**A Simulation Study of Infiltration
Into Surficial Sediments
at the Subsurface Disposal Area,
Idaho National Engineering Laboratory**

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ABSTRACT

Soil moisture monitoring data in the surficial sediments at the Subsurface Disposal Area (SDA) at the Idaho National Engineering Laboratory were used to calibrate two numerical infiltration models. The calibration was performed with the ultimate goal of providing a reliable estimate of hydraulic properties and infiltration amounts to be used in other modeling efforts. Two neutron probe access tubes and a tensiometer nest were monitored from 1986 to 1990 and again during 1993. The field measurements of moisture content and matric potential inside the SDA were used as calibration data for the two locations. The two locations showed vastly different behavior, which was well captured in the models. The average root mean square error between simulated and measured moisture contents over the simulation period was 0.03 and 0.06 for the two locations. The hydraulic parameters resulting from the calibration compared favorably with laboratory and field scale estimates.

The simulation results also provided the opportunity to partially explain infiltration and redistribution processes occurring at the SDA. The underlying fractured basalt appears to behave similar to a capillary barrier. This behavior inhibits moisture movement into the underlying basalts until moisture contents in the overlying silts approach saturation. As a result, a large proportion of recharge occurring at the SDA may be due to spring snowmelt, when the surficial sediments become nearly saturated. The results also indicated that a unit gradient boundary condition (free drainage due to gravity) at the bottom of the silts is not appropriate because of the very low relative hydraulic conductivity of the basalts. Finally, the amount of water moving into the SDA subsurface from spring snowmelt appears larger than cumulative snowfall, indicating that snow drifting due to local topography as well as current snow management practices may have a substantial influence on local infiltration.

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A Simulation Study of Infiltration into Surficial Sediments at the Subsurface Disposal Area, Idaho National Engineering Laboratory

1. INTRODUCTION

1.1 Background

Since the mid-1950s, the Radioactive Waste Management Complex (RWMC), located in the southwestern portion of the Idaho National Engineering Laboratory (INEL), has been used for storage and disposal of wastes generated by national defense programs and reactor research activities. The INEL is located along the western edge of the Eastern Snake River Plain, which encompasses most of the southeastern portion of Idaho and occupies approximately 890 mi². The RWMC consists of about 144 acres of a shallow depression surrounded by low hills and is divided into two major areas: (a) the Subsurface Disposal Area (SDA) in which low-level radioactive and other hazardous wastes have been buried in shallow pits excavated in the surficial sediments and (b) the Transuranic Storage Area in which transuranic wastes are stored above ground in covered pads. The location of the RWMC within the INEL and Snake River Plain is illustrated in Figure 1.

1.2 Motivation

Infiltration is the process in which surface water enters the soil. Infiltrated water moving down through wastes in the soil, becoming contaminated, and eventually reaching the aquifer is one of the most realistic scenarios for aquifer contamination at the SDA. Therefore, infiltration is an important factor controlling contaminant migration because it is responsible for the amount of dissolution and transport of contaminants away from the waste disposal pits.

Because of the possibility of serious consequences of atmosphere and aquifer contamination if wastes in the disposal pit migrate, a significant amount of effort has been devoted to investigate potential pathways for contaminant migration away from the SDA, including both field and modeling studies. One such field study consisted of a vadose zone monitoring program, which was conducted to characterize infiltration at the SDA (McElroy, 1990). From 1985 to 1987, a network of vadose zone instruments were installed at the SDA. The instrumentation included neutron probe access tubes (NATs) and tensiometers. Two NATs (W02 and W06) were regularly monitored for moisture content and matric potentials. The locations of NAT W02 and W06 within the SDA are illustrated in Figure 1. In addition to infiltration amount estimates, the monitoring program resulted in a substantial data base that can be used for model development and calibration.

During previous RWMC infiltration modeling studies, no attempts were made to calibrate the numerical models used because no quantitative data were available (Baca et al., 1992). They

Figure 1. Location of the RWMC.

were constrained to rely on the assumption of uniform infiltration rates across the SDA that were equivalent to the amount of precipitation occurring at either the nearby Central Facilities Area (CFA) weather station or the National Weather Service Station located in Pocatello, Idaho. Recent analysis of data gathered in the vadose zone monitoring program indicates that a substantially greater amount of water infiltrated into the underlying basalts than is shown in the CFA precipitation measurements. McElroy (1993) estimated that 56 cm and 24 cm of water infiltrated at NATs W06 and W02, respectively, during the spring of 1993, while only 12.2 cm of precipitation occurred between November 1992 and March 1993 at CFA. Additionally, the snowpack water equivalent measurements at NATs W02 and W06 taken early in 1993 were also higher than the cumulative precipitation measurements at CFA. McElroy (1993) measured maximum water equivalent snowpack amounts to be over 20 cm at both NATs.

Large recharge events due to localized infiltration, as seen in W06, could enhance contaminant migration in these areas. This information indicates that there is a need to use more detailed models for predicting SDA infiltration amounts. The moisture content and matric potential field measurements collected by McElroy (1993) provide a readily available source of data to calibrate two location-specific models.

1.3 Objective and Scope

A calibrated simulation study of moisture infiltration at NAT W02 and W06 was conducted to obtain a reliable estimate of hydraulic parameters, which then could be used to extend the simulation period backwards and forwards in time. Extending simulation back in time permits evaluation of water movement, which previous disposal practices were subject to; extending the simulation forward in time with estimated meteorological conditions allows evaluation of future conditions.

The objective of the simulation study is to obtain a good match between simulated and field estimates of moisture contents and matric potentials at W06, and moisture contents at W02. Once this objective is met, the calibrated simulations will provide (a) a reliable estimate of the amount and timing of net infiltration at the two locations, (b) a validation of hydraulic properties measured from W06 core samples presented in McElroy and Hubbell (1990) and field scale estimates of hydraulic properties presented in McElroy,^a and (c) an insight into the soil physics occurring at the SDA (i.e., explain the role of the surface soil-basalt interface and the presence of perched water in some of the NATs).

Section 2 of this report contains a description of NATs W02 and W06 as well as the monitoring program. Section 3 discusses an investigation of lateral flow into NAT W02 and W06 areas. Section 4 presents the modeling approaches including the methodology used to calibrate the numerical model at NATs W02 and W06, and results of the model calibration are discussed in Section 5. Lastly, Section 6 presents the conclusions and future modeling needs identified by this work.

a. Unpublished work, 1994.

2. NATS W02 AND W06

2.1 Geology and Climatic Conditions

Much of the Snake River Plain subsurface consists of a thin layer of sediments composed of silt, sand, clay, and gravel ranging in thickness from 2 to 24 ft, which are underlain by a complex sequence of basalt flows. The basalt flows continue down to through the aquifer, which is located approximately 120 m below the surface. The basalts are often fractured, especially near the top and bottom of each layer and are separated by discontinuous sedimentary interbeds.

The climate on the INEL is that of a semi-arid, high desert region and is characterized by large daily and seasonal temperature variations. During the summer, low humidity, clear skies, and high temperatures result in high evaporation rates while average winter temperatures remain below freezing for 2 to 3 months, essentially preventing most evapotranspiration during the winter. The average annual temperature is approximately 42°F and the average annual precipitation is about 22 cm with 30% falling as snow (Clawson et al., 1989). Most of the precipitation occurs during the late spring or early fall, with an occasional heavy thunderstorm occurring during the summer. Precipitation usually exceeds evaporation from October through May, and evaporation exceeds precipitation during June through September (Anderson et al., 1991).

2.2 NAT Description

NATs W02 and W06 were installed in the fall of 1986. The neutron access holes were hand-augured to the underlying basalt at 14.5 ft and 10.5 ft below land surface for holes W02 and W06, respectively. Carbon steel pipes were then installed leaving 2 ft of pipe extending above the ground (Hubbell et al., 1987). In addition to the neutron access holes, three tensiometer nests were installed at 3-, 6-, and 9-ft depths in a borehole located approximately 4 ft east of NAT W06. Table 1 provides a geologic description of layering in NAT W02 and the tensiometer access hole near NAT W06, which was recorded during their construction.

2.3 NAT Monitoring

In situ soil moisture and matric potential data at the NAT W02 and W06 locations were collected monthly from November 1986 to November 1990. In December 1992, neutron probe access tube monitoring was resumed with more frequent monitoring during the spring when the majority of infiltration occurred from snowmelt and spring rains. The neutron probes were monitored at least once a week prior to the spring snowmelt in March 1993, and monitored every other day during the snowmelt and subsequent infiltration in March and early April. As the soil profile began to dry, monitoring frequency was reduced to about once a week in April through June, twice a month in July, and once a month during August and September (McElroy, 1993).

Table 1. Geologic log of NATs W02 and W06 (McElroy, 1993).

W02		W06	
Depth (ft)	Description	Depth (ft)	Description
0.0	Silty clay	0.0	Sandy silt
2.5	Silt	1.7	Sandy silt
4.3	Sandy silt	2.8	Sandy silt
6.0	Sand	4.3	Sandy silt
7.7	Silt	6.0	Sandy silt
9.5	Silt	7.7	Clayey sandy silt
11.2	Silt	9.3	Sandy silt
13.0	Clayey silt	11.0	Sandy silt
14.7	Basalt	11.8	Basalt

3. INVESTIGATION OF LATERAL FLOW

Prior to performing the simulations, an investigation was conducted to determine if and at which depth lateral water movement may be occurring at the W02 and W06 NAT locations by analyzing the field measurements of moisture content. The net amount of water inflow or outflow at each monitored depth can be roughly estimated by summing the differences in moisture contents between each monitoring date using the equation

$$I_i = \sum_{t=1}^{t=t_f} 6(\theta_{i,t+1} - \theta_{i,t}) \quad (1)$$

where

- I = net water inflow or outflow at individual depths
- θ = moisture content at each depth interval
- t = times at which measurements were taken
- 6 = distance between moisture content recordings.

The maximum infiltration amounts were found by simply retaining the largest single difference from the equation for each depth; this is an attempt to quantify the amount of moisture that moved into the soil from the largest infiltration event (i.e., the spring snowmelt). The net and maximum flow amounts for each depth can then be used to estimate lateral flow by identifying areas of high and relatively low inflow. If a large maximum or net inflow occurred below areas of lower inflow, continuity would dictate that the infiltration would be a result of lateral flow.

The differencing was performed over the 1993 data, which extended between January 20 and October 11. The 1993 data were chosen because if any lateral flow did occur, it would most likely be due to the large and rapid spring snowmelt that occurred during 1993.

Results of the differencing (i.e., net and maximum and changes in moisture contents for 6-in. depth intervals at 1-ft increments) are presented in Table 2. Both net and maximum changes in moisture contents followed a generally decreasing trend with increasing depth in both NATs. These trends indicated that much of the infiltration occurs near the surface and also exits through the surface via evapotranspiration. The amounts by which net and maximum changes in moisture contents deviate from a decreasing trend are small compared to the gross infiltration amounts described in McElroy (1993). Furthermore, most areas that deviated from the decreasing infiltration with depth trend were in areas of relatively low conductivity with the exception of maximum infiltration in NAT W06. Lateral flow would most likely occur in areas of high conductivity immediately over areas of low conductivity. The appearance of higher infiltration amounts in low conductivity is probably due to water remaining longer in the low conductivity areas. These results suggest that lateral water movement does not appear to be a significant factor contributing to the increased infiltration occurring at NATs W02 or W06 during 1993.

Results of the differencing also indicate that the soil profiles in both NATs retained some of the water from the relatively large 1993 precipitation amount, which reflects the precipitation pattern previous to and during the period. The integration period consisted of a relatively wet year, which

was proceeded by a dry year. Finally, it should be noted that this analysis for lateral flow is only a crude estimation. Steady-state lateral flow would not be seen by the differencing equation.

Table 2. Infiltrated water amounts at various depths for NATs W02 and W06 (1987–1989).

Depth (ft)	Net infiltrated water (in.)		Maximum infiltrated water (in.)	
	W02	W06	W02	W06
1.0	0.25	0.41	1.55	1.85
2.0	0.29	0.46	1.44	1.34
3.0	0.13	0.50	1.62	1.04
4.0	0.05	0.46	0.20	1.09
5.0	0.22	0.33	0.35	1.17
6.0	0.17	0.25	0.26	1.25
7.0	0.00	0.18	0.04	0.71
8.0	0.00	0.14	0.04	0.67
9.0	0.08	0.24	0.11	0.78
10.0	-0.02	unknown	0.05	unknown
11.0	0.04	unknown	0.11	unknown
12.0	0.02	unknown	0.07	unknown
13.0	-0.02	unknown	0.01	unknown

4. MODELING APPROACH

To simulate infiltration, the underlying physical processes must be identified, and a suitable numerical model must be selected. Once a numerical model is chosen, input parameters representing the simulation site must be specified. These parameters include boundary conditions, initial conditions, model geometry, and soil hydraulic properties. This section contains a general discussion of infiltration and redistribution physics including the governing equation, the numerical model selected along with specification of the input parameters, and the methodology used in calibrating the model.

