
	715	0925 - 1004
	700	1005 - 1015
	645	1016 - 1027
	630	1028 - 1029
	530	1030 - 1113
	515	1114 - 1228
	530	1229 - 0114
1995	545	0115 - 0128
	600	0129 - 0212
	615	0213 - 0227
	630	0228 - 0316
	645	0317 - 0401
	745	0402 - 0403
	800	0404 - 0420
	815	0421 - 0508
	830	0509 - 0527
	845	0528 - 0728
	830	0729 - 0812

WISTER

(Latitude 34° 59', Longitude 94° 41')

Sunrise

Year	Local time	Dates mmdd
1994	730	0101 - 0124
	715	0125 - 0212
	700	0213 - 0225
	645	0226 - 0309
	630	0310 - 0320
	615	0321 - 0330
	600	0331 - 0402
	700	0403 - 0410
	645	0411 - 0422
	630	0423 - 0506
	615	0507 - 0528
	600	0529 - 0628
	615	0629 - 0724
	630	0725 - 0813
	645	0814 - 0902
	700	0903 - 0923
	715	0924 - 1012
	730	1013 - 1029
	645	1030 - 1114
	700	1115 - 1130
	715	1201 - 1220
	730	1221 - 0124
1995	715	0125 - 0212
	700	0213 - 0225
	645	0226 - 0309
	630	0310 - 0320
	615	0321 - 0330
	600	0331 - 0402
	700	0403 - 0410
	645	0411 - 0422
	630	0423 - 0506
	615	0507 - 0528
	600	0529 - 0628
	615	0629 - 0724
	630	0725 - 0813

Sunset

Year	Local time	Dates mmdd
1994	515	0101 - 0106
	530	0107 - 0122
	545	0123 - 0205
	600	0206 - 0221
	615	0222 - 0310
	630	0311 - 0328
	645	0329 - 0402
	745	0403 - 0416
	800	0417 - 0505
	815	0506 - 0524
	830	0525 - 0731
	815	0801 - 0814
	800	0815 - 0826
	745	0827 - 0906
	730	0907 - 0917
	715	0918 - 0927
	700	0928 - 1008
	645	1009 - 1020
	630	1021 - 1029
	530	1030 - 1103
	515	1104 - 1129
	500	1130 - 1210
	515	1211 - 0106
1995	530	0107 - 0122
	545	0123 - 0205
	600	0206 - 0221
	615	0222 - 0310
	630	0311 - 0328
	645	0329 - 0401
	745	0402 - 0416
	800	0417 - 0505
	815	0506 - 0524
	830	0525 - 0731
	815	0801 - 0814

VITA

Daniel Kenneth Fisher

Candidate for the Degree of

Doctor of Philosophy

Thesis: EVAPOTRANSPIRATION MEASUREMENTS AND RESISTANCE PARAMETER ESTIMATION UNDER RANGE/PASTURE CONDITIONS IN OKLAHOMA

Major Field: Biosystems Engineering

Biographical:

Education: Graduated from Doherty High School, Colorado Springs, Colorado in May 1976; received Bachelor of Science degree in Mechanical Engineering from the University of Central Florida, Orlando, Florida in December 1979; received Master of Science degree in Agricultural and Irrigation Engineering from Utah State University, Logan, Utah in December 1990. Completed the requirements for the Doctor of Philosophy degree with a major in Biosystems Engineering at Oklahoma State University in December 1995.

Experience:
Employed as Mechanical Engineer at Thiokol Chemical Corporation, 1980; employed as Mechanical Engineer at EDO Western Corporation, 1981 to 1982; served with United States Peace Corps as High School Mathematics Teacher in Swaziland, Africa, 1983 to 1985; employed as Mechanical Engineer at American Laser Corporation, 1986 to 1987; worked as Graduate Research Assistant in Department of Agricultural and Irrigation Engineering at Utah State University, 1988 to 1990; USDA National Needs Fellow in Department of Biosystems Engineering at Oklahoma State University, 1991 to 1993; Graduate Research Assistant in Department of Biosystems Engineering. at Oklahoma State University, 1993 to 1995.