4.1 Infiltration and Redistribution Physics

Infiltration is the process by which surface water enters the soil. Redistribution is the process through which water made available from infiltration redistributes itself during infiltration and after the infiltration has stopped. After surface water has infiltrated into the soil, it redistributes itself in response to gravity and capillary forces. The redistribution process will ultimately partition the infiltrated water into a three-part water balance. These parts consist of (a) surface losses that are due to evaporation and transpiration, (b) drainage that becomes aquifer recharge, and (c) storage that is water that remains in the vadose zone.

When water is applied in relatively small amounts, (i.e., at rates less than the soil's saturated conductivity), the water infiltrates as fast as it is applied, and the application rate controls the infiltration. However, as often is the case during spring snowmelt, application rates exceed the soil's capacity for infiltration, and the soil's hydraulic conductivity controls the infiltration rate after the initial soil wetting. In this latter case, the initial infiltration rate is relatively large and may even exceed the saturated hydraulic conductivity. This large initial infiltration rate is due to the extremely large matric potential gradients between the dry soil ahead of the wetting front and the moist soil behind the wetting front as well as the soil's capacity to store the initial water. Eventually, the infiltration rate will decrease with time because of pore infilling and eventually reach a steady-state rate equal to the soil's saturated hydraulic conductivity.

The partial differential equation governing unsaturated flow, including infiltration and redistribution, can be derived from the general mass conservation equation and Darcy's law as originally performed by Richards (1931). For the case of one-dimensional flow, Richards' equation is

$$C(h) \frac{\partial h}{\partial t} = - \frac{\partial}{\partial z} [K(h) \left(\frac{\partial h}{\partial z} + 1 \right)] \quad (2)$$

where

- h = suction head
- $C(h)$ = specific moisture capacity, the slope of the soil moisture curve $\partial\theta/\partial h$ in which θ is the volumetric moisture content
- z = depth into the soil
- t = time
- $K(h)$ = relative hydraulic conductivity.

4.2 Numerical Model

The UNSAT-H Version 2.01 computer code (Fayer and Jones, 1990) was chosen for the simulations in this study because of its ability to model infiltration as a function of meteorological conditions at semi-arid sites. The code uses an iterative finite-difference technique to solve a modified form of Richards' equation, which also accounts for water vapor diffusion. Specifically, the code has the ability to account for (a) liquid and vapor water movement, (b) heat transfer by conduction and convection, (c) evapotranspiration at the soil surface, and (d) transpiration by plants.

The UNSAT-H code has been verified and benchmarked by Baca and Magnuson (1990) and has been successfully applied to simulate moisture transport at several semi-arid locations (Fayer et al., 1992; Baca et al., 1992; Magnuson, 1993).

In order to solve Richards' equation, the UNSAT-H code must be supplied with four basic components. These components are soil hydraulic properties, computational grid, initial conditions, and boundary conditions. Each of these components will be discussed in turn.

4.2.1 Hydraulic Properties

Characterizing unsaturated flow requires three basic hydraulic properties for each material type identified in the simulation profile. These three properties are (a) the moisture characteristic curve, which is the relation between the matric potential and moisture content, (b) the hydraulic conductivity curve, which is the relation between the matric potential and the relative hydraulic conductivity, and (c) the saturated hydraulic conductivity.

Although obtaining soil hydraulic properties is one of the final objectives of this study, initial estimates of these properties were needed before beginning the calibration process. These initial estimates were obtained from hydrologic characterization of core samples taken from the SDA (McElroy and Hubbell, 1990; Bishop, 1991). These estimates were then revised as of part of the calibration process.

Points on the moisture characteristic curve and hydraulic conductivity curve are usually determined experimentally, and analytic curves are empirically curve fit to these data. The van Genuchten equations (van Genuchten, 1980) were used to represent these constitutive relationships. The equation for the characteristic curve is

$$\theta = \theta_r + (\theta_s - \theta_r) [1 + (\alpha h)^n]^{1-1/n} \quad (3)$$

and the equation for the hydraulic conductivity curve is

$$K(h) = K_s \frac{[1 - (\alpha h)^{n-2} [1 + (\alpha h)^n]^{-(1-1/n)}]^2}{[1 + (\alpha h)^n]^{(1-1/n)/2}} \quad (4)$$

where

- h = suction head
- K_s = saturated hydraulic conductivity
- θ = volumetric moisture content
- α = curve-fitting parameter
- n = curve-fitting parameter
- θ_r = residual saturation
- θ_s = porosity.

4.2.2 Computational Grid

The general model domain is a one-dimensional vertical column. Soil layer profiles were constructed for NATs W02 and W06 by defining distinct soil layers and assigning hydraulic properties. Transition layers were then assigned between the main layers, and the hydraulic properties for these layers were linearly interpolated from the bounding layers.

Soil layering was determined by analyzing field estimates of soil moisture profiles. Low conductivity zones in soils typically have a higher moisture content because water tends to accumulate in these regions. This is primarily due to the restriction of water flow by the low conductivity zones. Laboratory analysis of core samples taken from surficial sediments and sedimentary interbeds of the SDA (McElroy and Hubbell, 1990) included two silt samples from NAT W06, which represented a relatively low and a somewhat higher hydraulic conductivity zone. The lower and higher zones of conductivity from the soil moisture profiles for both NATs W02 and W06 were identified and assigned initial estimates of hydraulic properties from the NAT W06 core samples.

In addition to the low- and high-conductivity silt layers, the neutron probe data indicated that a dry layer exists near the surface of NAT W06 and that two very dry layers were present at 4-ft and 7-ft depths in NAT W02. The dry layers suggest that sand is present at these locations. Hydraulic properties of SDA interbed core sample taken from a 31-ft depth and described as "silty sand" in McElroy and Hubbell (1990) were assigned to the dry layer at the surface of W06, and hydraulic properties corresponding to a sample described as "sand" from a 234-ft depth core sample were assigned to the two sandy layers in NAT W02.

Finally, computational grids were assigned to the simulation profiles using exponentially decreasing and increasing spacing moving towards and away from soil type boundaries, respectively. Exponential spacing at material interfaces places more nodes in areas where they are needed (i.e., at high-gradient areas at the surface due to evaporation or infiltration and high-gradient areas across interfaces due to different material types). The end result is to reduce pressure gradients across adjacent nodes and provide a more accurate solution. The W02 model profile includes seven main soil layers and 12 transition layers and uses a total of 183 nodes. The W06 profile consists of five main soil layers and seven transition layers and uses a total of 123 nodes. The extent of layering and the depth of each layer was adjusted in the calibration process. Final simulation soil profiles are presented in Figure 2 to illustrate the model layering.

Figure 2. Simulation soil profiles for NATs W02 and W06.

4.2.3 Initial Conditions

Moisture movement within the surficial sediments is dynamic because the driving forces of precipitation and evapotranspiration continually change. There is rarely, if ever, a time when a uniform moisture content can be considered to be representative. The method used in this modeling study to obtain initial conditions is to select a time far enough in advance of any measurements so that the water profile in the surficial sediments is in equilibrium with the meteorologic and evapotranspirative conditions that have occurred prior to that time. The starting time that was chosen for this purpose was January 1, 1985. Since there were no field measurements of moisture content and matrix potential until near the end of 1986, this starting time allowed more than a full year as a buffer for this equilibrium to occur. Further improvement of the initial conditions was obtained by repetitively simulating one representative year of meteorological conditions until the soil moisture

tension profile was the same at the end of each repetitive year. The 1986 meteorological conditions were arbitrarily used for this repetitive simulation to obtain the initial conditions for January 1, 1985.

4.2.4 Boundary Conditions

The lower boundary condition was specified as a unit gradient (water movement across the bottom boundary layer is only influenced by gravity). The upper boundary, as implemented in the UNSAT-H code, can be either a flux or constant head depending on conditions at the soil surface. Initially, during periods of infiltration or evaporation, the boundary is a flux. However, if the surface node becomes less than a minimum suction head (saturated conditions) during infiltration, or if the surface node rises above a maximum value (unnaturally dry conditions) during evaporation, the upper boundary becomes a constant head until conditions revert to normal.

When the upper boundary condition is a flux, the flux amount is a function of meteorologic conditions. If the plant option is selected in the code, transpiration amounts are distributed throughout the near surface by a rooting depth function. Simulations were tried using the plant option with various rooting depth functions. However, as will be seen in Section 5, better results were obtained by modeling evapotranspiration simply as evaporation.

As discussed in the previous section, the UNSAT-H code requires daily records of meteorologic data in order to compute the upper boundary condition. These parameters are maximum and minimum air temperature, dewpoint temperature, solar radiation, average wind speed, average cloud cover, and daily precipitation. However, the cloud cover information is used only to calculate radiative heat losses at the soil surface when the heat transfer option has been selected.

An engineered barrier simulation study by Magnuson (1993) provided a representative meteorologic data base for the period from January 1981 through December 1990. This data base was extended through August 1993 using data collected by the National Oceanographic and Atmospheric Administration (NOAA) weather station located at CFA. Solar radiation and cloud cover information were not available from CFA. The missing solar radiation data were synthetically generated using the WGEN computer program (Richardson and Wright, 1984). WGEN allows the synthetic data to be conditioned on observed precipitation. Magnuson (1993) showed a high correlation between synthetic values generated with WGEN and measured values at a United States Geological Survey weather station adjacent to the SDA. The missing cloud cover information was not necessary because the UNSAT-H heat transfer option was not used.

Because the daily precipitation records collected at the NOAA weather station included all forms of precipitation including both rain and snow, the precipitation amounts were modified during the winter months to account for accumulation and melting of snow following the method outlined in Magnuson (1993). The results of this modification were to concentrate winter precipitation into a short period of snowmelt during the early spring.

When the ground surface is covered with snow, the snow prevents most evaporation from occurring by insulating the ground from wind and solar radiation. Additionally, as the ground freezes, the effective porosity and hydraulic conductivity can be reduced by any remaining moisture freezing in the soil pores. This reduces evaporation by limiting the amount of soil water that can move toward the soil surface. Finally, most vegetation becomes dormant during the winter months, further

decreasing evapotranspiration. The combination of the above processes effectively stops most evapotranspiration during the winter season. To accurately simulate winter soil processes, the potential evapotranspiration was set to zero during the winter period.

4.2.5 Model Calibration

Model calibration is the trial and error process of adjusting input data until computed data match the field observations. This calibration included adjusting parameters from the soil hydraulic parameters, the soil layering, and timing and amount of spring snowmelt. The initial estimates of soil layering and hydraulic parameters discussed in Sections 4.2.1 and 4.2.2 were adjusted until a reasonable match between field measurements of moisture contents were obtained for NAT W02 and both moisture contents and matric potentials for NAT W06. The initial estimate of spring snowmelt was simply the amount of precipitation that occurred each winter.

A buffer year (1985) was included at the start of the simulation in which the results were not used for calibration of the model parameters. The goal of the calibration process was to match moisture contents throughout the entire simulation period; however, most emphasis was placed on matching the 1993 field data because of much more frequent monitoring during the spring infiltration.

The field monitoring of moisture contents in NATs W02 and W06 during the 1993 spring snowmelt showed that approximately 24 cm of water moved into the soil over a 15-day period near NAT W02, and approximately 56 cm of water moved into the soil near NAT W06 over a 10-day period. Both these values are far greater than the 12.2 cm of precipitation that occurred at CFA during the 1992–1993 winter as indicated by McElroy (1993).

Since the main objective of this study was to match the observed moisture contents in the NATs, it was necessary to increase the amount of spring snowmelt to agree with the observed infiltration. To calculate the additional snowmelt needed to match the observed infiltration, it was necessary to (a) define the winter period for each year of the simulation, (b) sum the total precipitation during this period, and (c) determine a multiplying factor to increase the amount of frozen precipitation to account for the increased infiltration from drifting or snow berms as a result of road plowing.

The criteria for selecting the start of the winter period was the beginning of the first extended period in which the average temperature fell below freezing where the average temperature was the average of the maximum and minimum values. Conversely, the criteria for selecting the last day of the winter period was the day preceding the first period in which the average temperature was above freezing. Table 3 presents the last and first days of the winter period for each calendar year of the simulation.

Table 3. Winter period by calendar year.

Year	Last day	First day
1985	90	311
1986	46	322
1987	60	319
1988	56	312
1989	75	329
1990	60	330
1991	44	300
1992	40	297
1993	83	—

The total precipitation that occurred during the winter was summed for each year to provide a base snow accumulation. The 1993 total was compared to spring infiltration measured by McElroy (1993) to determine a maximum snow accumulation multiplication factor for NATs W02 and W06. Finally, the additional snow accumulation was distributed over a 15-day melting period for NAT W02 and over a 10-day melting period for NAT W06 in accordance with the snowmelt period described by McElroy (1993). Various multiplication factors were tried as part of the calibration process. Table 4 presents the base snow accumulation, the total precipitation during the winter period, and modified accumulations for NATs W02 and W06 for each year. The multiplication factors used in Table 4 are the final estimates and represent the drifted snow at NAT W02 and the snow berm at NAT W06.

The large amount of water that infiltrated near NAT W06 is plausible considering the NAT's location. The NAT is located in a shallow ditch next to a maintenance road. During the winter, the road is regularly plowed, which resulted in a 5-ft snow berm slightly uphill from the NAT during 1993. In addition, snowpack measurements taken by McElroy (1993) indicated that approximately eight inches of water equivalent snowpack accumulated near NATs W02 and W06 during the winter of 1993. This value is almost two times the precipitation at CFA during the same period, indicating the importance of drifting snow in water balance simulations at the SDA.

Appendix A contains the modified meteorological data base for the simulation period along with the dates over which the additional water was applied to match field infiltration amounts.

Table 4. Base and modified snowpack water equivalent.

Winter period	Base CFA precipitation (in.)	NAT W02 $\times$ 2.16 (in.)	NAT W06 $\times$ 5.12 (in.)
1984-85	3.28	7.23	17.14
1985-86	2.36	5.10	12.07
1986-87	1.08	2.33	5.52
1987-88	0.94	2.03	4.81
1988-89	3.51	7.58	17.96
1989-90	1.69	3.65	8.65
1990-91	0.41	0.89	2.10
1991-92	0.96	2.07	4.91
1992-93	4.30	9.30	22.00

5. MODELING RESULTS

Distinct layering was identified in both the W02 and W06 profiles, indicating that undisturbed soil is present at both locations. However, because NAT W06 is located in a shallow ditch next to a maintenance road, the top layers probably have been disturbed to a greater extent than NAT W02. The NAT W02 location represented a highly stratified area that included materials of vastly different properties (i.e., silt and sand). The NAT W06 location represented a less heterogenous area comprised primarily of silt. Final soil layering for the NATs are depicted in Figure 3, and final estimates of soil hydraulic properties for NATs W02 and W06 are presented in Tables 5 and 6, respectively. Finally, Appendix B contains the final UNSAT-H input decks used in the W02 and W06 simulations.

Figure 3. Soil type and layering for W02 and W06.

Table 5. Hydraulic properties for W02.

Soil layer	K_s (cm/hr)	θ_s	θ_r	α (1/cm)	n	Soil layer description
1	0.9	.500	.060	.0100	1.600	Silt
2	6.7	.485	.055	.0175	1.838	Transition
3	12.5	.470	.049	.0250	2.075	Transition
4	18.3	.455	.044	.0325	2.313	Transition
5	24.1	.440	.038	.0400	2.550	Sand
6	16.7	.463	.065	.0350	2.230	Transition
7	9.3	.487	.093	.0300	1.910	Transition
8	1.9	.510	.120	.0250	1.590	Sandy silt
9	18.2	.455	.064	.0309	2.308	Transition
10	12.4	.470	.089	.0218	2.065	Transition
11	6.5	.485	.115	.0127	1.823	Transition
12	0.6	.500	.140	.0036	1.580	Silt
13	0.8	.503	.133	.0054	1.583	Transition
14	0.9	.507	.127	.0072	1.587	Transition
15	1.0	.510	.120	.0090	1.590	Sandy silt
16	1.0	.230	.015	.0384	1.474	Basalt

Table 6. Hydraulic properties for W06.

Soil layer	K_s (cm/hr)	θ_s	θ_r	α (1/cm)	n	Soil layer description
1	11.4	.554	.038	.0155	1.800	Silty sand
2	9.8	.540	.064	.0147	1.763	Transition
3	8.2	.527	.089	.0139	1.725	Transition
4	6.6	.514	.115	.0131	1.688	Transition
5	5.0	.500	.140	.0123	1.650	Silt
6	7.5	.503	.133	.0169	1.630	Transition
7	10.0	.507	.127	.0216	1.610	Transition
8	12.5	.510	.120	.0262	1.590	Sandy silt
9	10.0	.507	.127	.0216	1.610	Transition
10	7.5	.503	.133	.0169	1.630	Transition
11	5.0	.500	.140	.0123	1.650	Silt
12	1.0	.230	.015	.0384	1.474	Basalt

5.1 Evaluation of Calibration Results

To evaluate the match between the simulated and field moisture contents, both quantitative and qualitative judging were used. However, only qualitative judging was used to evaluate the match between matric potentials for NAT W06 because of the sparse number of data points (i.e., measurements were taken only at the 3-, 6-, and 9-ft depths). Two quantitative indicators were chosen to measure the match between field and simulated data. The first indicator was the root mean square (RMS) error, and the second was the correlation coefficient. Data pairs corresponding to 6-in. measurement intervals were compared with the quantitative indicators. To ensure that the data points compared corresponded to the same depth, a linear interpolation was used to obtain simulation moisture contents at the field measurement depths.

The RMS error provides a good estimation of the average error throughout the data set being compared and is defined by

$$\text{RMS} = \frac{\sqrt{\sum_{i=1}^k (s_i - f_i)^2}}{k} \quad (5)$$

where

- f_i = field moisture content
- s_i = simulation moisture content
- k = number of comparison points.

The correlation coefficient measures the degree to which there is a linear relationship between corresponding field and simulation data. It provides an estimate of how well the trends between the data sets agree (i.e., the shape of the soil moisture profile). The correlation coefficient is defined to be the quantity

$$r = \frac{\sum_{i=1}^k s_i f_i - \frac{1}{k} \sum_{i=1}^k s_i \sum_{i=1}^k f_i}{\sqrt{[k \sum_{i=1}^k s_i^2 - (\sum_{i=1}^k s_i)^2][k \sum_{i=1}^k f_i^2 - (\sum_{i=1}^k f_i)^2]}} \quad (6)$$

A perfect linear relationship between data sets would result in a correlation coefficient of 1 while at the other end of the scale, a correlation coefficient of 0 would indicate that the data sets are completely independent.

Finally, graphical comparisons between the field and simulation data were used as the qualitative judging criteria. Plots were made of the field data superimposed over the simulation data, and the agreement was visually evaluated.

5.2 NAT W02 Simulation Results

Results from the W02 simulation illustrate the dramatic effect that natural layering in the sediments has on infiltration. The two distinct sand layers show a sharp drop in soil moisture. The sand layers behave as a natural capillary barrier as the larger pore spaces in the sand retain less moisture and have lower tensions than the surrounding silts. The very low moisture contents in the sand corresponds to a very low relative hydraulic conductivity, which tends to reduce infiltration and redistribution into the sand until the overlying silt layers become nearly saturated.

5.2.1 Comparison of Field and Simulation Results

A graphical comparison of field and simulation moisture contents is presented in Figures 4 and 5 and clearly illustrates the drying effect of the sand layers. Soil moisture profiles for representative days during winter, spring, summer, and fall seasons from 1987 to 1990 are presented for the simulation period along with soil moisture profiles before, during, and after the 1993 snowmelt. Simulated profiles are represented by dashed lines while field profiles are represented by the solid lines. Moisture contents below the second sand layer remained relatively constant throughout the modeling period.

Static moisture contents at this depth indicate that the amount of drainage at NAT W02 will be between two extremes, which are (a) steady-state drainage due to gravity at a rate equivalent to the relative hydraulic conductivity or (b) no drainage because the upward capillary forces are in equilibrium with the downward gravitational forces. The latter extreme appears to be occurring at NAT W02 because the simulation predicted matric potential gradients to be negative unity at this depth and the infiltration amounts to be very small. Only 1.6 cm of water moved from the silts into basalts below NAT W02 during the simulation period while if steady-state drainage was occurring, the amount would have been approximately 45 cm.

The overall agreement between field and simulation moisture content is good. However, there appears to be an anomaly during 1986 (results not shown) and 1987. The field moisture content measurements suggest that evapotranspiration occurred only to a depth of 30 cm while the model predicted a behavior similar to other years in which evapotranspiration occurred down to the first sand layer at 90 cm. Differences between the field and simulation data may be due to recontouring of the surface near NAT W02 during 1986 and 1987, which would reduce the capacity for evaporation and plant growth.

In an attempt to get a better estimate of the 1986 initial conditions, the initialization period was extended backwards by starting the simulation in 1982. However, the extended initial conditions did not improve the match during 1986 and 1987. Nevertheless, the 1993 spring infiltration event from the snowpack melting was well captured by the simulation. Moisture content in the top soil layer rose to a maximum of approximately 0.40 on March 29, 1993, in both the simulation and field measurements.

The average RMS error for the time points illustrated in the graphical comparison (Figures 4 and 5) was 0.06. The largest RMS error was 0.08 for April 8, 1987, and the smallest error was 0.05 for July 26, 1988. The average correlation coefficient was 0.87 with the lowest being 0.72 for October 2, 1992, and the highest being 0.94 for January 4, 1989. The overall agreement between the field and simulation moisture contents was good as indicated by the low RMS error and high correlation coefficients.

Figure 4. NAT W02 field and simulation moisture contents for 1987 to 1989. (Simulated moisture contents are dashed lines, and field moisture contents are solid lines.)

Figure 5. NAT W02 field and simulation moisture contents for 1990 to 1993. (Simulated moisture contents are dashed lines and field moisture contents are solid lines.)

5.2.2 Localized Recharge

The amount of water that infiltrated past the basalt interface is a good indication of aquifer recharge because this water has no chance of returning to the surface via evapotranspiration. This is primarily due to the depth of the interface and the fact that the moisture retention for the basalt is much lower than the silts at the same tensions. The simulated daily drainage into the underlying basalt is illustrated in Figure 6, and yearly drainage is presented in Table 7.

Figure 6. Daily drainage from NAT W02.

Table 7. Yearly simulation drainage from NAT W02.

Year	Drainage (cm)
1986	0.20
1987	0.25
1988	0.23
1989	0.21
1990	0.19
1991	0.18
1992	0.17
1993	0.16 ^a

a. Drainage is for January 1 through August 31.

The simulation results indicated that a total of 1.6 cm of recharge occurred during the simulation period (1986 to 1993) and that 0.12 cm of recharge occurred from the 1993 spring snowmelt (January through July). The latter amount compared favorably to the less than 3 cm estimated by McElroy (1993). Two drainage peaks can be seen, one during spring 1986 and the other during spring 1993.

The two peaks represent the two wettest years during the simulation period. The time-dependent drainage plot in Figure 6 illustrates that NAT W02 may respond to years with high precipitation amounts and not to individual spring infiltration events.

5.2.3 Plant Transpiration

Although the final W02 simulation did not directly include the effects of plant transpiration, the plants around NAT W02 and their effect on evapotranspiration warrants some discussion. The standard operating procedure at the SDA throughout the simulation period has been to reseed crested wheatgrass each spring in the inactive areas. Crested wheatgrass is a long-lived perennial bunchgrass that can quickly establish a stable monoculture. The area surrounding NAT W02 sustains an abundant population as observed by the authors.

A field study performed by Anderson et al. (1987) compared the ability of crested wheatgrass and other monocultures to deplete water from a clay loam soil at the INEL. The results showed that the plants extracted increasingly more water from the soil as they established deeper roots over the 3-year study period. However, when plants were included in the UNSAT-H simulations, the end result was a small decrease in overall evapotranspiration. These results did not improve the agreement between the simulation, and the field measurements and were not included in this report.

The field study conducted by Anderson et al. (1987) suggested that overall evapotranspiration was increased by the presence of plants. Therefore, the exclusion of plants in the simulation may be responsible for some of the discrepancies between the observed and simulated moisture contents. Simulated moisture contents in the topmost layer were higher than those observed in the field at the end of the growing period (i.e. late summer and fall). Observed moisture contents were near 0.10, which is the lower limit of water extraction by crested wheatgrass (Anderson et al., 1987), while simulated moisture contents were 0.15 to 0.20. In separate simulations not presented, the upper soil hydraulic parameters were changed to those of a sandy-type soil. This resulted in a better match between moisture contents during the dry summer periods, but did not match the observed spring infiltration response, and the best overall agreement was obtained using the silt-type soil.

The divergence from observed phenomenon seen in the field and that seen in the model may be due in part to the method that UNSAT-H uses to calculate transpiration. If the plant option is selected, total potential evapotranspiration is partitioned between potential transpiration and potential evaporation. The amount of transpiration that may occur is then constrained by the current growth stage of the plants. Conversely, if the plant option is not selected, the entire potential evapotranspiration becomes potential evaporation. In conclusion, the results of this particular calibration exercise suggest that the UNSAT-H code appears to simulate evapotranspiration better as evaporation than as two distinct processes (i.e., evaporation and transpiration for this particular application).

A more likely reason why the plant option did not improve the agreement between field and simulation results may be due to inadequate parameterization of crested wheatgrass transpiration. To simulate transpiration, the UNSAT-H code requires input of several parameters related to plant roots, and adequate information defining these parameters were not available for crested wheatgrass.

5.3 NAT W06 Simulation Results

The behavior of NAT W06 was vastly different from NAT W02 in that water infiltrated quickly through the entire profile. The silty sand layer at the surface encouraged infiltration while it inhibited evaporation. The relatively high conductivity of sand allows surface water to quickly move through the sand layer during an infiltration event. As the potential evaporation rates increased after the event, the lower tensions in the larger sand pores restrict the movement of water back to the surface. A silt or clay soil would have more readily allowed water to be brought back to the surface.

5.3.1 Comparison of Field and Simulation Results

Agreements between the simulated and field moisture contents through the simulation period were very good as shown in Figures 7 and 8. Details of the 1993 snowmelt agreed closely. By March 29, 1993, both the field measurements and the simulation indicated that the bottom of NAT W06 approached saturation. However, the simulation results show that the soil profile began to dry sooner than the field data. This discrepancy may be in part due to the UNSAT-H code not being able to simulate saturated conditions. Complete agreement with the field data should have included the occurrence of perched water at the basalt interface during the spring snow melt.

Graphical comparison of simulated soil tensions and field measurements are presented in Figures 9 and 10. The illustrated dates vary slightly from those illustrated in Figures 7 and 8 due to data availability. The asterisks represent field measurements at 3, 6, and 9 ft below the soil surface, and the solid line represents simulated tensions. Overall agreement between field and simulated tensions appear to be fair. The general trends of greater tensions near the surface are seen in both the field and simulated data.

The average RMS error for the days illustrated in the graphical comparison of moisture content (Figures 7 and 8) was 0.03. The largest RMS error was 0.09 for June 9, 1993, and the smallest error was 0.01 for November 10, 1987. The average correlation coefficient was 0.78. The lowest was 0.2 for May 8, 1990, and the highest was 0.99 for November 10, 1987.

5.3.2 Localized Recharge

Most recharge occurring near NAT W06 appears to be a result of spring snowmelt. Figure 11 illustrates that three significant recharge events took place during the simulation period. These events took place in 1986, 1989, and 1993. A higher than average winter precipitation was experienced during these years with 1993 being the most dramatic year. During the spring-summer of 1993 (March 26 to July 25), the simulation predicted 36 cm of water passed through the basalt interface, which compares favorably to 28 cm of net downward drainage estimated by McElroy (1993). The time-dependent drainage shown in the lower half of Figure 11 shows a response every year and not just years with high infiltration, as did NAT W02. Total recharge over the simulation period was 87 cm, which was primarily due to the assumption of a snow berm proportional to winter precipitation amounts adjacent to NAT W06. Table 8 presents yearly drainage from NAT W06.

Figure 7. NAT W06 field and simulation moisture contents for 1987 to 1989. (Simulated moisture contents are dashed lines and field moisture contents are solid lines.)

Figure 8. NAT W06 field and simulation moisture contents for 1990 to 1993. (Simulated moisture contents are dashed lines and field moisture contents are solid lines.)

Figure 9. NAT W06 field and simulation tensions for 1987 to 1989. (Simulated tensions are solid lines and the asterisks are field tensions.)

Figure 10. NAT W06 field and simulation tensions for 1990 to 1993. (Simulated tensions are solid lines and the asterisks are field tensions.)

Figure 11. Drainage from NAT W06 (two different vertical scales).

Table 8. Yearly simulation drainage from NAT W06.

Year	Drainage (cm)
1986	21
1987	2
1988	1
1989	20
1990	5
1991	1
1992	2
1993	36 ^a

a. Drainage is for January 1 through August 31.

5.3.3 Comparison with Laboratory Scale Properties

In 1989, selected sediment samples from the SDA were analyzed for hydrological and physical properties (McElroy and Hubbell, 1990). The analysis included two samples taken from borehole W06, located approximately 4 ft east of NAT W06. The samples were collected during the summer of 1986 and archived until 1989 when they were submitted for analysis. Measurements were performed for the following:

- Hydraulic conductivity
- Moisture-retention characteristics
- Moisture content
- Bulk density
- Porosity
- Particle density
- Particle-size distribution
- Unsaturated hydraulic conductivity
- Air permeability.

The majority of the testing was performed by a private laboratory. However, one of the W06 samples was analyzed by the INEL laboratory for saturated hydraulic conductivity.

The W06 samples were taken from two depth ranges. The first was taken from a core section located 52 to 82 cm below the surface. The second was taken from a core section located 335 to 360 cm below the surface. Because the samples were taken from a known general depth, the opportunity presented itself to compare the laboratory hydraulic properties with the calibrated properties from the NAT simulation. Laboratory properties are compared to the calibrated properties in Tables 9 and 10. Because the archived core sections extended through more than one layer of the simulation profile, properties are presented for depth ranges rather than specific depths.

Results of the comparison show that the calibrated hydraulic parameters agree well with the laboratory parameters. This was expected because the laboratory parameters were used as the initial estimates in the model. The calibrated parameters were within the 95% confidence limits of the laboratory parameters with the exception of α and K_s . To match the field tension measurements, it was necessary to significantly increase α . Increasing α had the effect of decreasing the air entry potential and lowering the soil moisture curve. It was necessary to increase the K_s values to match the travel times of the wetting front created by the spring snowmelt. The calibrated K_s was an order of magnitude higher than the values determined by the private lab. However, the calibrated K_s was also an order of magnitude lower than the value determined by the INEL lab.

One reason for the discrepancies between the lab estimates and the calibration estimates of hydraulic properties is that significant spatial variations may be occurring over small distances in the SDA sediments. Laboratory analysis of different samples taken from the same relatively short core sections resulted in significantly different parameter estimates for some cases. Furthermore, the depth range from which the two core sections were extracted extended through several of the simulation layers. For these reasons, the limited data from the laboratory analysis should be viewed with discretion because it may represent only a small portion of the surficial sediments.

Table 9. Laboratory scale hydraulic properties.

Depth range (cm)	K_s (cm/hr)	INEL Lab. K_s	α (1/cm)	Lower 95%	Upper 95%	n	Lower	Upper	θ_s	θ_r	Variation (approx.)
52-82	0.61	36.0	0.0012	0.0044	0.0195	1.5891	1.3293	1.8489	0.511	0.126	12
335-360	0.21	—	0.0071	0.0041	0.0100	1.5756	1.4017	1.7498	0.496	0.142	14

Table 10. Simulation hydraulic properties.

Depth range (cm)	K_s (cm/hr)	α (1/cm)	n	θ_s	θ_r	Variation (approx.)
43-57	8.20	0.0139	1.725	0.527	0.089	3
57-70	6.60	0.0131	1.687	0.514	0.115	4
70-100	5.00	0.0123	1.650	0.500	0.140	5
230-320	5.00	0.0123	1.650	0.500	0.140	11

5.3.4 Comparison with Field Scale Properties

The frequent monitoring of NAT W06 during the 1993 spring snowmelt infiltration event provided sufficient data to perform field scale estimation of hydraulic properties. McElroy^b used the soil moisture and matric potential data during drainage periods to estimate hydraulic parameters for a characteristic curve and an unsaturated conductivity curve at different depths. Estimates for K_s , θ_s , θ_r , and n were obtained using the UNGRA computer code (van Genuchten, 1988) at 1/2-ft intervals, while estimates for K_s , θ_s , θ_r , n , and α at 3-ft and 6-ft depths were determined using the RETC computer code (van Genuchten, 1985). Results of the field scale investigation in Table 11 can be compared to the simulation results in Table 12.

Results from the comparison indicate that the calibrated K_s values in the low conductivity zones tend to be an order of magnitude higher while the high conductivity zones values are comparable. Field estimates of porosity are lower than the calibration estimates. Values of 0.40 vs. 0.50 were obtained for the calibration and field estimates, respectively. Estimates for residual moisture contents in most of the relatively high conductivity zones were zero, suggesting that the very low pressure section of the soil moisture curve determined from the field parameters may not be valid. Field estimates for α at the 3- and 6-ft depths were lower and higher, respectively, than the calibration estimates. Finally, field estimates for the n parameter tended to be lower than the calibration estimates, especially in the higher conductivity regions. A significant amount of variation was seen in the field estimates, which can be seen in the large spread between the 95% confidence intervals. As can be seen in Table 11, many of the intervals ranged in the negative range, which physically should not occur.

To evaluate the usefulness of the field scale estimations of hydraulic parameters, a simulation was run using these parameters. Because field estimates of hydraulic parameters were not available for the top 1 ft of soil, the parameters were estimated from the other layers. Additionally, because α was evaluated only at the 3 and 6 ft depths, intermediate values were estimated and were improved through a very limited series of calibration runs.

Figures 12 and 13 illustrate that the soil moistures predicted with the field measurements show reasonable agreement with the actual field measurements. The hydraulic conductivities of the higher moisture content zones were nearly two orders of magnitude lower than those estimated by the calibration runs. As can be seen in Figures 12 and 13, the wetting front resulting from the 1993 spring snowmelt does not appear to move as fast as the field measurements indicate. Also, during the same heavy infiltration periods, the simulation results indicated that a significant proportion of the applied water was lost to runoff due to the very low hydraulic conductivity near the surface.

The simulation results showed that simply relying on the field data for hydraulic properties may not be appropriate. Some interpretation of the field estimates is necessary when the data are input into a numerical model. Nevertheless, field estimates can provide a good initial estimate for the hydraulic properties.

b. Unpublished work, 1994.

Table 11. Field scale hydraulic properties.

Depth (cm)	K _s (cm/hr)	Lower 95%	Upper 95%	θ _i	Lower	Upper	θ _r	Lower	Upper	α (1/cm)	Lower	Upper	n	Lower	Upper
30.5	0.81	-4.42	6.04	.441	.316	.566	.000			0.0300 ^a			1.235	1.040	1.420
45.7	0.02	-0.01	0.05	.386	.376	.397	.000			0.0055 ^a			1.535	.9217	2.148
61.0	0.02	-0.01	0.05	.386	.376	.397	.000			0.0055 ^a			1.535	.9217	2.148
76.2	1.20	-105	107.	.394	.382	.406	.171	-9.10	9.44	0.0500 ^a			1.134	-5.800	8.067
91.4	0.15	-0.20	0.51	.382	.376	.388	.000			0.0055	-0.0009	0.1200	1.158	1.037	1.285
107.	2.66	-27.4	32.7	.391	.304	.477	.000			0.0220 ^a			1.124	.9122	1.335
122.	3.26	-37.7	44.2	.376	.262	.491	.000			0.0385 ^a			1.141	.8909	1.391
137.	0.06	-0.29	0.41	.364	.302	.425	.221	-.234	.675	0.0551 ^a			2.378	-7.478	12.35
167.	2.42	-13.7	18.5	.403	.309	.496	.000			0.0551 ^a			1.220	.9971	1.443
183.	45.5	-208	299.	.524	.335	.711	.000			0.1046	-0.1462	0.3554	1.233	1.168	1.298
213.	0.04	0.01	0.07	.347	.259	.319	.283	.259	.319	0.0055 ^a			18.73	-132.2	169.6
229.	3.92	-74.7	82.6	.368	.226	.511	.000			0.0055 ^a			1.131	.7026	1.559
244.	11.9	-95.9	119.	.402	.296	.508	.000			0.0055 ^a			1.141	1.002	1.281

a. Estimated through limited calibration.

Table 12. Simulation hydraulic properties.

Depth (cm)	K_s (cm/hr)	θ_s	θ_r	α (1/cm)	n	Soil layer description
30-43	9.8	.540	.064	.0147	1.763	Transition
43-57	8.2	.527	.089	.0139	1.725	Transition
57-70	6.6	.514	.115	.0131	1.688	Transition
70-100	5.0	.500	.140	.0123	1.650	Silt
100-110	7.5	.503	.133	.0169	1.630	Transition
110-120	10.0	.507	.127	.0216	1.610	Transition
120-190	12.5	.510	.120	.0262	1.590	Sandy Silt
190-210	10.0	.507	.127	.0216	1.610	Transition
210-230	7.5	.503	.133	.0169	1.630	Transition
230-320	5.0	.500	.140	.0123	1.650	Silt

Figure 12. NAT W06 field and simulation moisture contents using field estimated parameters for 1987 to 1989. (Simulated are dashed lines and field are solid lines.)

Figure 13. NAT W06 field and simulation moisture contents using field estimated parameters for 1990 and 1989. (Simulated are dashed lines and field are solid lines.)

5.3.5 Role of Basalt Interface at NAT W06

The simulation results provided an opportunity to quantitatively explain some of the infiltration and redistribution phenomena occurring at the SDA. One such phenomenon is the role played by the basalt interface. The basalt interface appears to behave similar to a capillary barrier, which inhibits water movement out of the overlying silts until they become nearly saturated. This behavior is primarily due to the very low relative hydraulic conductivity of basalt at the baseline tensions (the relative steady matric potential prior to water movement from snowmelt or precipitation). The basalts also retain much less water than the silts at the same tension.

This behavior can also be seen in the soil moisture curves and relative hydraulic conductivity curves. Baseline tensions at the basalt interface are near 170 cm. Figure 14 illustrates the soil moisture curves and the relative hydraulic conductivity curves at the silt and basalt from simulation W06. Moisture contents at 170 cm tension are 0.10 for the basalt and 0.35 for the silts while the relative hydraulic conductivity is 0.1 cm/hr for the silts and near zero for the basalt.

Figure 14. Comparison of basalt and sand soil moisture curves.

The presence of perched water immediately over the basalt interface can also be explained in the constitutive relation curves. The relative hydraulic conductivity of the basalt is near zero until tensions drop to 50 cm while the corresponding silt moisture content is approaching saturation. The end result is that a large influx of water, such as that from the spring snowmelt, causes the silts to quickly saturate and then backs up until sufficient time has passed to allow drainage into the basalts.

This behavior can be clearly seen during the 1993 spring snowmelt at NAT W06. Drainage from the sediments remain extremely low until soil moisture approaches saturation at which time a large pulse of water enters the basalt. Figure 15 shows sediment moisture contents in the silts immediately above the basalt and daily drainage into the basalt layer.

From a modeling standpoint, the significance of the basalt interface is that a unit gradient boundary condition (free drainage due to gravity) is not appropriate at the bottom of the silts, and infiltration modeling at the SDA should include the underlying basalts.

Finally, it should be noted that this simulation study consisted of a 1-dimensional model that assumed a sharp interface between the silt and basalt. The effects of fracturing or 2-dimensional effects due to the uneven nature of the basalt surface were not considered. Because most of the near-surface fractures are likely to be infilled with silt, the actual behavior of the basalt interface may be similar but is probably spread out over a small distance.

Figure 15. Sediment moisture contents and daily drainage during 1993.

6. CONCLUSIONS AND FUTURE DIRECTIONS

A calibrated simulation study of moisture infiltration at two locations within the INEL SDA was conducted for the purpose of obtaining insight into the amount and timing of infiltration occurring at the SDA. The main focus of this simulation was on obtaining a good match between field and simulated data. In the process of performing the calibration exercise and obtaining this match, insight was gained as to the nature of infiltration at the SDA, which allowed the following conclusions and recommendations to be drawn.

6.1 Conclusions

The infiltration occurring at the SDA appears to be highly localized as the amounts and timing can vary dramatically at different locations. The net infiltration at the two locations was vastly different, with the W02 simulation predicting only 2.4 cm of net infiltration occurring during the 1986 through 1993 simulation period. During the same period, nearly 87.0 cm of water moved down at the W06 location.

The underlying fractured basalt appears to behave similar to a capillary barrier. This behavior inhibits moisture movement into the underlying basalts until moisture contents in the silts approach saturation. Furthermore, a unit gradient assumption in the silts is not appropriate because the basalts have a much lower relative hydraulic conductivity than the silts at the same tension. As a result, a large proportion of recharge occurring at the SDA is due to spring snowmelt, and only a relatively small amount of recharge occurs otherwise.

Snowpack water equivalents can be greater than cumulative winter precipitation due to the accumulation of drifting snow within the SDA. The field data collected by McElroy (1993) indicate that snowpack water equivalent was up to twice the cumulative winter precipitation at CFA. The simulation results reinforced this conclusion because adjusting the timing and increasing the amount of spring infiltration from snowmelt was necessary to obtain good agreement between field and simulated moisture contents.

6.2 Recommendations

Current snow management practices at the SDA should be reviewed to prevent creation of snow berms over or near waste pits. The NAT W06 simulation suggested that a large amount of water quickly saturated the surficial sediments and moved into the underlying basalt during the 1993 spring thaw. The large snow berm that accumulated from plowing the maintenance was primarily responsible for this infiltration and recharge event.

6.3 Future Modeling Needs

Currently, 14 additional NATs are being installed in the SDA with five of these being placed in disturbed areas such as the early waste retrieval pits and cover material over the low-level waste pits. Future modeling efforts at the SDA should include calibrating models to these additional locations. This additional calibration effort would provide a representative numerical data base of hydraulic parameters for the SDA surficial sediments. This data base could then be used to predict future

overall infiltration rates for the SDA. Predictions using the models in this report and the additional models would be the first "hard" estimates (estimates from models based on observed field conditions) of infiltration amounts and timing available for use in RWMC performance assessment studies.

The travel time for infiltrated water to move through the vadose zone to the aquifer is critical to estimate whether nonsorbing radionuclides pose a threat to aquifer contamination. If travel times are much larger than contaminant half-lives, the threat of contamination is minimal. However, if travel times are shorter or on the order of contaminant half-lives, some remedial action may be necessary, such as removing or preventing snow accumulation within the SDA. As the amount of water entering the vadose zone increases, the travel time through the vadose zone decreases because of higher relative hydraulic conductivities of the wetter soil. The snow berm near NAT W06 in 1993 probably represents an extreme case for an infiltration event resulting from snowmelt.

The amount and timing of water movement into the basalts predicted by the NAT W06 simulation could be used as an upper boundary condition in a vadose zone model that extends to the water table. This model could then be used to predict the extent of water travel times being accelerated by the increased infiltration at NAT W06. Furthermore, data on perched water levels at depths down to 200 ft have been and continue to be collected (Hubbell, 1990; 1993). The data collected indicate that the perched water has a transient behavior that may be correlated to the transient infiltration discussed in this report. The perched water and infiltration data could be used to calibrate the deep vadose zone model with the ultimate goal of also predicting the amounts and timing of water movement to the aquifer.

7. REFERENCES

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Appendix A

Meteorologic Data Base

Appendix A

Meteorologic Data Base

This appendix contains 1991 to 1993 base data from the meteorologic data used in the UNSAT-H calibration simulations. The precipitation received during sub-freezing periods is shifted later to nonfreezing periods. Water application amounts and dates for the increased snowmelt are presented in Table A-1, and the base meteorologic data are presented in Table A-2.

Table A-1. Increased water application amounts and dates.

Year	Daily additional water (in.)		Application dates	
	W02	W06	W02	W06
1985	0.26	1.37	91-105	91-100
1986	0.18	0.97	47-61	47-56
1987	0.08	0.45	61-75	61-70
1988	0.07	0.39	57-71	57-66
1989	0.27	1.45	76-90	76-85
1990	0.13	0.70	61-75	61-70
1991	0.03	0.17	45-59	45-54
1992	0.07	0.40	41-55	41-50
1993	0.33	1.77	84-98	84-93

Table A-2. Base meteorologic data for 1991 to 1993.

Year 1991															
Day	Temp.	Dew	Solar	Wind	Cloud	Precip		Day	Temp.	Dew	Solar	Wind	Cloud	Precip	
	Max. Min.	Pt	Rad	Speed	Cover				Max. Min.	Pt	Rad	Speed	Cover		
1	18.0-14.1	-6.0	170.	4.3	.0	.00		8	28.0 16.0	20.1	164.	3.8	.0	.00	
2	19.9-16.1	-5.3	177.	4.3	.0	.00		9	28.0 .0	15.4	196.	5.1	.0	.00	
3	21.9-14.1	-2.7	222.	4.5	.0	.00		10	25.0 3.9	15.1	138.	2.2	.0	.00	
4	25.0-17.0	-2.6	103.	2.7	.0	.00		11	27.0 17.1	20.8	143.	2.7	.0	.00	
5	17.1-18.0	-5.8	148.	3.4	.0	.00		12	39.0 21.9	27.0	47.	3.4	.0	.00	
6	21.0-11.9	5.4	143.	3.4	.0	.00		13	39.0 25.0	28.4	70.	12.5	.0	.00	
7	27.0 8.1	17.2	183.	2.7	.0	.00		14	36.0 12.9	23.4	196.	5.4	.0	.00	
								15	37.0 21.0	23.5	189.	6.0	.0	.00	
								16	30.0 7.0	18.5	141.	7.2	.0	.00	

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
17	30.9 19.9	22.1	98.	2.2	.0	.00
18	30.0 25.0	25.3	120.	3.1	.0	.00
19	32.0 -6.0	14.0	151.	10.7	.0	.00
20	23.0-14.1	-9	224.	4.7	.0	.00
21	28.0-13.0	-2	211.	5.6	.0	.00
22	21.0 -6.0	5.7	159.	2.9	.0	.00
23	26.1-13.0	3.4	193.	4.3	.0	.00
24	32.0 -2.9	7.5	144.	4.3	.0	.00
25	21.0 -9.0	-2	234.	3.8	.0	.00
26	26.1-14.1	-6	232.	4.3	.0	.00
27	30.9-11.9	3.4	276.	3.4	.0	.00
28	21.0-13.0	.0	279.	7.2	.0	.00
29	8.1-18.9	-10.7	256.	5.4	.0	.00
30	14.0-20.0	-7.6	162.	4.3	.0	.00
31	32.0 -8.0	1.6	128.	3.4	.0	.00
32	39.0 -6.0	5.0	197.	4.0	.0	.00
33	41.0 -2.9	9.9	226.	4.7	.0	.00
34	41.0 19.0	23.5	214.	3.6	.0	.00
35	44.1 12.9	23.0	172.	2.9	.0	.00
36	39.9 16.0	24.6	213.	2.9	.0	.00
37	45.0 10.0	19.8	273.	4.9	.0	.00
38	46.0 10.0	20.5	315.	4.3	.0	.00
39	48.0 10.0	20.8	238.	2.7	.0	.00
40	44.1 15.1	22.3	171.	4.5	.0	.00
41	46.9 10.9	20.1	256.	4.5	.0	.00
42	50.0 9.0	19.4	332.	3.6	.0	.00
43	44.1 16.0	23.9	310.	8.5	.0	.00
44	48.0 26.1	29.3	256.	7.4	.0	.28
45	45.0 28.0	30.2	327.	3.8	.0	.00
46	48.0 32.0	34.0	303.	4.0	.0	.00
47	44.1 34.0	36.1	203.	6.7	.0	.00
48	41.0 23.0	19.9	246.	7.4	.0	.00
49	39.0 12.9	19.2	271.	7.4	.0	.00
50	43.0 19.0	24.6	312.	4.5	.0	.00
51	55.9 18.0	26.4	188.	9.6	.0	.00
52	51.1 25.0	27.9	376.	6.9	.0	.00
53	57.9 24.1	24.8	198.	4.5	.0	.00
54	48.9 19.9	20.1	255.	5.1	.0	.00
55	45.0 18.0	14.2	143.	6.9	.0	.00
56	48.0 12.9	14.4	202.	3.1	.0	.00
57	52.0 17.1	12.4	257.	2.7	.0	.00
58	48.0 9.0	13.6	322.	4.5	.0	.00
59	44.1 8.1	21.9	249.	6.7	.0	.00
60	46.9 32.0	34.0	158.	9.4	.0	.01
61	48.9 34.0	31.3	183.	18.3	.0	.03
62	45.0 30.0	34.0	272.	13.2	.0	.15
63	46.0 35.1	36.9	96.	12.1	.0	.89
64	39.0 19.9	14.7	435.	16.8	.0	.00
65	33.1 15.1	13.6	205.	6.5	.0	.00
66	37.0 15.1	16.0	272.	11.9	.0	.00
67	43.0 16.0	15.4	451.	7.8	.0	.00
68	48.9 12.9	18.1	405.	5.6	.0	.00
69	52.0 19.9	23.5	399.	9.2	.0	.00
70	44.1 27.0	27.1	199.	7.6	.0	.05
71	37.9 21.9	21.7	282.	10.1	.0	.00
72	44.1 28.0	26.6	157.	4.7	.0	.00
73	45.0 25.0	27.7	351.	4.5	.0	.01
74	44.1 18.0	25.2	401.	4.3	.0	.00
75	46.0 21.0	21.0	338.	8.7	.0	.00

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
76	52.0 21.9	22.6	107.	6.7	.0	.00
77	55.0 21.9	22.5	283.	4.7	.0	.00
78	55.9 21.9	21.7	485.	8.5	.0	.00
79	46.9 19.9	23.2	307.	13.6	.0	.00
80	51.1 12.9	17.8	202.	4.7	.0	.00
81	50.0 19.9	18.5	479.	10.5	.0	.00
82	44.1 26.1	29.5	529.	6.0	.0	.03
83	46.9 28.9	23.7	534.	11.6	.0	.00
84	48.0 28.9	27.0	245.	9.4	.0	.01
85	44.1 21.9	23.4	438.	8.1	.0	.00
86	46.9 21.0	19.0	271.	10.1	.0	.00
87	55.0 19.0	19.2	436.	12.5	.0	.00
88	50.0 19.0	11.5	542.	8.1	.0	.00
89	57.0 14.0	19.8	471.	5.1	.0	.00
90	63.0 17.1	21.2	417.	4.5	.0	.00
91	64.9 23.0	19.4	337.	5.1	.0	.00
92	63.0 26.1	26.2	372.	11.9	.0	.00
93	60.1 24.1	20.8	436.	10.7	.0	.00
94	68.0 34.0	24.8	520.	9.2	.0	.00
95	69.1 45.0	23.4	550.	15.2	.0	.00
96	59.0 37.0	30.9	300.	18.3	.0	.00
97	50.0 23.0	18.1	385.	13.9	.0	.00
98	48.0 10.9	10.6	249.	6.7	.0	.00
99	53.1 28.0	25.0	394.	13.4	.0	.00
100	43.0 25.0	14.0	482.	9.6	.0	.00
101	46.0 26.1	14.0	584.	16.8	.0	.00
102	46.9 35.1	16.2	466.	20.8	.0	.00
103	48.0 25.0	15.3	568.	7.4	.0	.00
104	59.0 18.0	20.1	379.	9.6	.0	.00
105	57.0 39.0	32.4	178.	6.5	.0	.04
106	50.0 30.0	32.7	346.	5.8	.0	.08
107	55.0 25.0	28.2	479.	4.9	.0	.07
108	48.9 33.1	34.5	155.	5.4	.0	.19
109	59.0 30.0	30.4	512.	3.4	.0	.00
110	62.1 32.0	31.1	620.	6.7	.0	.00
111	64.0 39.9	35.4	516.	6.3	.0	.07
112	64.9 32.0	30.6	539.	4.5	.0	.00
113	66.9 34.0	33.8	483.	6.0	.0	.00
114	59.0 37.0	35.2	652.	12.5	.0	.00
115	53.1 30.9	28.6	483.	14.3	.0	.00
116	48.0 25.0	19.9	683.	6.3	.0	.00
117	48.0 21.0	15.3	658.	7.8	.0	.00
118	59.0 21.0	16.7	649.	6.3	.0	.00
119	46.9 32.0	29.8	698.	6.5	.0	.06
120	54.0 26.1	26.6	451.	4.0	.0	.00
121	62.1 28.9	25.3	141.	13.9	.0	.03
122	46.0 37.0	34.0	229.	16.3	.0	.03
123	45.0 34.0	32.5	279.	5.8	.0	.01
124	53.1 28.0	30.4	594.	4.0	.0	.00
125	64.9 24.1	29.7	464.	7.4	.0	.00
126	57.0 45.0	43.0	573.	6.9	.0	.22
127	64.0 44.1	38.8	725.	7.8	.0	.00
128	60.1 44.1	42.3	439.	8.9	.0	.47
129	48.9 39.9	37.6	708.	5.8	.0	.44
130	45.0 39.9	37.0	666.	5.8	.0	.32
131	55.9 39.0	38.7	350.	2.9	.0	.17
132	57.0 34.0	37.4	733.	4.3	.0	.00
133	64.9 39.0	36.3	743.	5.8	.0	.00
134	64.0 41.0	40.8	436.	7.8	.0	.02

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
135	68.0 42.1	35.8	726.	5.8	.0	.00
136	72.0 36.0	35.8	637.	4.5	.0	.00
137	71.1 45.0	42.1	416.	9.4	.0	.02
138	64.0 35.1	38.5	328.	11.6	.0	.01
139	70.0 28.9	30.2	758.	6.5	.0	.00
140	69.1 36.0	32.7	579.	6.3	.0	.00
141	78.1 35.1	32.2	666.	5.1	.0	.00
142	78.1 37.0	36.9	752.	6.5	.0	.21
143	75.0 46.0	40.3	767.	6.7	.0	.00
144	77.0 37.0	34.5	657.	8.5	.0	.00
145	72.0 46.9	35.8	721.	16.1	.0	.00
146	63.0 43.0	26.2	538.	9.2	.0	.00
147	63.0 28.9	25.9	641.	6.0	.0	.00
148	66.9 25.0	25.5	553.	4.9	.0	.00
149	64.9 34.0	30.2	633.	10.1	.0	.00
150	63.0 42.1	38.5	779.	9.8	.0	.08
151	71.1 41.0	37.0	611.	15.2	.0	.00
152	78.1 39.0	39.0	726.	5.4	.0	.00
153	81.0 39.9	43.7	590.	6.5	.0	.05
154	80.1 43.0	48.6	657.	6.9	.0	.00
155	73.9 46.0	50.2	366.	6.9	.0	.61
156	51.1 45.0	43.0	266.	10.7	.0	.41
157	73.9 43.0	46.6	590.	8.9	.0	.00
158	69.1 44.1	41.0	425.	15.2	.0	.00
159	73.9 37.0	42.8	681.	6.3	.0	.00
160	79.0 42.1	45.1	595.	3.6	.0	.00
161	84.9 43.0	43.5	475.	4.9	.0	.00
162	86.0 43.0	44.6	485.	13.0	.0	.00
163	80.1 51.1	42.1	645.	14.1	.0	.00
164	73.0 51.1	40.3	793.	15.9	.0	.00
165	64.0 42.1	37.4	687.	17.0	.0	.00
166	75.9 32.0	37.9	771.	6.9	.0	.00
167	81.0 37.0	35.2	628.	14.1	.0	.00
168	73.0 48.0	26.6	680.	15.4	.0	.00
169	84.0 37.0	30.9	598.	6.3	.0	.00
170	84.9 60.1	40.1	612.	11.6	.0	.00
171	75.9 48.0	37.2	538.	11.4	.0	.00
172	80.1 41.0	36.7	794.	4.7	.0	.00
173	81.0 46.9	34.5	794.	9.6	.0	.00
174	86.0 48.9	41.2	692.	9.6	.0	.00
175	80.1 50.0	40.8	793.	7.4	.0	.00
176	73.9 45.0	40.8	691.	7.2	.0	.01
177	70.0 37.0	37.2	773.	11.4	.0	.00
178	72.0 35.1	41.5	713.	8.3	.0	.06
179	73.9 51.1	43.2	791.	5.1	.0	.01
180	75.0 46.9	42.4	619.	13.0	.0	.00
181	73.9 46.0	43.5	790.	12.5	.0	.00
182	82.9 36.0	37.4	789.	5.4	.0	.00
183	89.1 44.1	39.7	764.	5.6	.0	.00
184	93.9 45.0	37.4	611.	6.0	.0	.00
185	97.0 46.0	36.1	670.	10.5	.0	.00
186	95.0 53.1	34.9	540.	15.0	.0	.00
187	91.9 55.9	34.0	783.	12.5	.0	.00
188	91.0 48.9	31.3	686.	9.2	.0	.00
189	93.9 46.9	32.7	570.	8.5	.0	.00
190	90.0 53.1	45.1	638.	9.6	.0	.00
191	86.0 54.0	39.2	709.	10.1	.0	.00
192	88.0 43.0	32.9	776.	5.8	.0	.00
193	93.9 45.0	38.1	775.	5.6	.0	.00

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
194	95.0 51.1	41.4	753.	7.8	.0	.00
195	93.9 62.1	43.0	760.	10.1	.0	.00
196	95.0 52.0	39.9	714.	7.8	.0	.00
197	93.9 51.1	36.3	767.	9.4	.0	.00
198	88.0 46.9	37.6	709.	12.3	.0	.00
199	87.1 52.0	37.4	458.	13.9	.0	.00
200	87.1 48.9	40.6	589.	10.1	.0	.00
201	87.1 51.1	48.4	653.	7.2	.0	.00
202	88.0 46.0	47.3	512.	6.3	.0	.00
203	91.0 46.9	46.6	701.	6.5	.0	.00
204	89.1 55.0	50.4	441.	8.5	.0	.06
205	87.1 54.0	52.9	482.	8.1	.0	.04
206	78.1 52.0	51.8	723.	8.1	.0	.40
207	84.9 46.0	46.9	670.	5.8	.0	.00
208	90.0 46.9	44.1	493.	3.8	.0	.00
209	95.0 46.9	44.1	560.	3.8	.0	.00
210	96.1 50.0	41.4	628.	1.8	.0	.03
211	95.0 48.0	44.4	605.	5.6	.0	.00
212	91.9 53.1	45.1	730.	7.8	.0	.00
213	88.0 57.0	37.2	727.	13.0	.0	.00
214	89.1 42.1	31.6	657.	5.8	.0	.00
215	90.0 48.9	34.0	665.	6.5	.0	.00
216	84.9 59.0	40.8	626.	7.6	.0	.00
217	87.1 57.0	47.8	561.	7.4	.0	.00
218	90.0 48.9	44.1	228.	7.4	.0	.03
219	91.9 46.9	39.6	537.	7.4	.0	.00
220	95.0 45.0	32.9	549.	5.1	.0	.00
221	95.0 45.0	31.8	459.	5.4	.0	.00
222	91.0 50.0	39.4	434.	9.6	.0	.00
223	91.0 55.0	34.7	433.	8.7	.0	.00
224	90.0 54.0	28.6	465.	10.3	.0	.00
225	91.9 46.0	31.6	448.	10.3	.0	.00
226	90.0 64.0	37.6	453.	12.5	.0	.00
227	84.0 55.9	47.8	651.	6.7	.0	.00
228	82.0 48.9	52.5	454.	6.5	.0	.11
229	88.0 45.0	46.2	670.	5.1	.0	.00
230	93.0 50.0	43.9	666.	6.9	.0	.00
231	88.0 57.9	50.0	500.	7.8	.0	.03
232	91.0 44.1	48.4	471.	5.4	.0	.00
233	95.0 46.9	43.5	611.	5.6	.0	.00
234	95.0 45.0	41.0	537.	5.8	.0	.00
235	96.1 55.9	37.9	601.	10.3	.0	.02
236	93.9 54.0	32.4	543.	9.6	.0	.00
237	91.9 55.9	45.5	190.	7.4	.0	.01
238	84.9 54.0	54.1	632.	8.7	.0	.00
239	90.0 59.0	53.2	508.	9.2	.0	.58
240	75.9 51.1	46.4	456.	9.4	.0	.00
241	87.1 42.1	39.6	618.	5.1	.0	.00
242	93.9 44.1	37.8	614.	5.8	.0	.00
243	93.0 46.9	40.3	573.	8.3	.0	.00
244	90.0 54.0	44.6	502.	9.2	.0	.00
245	87.1 50.0	40.1	577.	11.0	.0	.00
246	84.9 45.0	37.2	545.	4.5	.0	.00
247	88.0 43.0	36.1	587.	4.7	.0	.00
248	89.1 42.1	35.6	586.	4.5	.0	.00
249	91.9 42.1	37.9	544.	6.3	.0	.00
250	84.0 53.1	54.1	398.	5.8	.0	.22
251	73.0 54.0	50.4	194.	9.4	.0	.02
252	69.1 46.9	48.7	273.	8.1	.0	.48

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
253	63.0 50.0	50.4	359.	8.3	.0	.16
254	62.1 45.0	45.7	297.	4.5	.0	.10
255	70.0 37.0	42.4	464.	3.4	.0	.00
256	73.9 37.9	43.2	521.	8.3	.0	.00
257	57.9 41.0	33.1	349.	10.7	.0	.00
258	66.0 30.0	30.4	536.	4.5	.0	.00
259	75.0 30.9	33.8	451.	5.4	.0	.00
260	72.0 37.9	36.0	244.	8.7	.0	.00
261	71.1 39.0	27.9	444.	7.4	.0	.00
262	82.0 35.1	30.0	455.	4.5	.0	.00
263	84.0 34.0	31.8	384.	7.4	.0	.00
264	70.0 45.0	23.5	495.	14.1	.0	.00
265	66.0 32.0	19.2	501.	6.0	.0	.00
266	73.0 30.9	22.6	446.	4.0	.0	.00
267	79.0 32.0	27.5	393.	4.7	.0	.00
268	84.0 32.0	29.8	485.	4.5	.0	.00
269	84.9 32.0	27.7	480.	3.8	.0	.00
270	86.0 34.0	29.8	475.	4.5	.0	.00
271	73.0 54.0	48.0	298.	7.8	.0	.10
272	72.0 46.0	47.3	465.	4.5	.0	.00
273	78.1 35.1	40.1	368.	6.3	.0	.00
274	82.0 36.0	35.6	199.	10.3	.0	.00
275	75.9 39.0	28.6	298.	9.2	.0	.00
276	70.0 35.1	18.7	239.	10.5	.0	.00
277	61.0 19.9	18.5	343.	4.5	.0	.00
278	69.1 19.0	13.8	324.	3.6	.0	.00
279	77.0 23.0	16.9	412.	4.7	.0	.00
280	75.9 32.0	22.3	418.	5.6	.0	.00
281	77.0 30.0	24.4	419.	5.1	.0	.00
282	79.0 27.0	23.7	366.	4.3	.0	.00
283	84.0 33.1	25.5	208.	4.5	.0	.00
284	82.9 32.0	26.8	163.	4.9	.0	.00
285	81.0 30.9	24.3	267.	9.8	.0	.00
286	71.1 39.0	22.8	325.	7.2	.0	.00
287	77.0 32.0	23.9	364.	5.6	.0	.00
288	79.0 28.9	27.1	377.	5.4	.0	.00
289	75.9 28.9	27.3	222.	13.4	.0	.00
290	64.9 39.0	28.4	241.	20.1	.0	.00
291	55.0 19.0	17.2	317.	4.7	.0	.00
292	57.0 26.1	16.9	235.	2.7	.0	.00
293	64.0 21.0	22.6	363.	4.5	.0	.00
294	66.9 25.0	33.3	357.	16.3	.0	.00
295	57.9 43.0	37.2	208.	14.3	.0	.03
296	45.0 25.0	30.9	277.	12.3	.0	.00
297	43.0 16.0	21.9	287.	8.9	.0	.00
298	39.9 30.9	32.9	152.	9.2	.0	.03
299	46.0 37.0	40.1	67.	13.2	.0	.22
300	39.9 12.9	32.2	66.	9.8	.0	.00
301	34.0 5.0	18.3	102.	4.0	.0	.00
302	30.0 16.0	16.7	141.	12.3	.0	.00
303	30.0 1.0	12.2	249.	7.2	.0	.00
304	28.9 21.0	21.2	185.	4.3	.0	.00
305	27.0 9.0	14.5	117.	11.4	.0	.00
306	28.0 -2.0	1.4	242.	5.4	.0	.00
307	23.0 -2.0	6.1	221.	4.0	.0	.00
308	28.0 10.0	13.5	153.	3.1	.0	.00
309	37.9 21.0	26.1	264.	3.8	.0	.00
310	36.0 23.0	29.7	294.	3.6	.0	.00
311	41.0 24.1	28.9	290.	4.3	.0	.03

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
312	48.9 25.0	32.2	287.	4.9	.0	.22
313	54.0 36.0	38.7	57.	5.1	.0	.03
314	46.9 28.9	34.3	280.	2.9	.0	.00
315	45.0 25.0	30.4	220.	2.5	.0	.00
316	55.0 21.0	31.3	274.	4.9	.0	.00
317	45.0 37.0	37.8	158.	8.5	.0	.18
318	42.1 30.9	22.8	268.	15.0	.0	.00
319	44.1 19.0	17.8	225.	9.8	.0	.00
320	43.0 12.0	19.0	256.	3.8	.0	.00
321	34.0 17.1	28.2	52.	4.0	.0	.00
322	37.9 21.9	27.5	93.	6.7	.0	.00
323	34.0 9.0	20.8	58.	3.6	.0	.00
324	39.9 21.0	29.7	204.	8.3	.0	.00
325	39.9 21.9	21.6	153.	9.8	.0	.00
326	35.1 10.0	12.4	246.	4.7	.0	.00
327	24.1 .0	10.9	112.	4.3	.0	.00
328	28.0 17.1	21.2	48.	3.4	.0	.00
329	30.0 21.9	25.7	86.	2.2	.0	.00
330	36.0 12.9	25.7	48.	4.3	.0	.00
331	37.0 23.0	29.5	47.	9.6	.0	.00
332	32.0 12.0	18.5	188.	8.1	.0	.00
333	30.9 12.9	14.9	69.	13.9	.0	.00
334	24.1 -7.1	1.8	108.	6.0	.0	.00
335	23.0 -8.0	3.6	160.	4.7	.0	.00
336	37.0 8.1	12.9	155.	3.8	.0	.00
337	28.9 3.0	14.7	108.	3.6	.0	.00
338	35.1 10.0	18.9	224.	3.1	.0	.00
339	36.0 7.0	16.7	208.	2.9	.0	.00
340	45.0 24.1	27.9	133.	9.2	.0	.15
341	46.9 28.9	30.9	123.	10.1	.0	.35
342	32.0 21.0	23.5	219.	8.1	.0	.00
343	30.9 17.1	23.0	218.	3.1	.0	.00
344	35.1 17.1	20.7	217.	4.0	.0	.00
345	21.9 15.1	19.4	204.	2.2	.0	.00
346	33.1 18.0	21.7	197.	8.9	.0	.00
347	32.0 5.0	13.1	168.	6.9	.0	.00
348	26.1 1.0	7.3	136.	3.8	.0	.00
349	28.0 -2.0	6.3	130.	4.9	.0	.00
350	32.0 1.0	7.7	190.	3.8	.0	.00
351	35.1 1.0	9.3	143.	4.7	.0	.00
352	30.0 7.0	18.1	142.	2.9	.0	.00
353	36.0 7.0	19.9	186.	5.1	.0	.00
354	19.0 .0	10.9	213.	2.9	.0	.00
355	24.1 1.0	9.3	213.	4.9	.0	.00
356	30.9 .0	1.2	164.	3.8	.0	.00
357	30.9 1.0	12.6	124.	4.7	.0	.00
358	35.1 3.0	11.5	185.	4.3	.0	.00
359	34.0 1.0	10.6	198.	3.6	.0	.00
360	34.0 1.0	10.6	215.	4.3	.0	.00
361	33.1 1.9	11.8	189.	4.7	.0	.00
362	36.0 1.9	11.8	216.	4.0	.0	.00
363	33.1 21.0	23.2	217.	4.0	.0	.00
364	35.1 12.9	20.3	207.	3.6	.0	.00
365	37.0 8.1	21.2	164.	2.9	.0	.00

Year 1992

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
1	26.1 12.0	21.2	170.	2.2	.0	.00
2	30.0 6.1	17.2	177.	2.5	.0	.00
3	32.0 -.9	9.3	222.	3.8	.0	.00
4	33.1 10.9	21.2	103.	4.7	.0	.00
5	32.0 18.0	24.3	148.	5.6	.0	.00
6	36.0 25.0	28.8	143.	4.7	.0	.00
7	32.0 19.9	26.6	183.	9.6	.0	.00
8	25.0 12.9	21.0	164.	6.5	.0	.00
9	25.0 7.0	14.2	196.	3.8	.0	.00
10	28.9 1.0	7.3	138.	4.7	.0	.00
11	33.1 -.9	9.0	143.	4.0	.0	.00
12	35.1 -2.0	6.3	153.	4.5	.0	.00
13	23.0 3.9	14.9	70.	2.2	.0	.00
14	28.0 5.0	18.3	196.	7.2	.0	.00
15	21.9 -5.1	5.4	189.	4.5	.0	.00
16	27.0 3.9	16.0	141.	3.4	.0	.00
17	35.1 1.0	12.0	98.	3.8	.0	.00
18	28.0 -.9	6.1	120.	3.4	.0	.00
19	30.0 -6.0	3.2	151.	4.7	.0	.00
20	32.0 -5.1	3.2	224.	4.9	.0	.00
21	28.9 -7.1	2.1	211.	3.8	.0	.00
22	25.0 -2.0	5.7	159.	4.0	.0	.00
23	39.0 1.9	14.0	193.	3.8	.0	.00
24	48.0 10.0	18.1	144.	6.5	.0	.00
25	45.0 12.9	21.4	234.	5.4	.0	.00
26	37.9 8.1	18.0	232.	4.0	.0	.00
27	42.1 9.0	16.9	276.	3.6	.0	.00
28	43.0 15.1	24.8	279.	7.4	.0	.00
29	39.9 15.1	25.0	256.	3.4	.0	.00
30	39.0 12.9	19.9	162.	3.8	.0	.00
31	45.0 7.0	14.9	128.	4.5	.0	.00
32	50.0 9.0	16.9	197.	4.3	.0	.00
33	42.1 14.0	19.4	226.	3.6	.0	.00
34	46.0 10.9	17.1	214.	5.6	.0	.00
35	44.1 9.0	12.9	172.	5.1	.0	.00
36	41.0 3.9	11.5	213.	4.3	.0	.00
37	37.9 5.0	12.6	273.	5.4	.0	.00
38	44.1 6.1	13.5	315.	4.5	.0	.00
39	46.0 21.0	24.1	238.	4.7	.0	.00
40	42.1 12.9	23.4	171.	4.5	.0	.00
41	43.0 23.0	30.7	256.	4.7	.0	.00
42	48.9 28.9	33.6	332.	3.8	.0	.00
43	45.0 32.0	32.9	310.	4.9	.0	.00
44	41.0 30.9	33.6	121.	3.6	.0	.30
45	43.0 19.9	28.8	327.	6.3	.0	.00
46	44.1 26.1	29.5	303.	4.7	.0	.00
47	37.0 28.9	28.6	203.	10.7	.0	.00
48	39.9 21.0	21.2	246.	6.9	.0	.00
49	41.0 23.0	11.8	135.	5.6	.0	.00
50	43.0 32.0	32.9	312.	12.5	.0	.10
51	51.1 37.9	37.9	188.	14.3	.0	.00
52	43.0 32.0	34.0	376.	8.1	.0	.00
53	48.9 30.0	32.2	198.	7.4	.0	.00
54	48.0 28.0	21.4	255.	7.2	.0	.00
55	37.9 24.1	27.1	143.	3.1	.0	.00
56	50.0 21.0	28.0	202.	3.1	.0	.00
57	55.9 21.9	27.9	257.	3.1	.0	.00

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
58	59.0 23.0	29.3	322.	4.0	.0	.00
59	60.1 21.9	29.7	249.	4.0	.0	.00
60	59.0 25.0	27.5	323.	5.4	.0	.00
61	54.0 33.1	32.5	397.	4.9	.0	.00
62	62.1 37.9	29.7	253.	5.6	.0	.00
63	55.9 32.0	34.7	435.	5.1	.0	.00
64	53.1 30.9	33.4	88.	4.7	.0	.10
65	53.1 30.0	35.2	113.	4.7	.0	.10
66	43.0 33.1	35.6	379.	4.7	.0	.10
67	54.0 27.0	27.5	405.	11.0	.0	.00
68	54.0 26.1	23.7	399.	6.9	.0	.00
69	57.0 19.9	25.3	345.	4.5	.0	.00
70	62.1 23.0	24.3	282.	3.6	.0	.00
71	64.9 19.0	24.8	157.	3.6	.0	.00
72	64.9 19.9	24.6	465.	4.0	.0	.00
73	66.0 21.9	26.6	401.	4.9	.0	.00
74	63.0 30.0	27.7	338.	5.8	.0	.00
75	52.0 25.0	30.9	107.	6.3	.0	.00
76	46.9 33.1	34.3	283.	5.1	.0	.00
77	46.0 30.9	31.1	485.	6.0	.0	.00
78	53.1 24.1	26.2	307.	6.0	.0	.00
79	57.9 26.1	19.8	202.	9.6	.0	.00
80	51.1 26.1	14.0	479.	13.4	.0	.00
81	54.0 15.1	18.1	529.	6.0	.0	.00
82	57.0 30.9	28.0	534.	4.7	.0	.00
83	57.9 21.9	28.2	400.	3.6	.0	.00
84	59.0 18.0	21.2	438.	3.6	.0	.00
85	57.9 23.0	26.1	271.	6.5	.0	.00
86	57.9 36.0	33.8	436.	10.7	.0	.00
87	57.9 24.1	26.6	542.	4.3	.0	.00
88	62.1 19.0	28.2	471.	5.6	.0	.00
89	63.0 27.0	32.5	417.	4.7	.0	.00
90	62.1 23.0	22.6	337.	11.2	.0	.00
91	68.0 21.0	21.7	372.	4.3	.0	.00
92	72.0 25.0	24.8	436.	5.6	.0	.00
93	75.0 25.0	23.2	520.	8.5	.0	.00
94	66.0 37.0	25.5	550.	13.6	.0	.00
95	51.1 28.0	13.6	300.	17.9	.0	.00
96	50.0 19.0	7.7	385.	15.4	.0	.00
97	57.0 9.0	12.0	249.	9.6	.0	.00
98	61.0 39.0	24.8	394.	16.3	.0	.00
99	63.0 41.0	33.4	482.	23.0	.0	.00
100	60.1 41.0	34.9	584.	21.5	.0	.00
101	66.9 33.1	35.6	466.	6.9	.0	.00
102	69.1 33.1	33.3	568.	6.0	.0	.00
103	69.1 37.9	37.8	379.	12.3	.0	.00
104	71.1 34.0	34.2	394.	6.3	.0	.00
105	70.0 43.0	39.4	504.	5.4	.0	.00
106	70.0 33.1	35.8	592.	10.5	.0	.00
107	60.1 34.0	22.8	385.	18.1	.0	.00
108	57.0 33.1	23.0	512.	13.6	.0	.00
109	57.9 23.0	21.7	620.	6.7	.0	.00
110	64.9 21.0	22.8	620.	4.9	.0	.00
111	62.1 39.0	31.1	539.	9.8	.0	.00
112	51.1 30.9	32.7	483.	13.9	.0	.00
113	52.0 21.9	17.2	652.	7.2	.0	.00
114	63.0 12.9	13.6	483.	4.7	.0	.00
115	73.9 21.9	17.2	683.	4.7	.0	.00
116	82.0 27.0	22.8	658.	6.5	.0	.00

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
117	78.1 41.0	23.5	649.	12.3	.0	.00
118	79.0 35.1	27.0	698.	8.5	.0	.00
119	86.0 33.1	28.9	451.	9.4	.0	.00
120	64.9 48.9	25.7	337.	18.6	.0	.00
121	64.9 42.1	27.1	459.	7.2	.0	.00
122	73.0 21.9	16.5	491.	5.8	.0	.00
123	79.0 28.9	19.2	594.	4.7	.0	.00
124	82.9 30.0	21.0	464.	5.1	.0	.00
125	84.9 32.0	21.4	674.	4.9	.0	.00
126	89.1 34.0	21.2	725.	6.3	.0	.00
127	87.1 43.0	29.1	595.	5.1	.0	.00
128	77.0 46.0	33.1	731.	10.7	.0	.00
129	57.9 30.0	32.0	734.	9.8	.0	.00
130	69.1 24.1	25.9	546.	15.4	.0	.00
131	68.0 39.0	20.8	733.	22.6	.0	.00
132	70.0 21.9	12.7	743.	8.9	.0	.00
133	80.1 39.0	23.9	601.	8.5	.0	.00
134	82.9 37.0	30.6	726.	8.1	.0	.00
135	68.0 48.0	44.2	493.	6.3	.0	.30
136	77.0 35.1	32.5	593.	6.3	.0	.00
137	84.9 37.9	32.7	543.	6.0	.0	.00
138	84.9 45.0	33.4	758.	8.9	.0	.00
139	84.9 43.0	28.8	579.	9.6	.0	.00
140	73.9 50.0	37.6	666.	14.3	.0	.00
141	68.0 44.1	34.7	765.	7.6	.0	.00
142	79.0 36.0	36.1	767.	5.1	.0	.00
143	84.9 41.0	33.3	657.	5.4	.0	.00
144	88.0 41.0	34.0	721.	5.8	.0	.00
145	87.1 52.0	38.5	538.	8.5	.0	.00
146	81.0 52.0	40.6	641.	11.4	.0	.00
147	75.0 46.0	33.4	553.	5.8	.0	.00
148	78.1 42.1	33.6	633.	6.9	.0	.00
149	73.0 46.0	39.2	779.	7.6	.0	.00
150	77.0 44.1	35.8	611.	8.7	.0	.00
151	77.0 50.0	50.3	726.	10.5	.0	.00
152	84.0 39.0	30.6	709.	5.6	.0	.00
153	84.9 46.9	39.0	657.	6.0	.0	.00
154	84.0 41.0	33.1	582.	8.9	.0	.00
155	82.9 39.9	20.7	525.	13.4	.0	.00
156	72.0 43.0	30.0	590.	8.1	.0	.00
157	78.1 42.1	30.4	425.	6.9	.0	.00
158	84.9 39.0	27.3	681.	5.8	.0	.00
159	86.0 45.0	31.6	595.	6.5	.0	.00
160	88.0 42.1	33.3	475.	7.4	.0	.00
161	86.0 51.1	43.0	190.	6.0	.0	.20
162	84.0 54.0	46.0	645.	7.2	.0	.00
163	86.0 41.0	38.3	793.	16.3	.0	.00
164	62.1 39.9	32.2	687.	10.5	.0	.00
165	69.1 42.1	38.8	692.	10.1	.0	.40
166	63.0 48.9	44.1	438.	11.0	.0	.40
167	59.0 46.0	48.0	529.	12.8	.0	.20
168	72.0 48.0	48.9	598.	4.0	.0	.00
169	82.0 51.1	45.7	612.	6.5	.0	.00
170	84.9 55.0	42.6	538.	6.9	.0	.00
171	86.0 55.0	44.1	794.	7.2	.0	.00
172	90.0 48.9	41.4	794.	4.7	.0	.00
173	93.9 53.1	44.2	692.	5.6	.0	.00
174	97.0 57.0	45.7	793.	6.3	.0	.00
175	96.1 53.1	46.4	691.	7.8	.0	.10

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
176	78.1 59.0	55.0	695.	9.6	.0	.10
177	82.9 57.0	52.0	784.	7.8	.0	.00
178	84.0 55.9	54.1	791.	7.4	.0	.00
179	89.1 48.0	49.6	619.	8.7	.0	.00
180	72.0 51.1	46.2	774.	11.6	.0	.10
181	66.9 46.9	42.3	731.	12.1	.0	.10
182	69.1 37.9	41.0	764.	6.0	.0	.00
183	73.9 50.0	43.0	611.	5.6	.0	.00
184	84.0 48.0	41.4	670.	7.4	.0	.00
185	90.0 57.0	41.0	540.	11.0	.0	.00
186	88.0 45.0	34.2	783.	10.3	.0	.00
187	82.9 57.9	29.3	686.	15.2	.0	.00
188	79.0 50.0	33.4	570.	16.6	.0	.00
189	82.0 43.0	29.1	638.	11.9	.0	.00
190	79.0 39.9	35.6	709.	6.9	.0	.00
191	82.9 43.0	35.1	776.	8.5	.0	.00
192	73.0 54.0	35.8	775.	9.8	.0	.10
193	73.9 53.1	35.8	670.	5.4	.0	.10
194	86.0 45.0	35.8	760.	8.9	.0	.00
195	89.1 52.0	35.8	714.	16.3	.0	.00
196	86.0 45.0	35.8	767.	5.8	.0	.00
197	87.1 53.1	35.8	709.	7.2	.0	.00
198	91.9 48.9	36.7	458.	6.0	.0	.00
199	91.0 50.0	39.0	589.	8.1	.0	.00
200	88.0 57.0	45.0	653.	9.2	.0	.00
201	88.0 45.0	48.4	512.	11.4	.0	.00
202	81.0 46.9	46.2	701.	8.5	.0	.00
203	88.0 48.9	43.9	611.	7.6	.0	.00
204	80.1 53.1	31.5	634.	13.2	.0	.00
205	84.0 48.9	28.8	747.	8.7	.0	.00
206	86.0 43.0	29.1	670.	6.9	.0	.00
207	93.0 43.0	29.7	493.	5.6	.0	.00
208	95.0 46.9	31.5	560.	6.3	.0	.00
209	93.9 50.0	38.7	715.	6.0	.0	.00
210	91.9 45.0	31.5	605.	5.4	.0	.00
211	93.0 52.0	36.7	730.	6.3	.0	.00
212	95.0 48.9	35.6	727.	6.5	.0	.00
213	100.0 52.0	36.5	657.	6.0	.0	.00
214	100.9 48.9	36.7	665.	8.1	.0	.00
215	96.1 59.0	36.5	626.	11.2	.0	.00
216	93.9 46.9	25.9	561.	8.1	.0	.00
217	93.0 51.1	25.7	465.	11.9	.0	.00
218	91.0 48.0	34.3	537.	13.2	.0	.00
219	91.9 51.1	33.6	549.	14.5	.0	.00
220	89.1 55.9	39.0	459.	15.0	.0	.00
221	91.9 53.1	35.8	434.	11.6	.0	.00
222	98.1 45.0	31.6	433.	5.4	.0	.00
223	97.0 50.0	34.3	465.	6.9	.0	.00
224	99.0 55.0	32.9	448.	6.9	.0	.00
225	99.0 53.1	33.6	453.	5.6	.0	.00
226	98.1 53.1	36.5	651.	4.7	.0	.00
227	84.9 53.1	44.1	588.	6.9	.0	.00
228	88.0 57.0	50.5	670.	5.6	.0	.00
229	89.1 57.9	50.5	666.	6.9	.0	.00
230	93.0 48.0	44.6	612.	5.4	.0	.00
231	96.1 48.9	42.4	471.	7.2	.0	.00
232	91.9 46.0	44.1	611.	7.6	.0	.00
233	90.0 51.1	37.4	537.	9.2	.0	.00
234	75.9 57.0	27.9	645.	17.7	.0	.00

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
235	68.0 42.1	27.0	543.	12.8	.0	.00
236	69.1 30.9	7.3	406.	6.3	.0	.00
237	68.0 26.1	19.0	632.	4.7	.0	.00
238	75.9 24.1	9.1	608.	6.0	.0	.00
239	86.0 30.0	13.6	456.	7.8	.0	.00
240	87.1 50.0	22.3	618.	15.9	.0	.00
241	82.9 39.9	25.3	614.	7.2	.0	.00
242	86.0 37.0	27.7	573.	7.6	.0	.00
243	69.1 46.9	49.6	357.	6.0	.0	.10
244	79.0 37.9	45.1	473.	6.0	.0	.10
245	82.9 39.9	36.3	545.	9.6	.0	.00
246	84.0 45.0	39.9	491.	7.6	.0	.20
247	68.0 48.9	47.1	492.	10.3	.0	.10
248	68.0 37.9	37.4	430.	13.9	.0	.10
249	63.0 43.0	37.9	398.	13.2	.0	.10
250	64.0 28.0	24.1	381.	4.9	.0	.00
251	75.9 39.9	26.6	433.	13.2	.0	.00
252	75.9 35.1	32.0	490.	5.4	.0	.00
253	82.0 34.0	28.9	446.	4.7	.0	.00
254	79.0 48.9	34.3	464.	5.6	.0	.00
255	71.1 43.0	34.0	521.	14.8	.0	.00
256	62.1 34.0	14.2	349.	17.2	.0	.00
257	72.0 21.9	15.6	536.	4.9	.0	.00
258	77.0 32.0	18.5	451.	10.3	.0	.00
259	80.1 39.0	21.7	244.	13.4	.0	.00
260	80.1 43.0	25.2	444.	13.4	.0	.00
261	79.0 30.9	24.3	455.	5.4	.0	.00
262	75.0 32.0	24.6	384.	8.1	.0	.00
263	78.1 36.0	32.7	495.	10.3	.0	.00
264	80.1 39.9	39.6	501.	4.9	.0	.00
265	88.0 37.0	35.1	446.	6.3	.0	.00
266	86.0 45.0	37.6	393.	9.6	.0	.00
267	70.0 43.0	31.8	485.	17.7	.0	.00
268	64.9 37.0	26.2	480.	9.2	.0	.00
269	68.0 24.1	23.7	475.	7.4	.0	.00
270	77.0 30.0	22.5	425.	7.2	.0	.00
271	81.0 24.1	19.0	465.	5.1	.0	.00
272	86.0 28.9	21.7	368.	4.0	.0	.00
273	88.0 28.9	21.9	199.	4.7	.0	.00
274	87.1 36.0	22.6	298.	4.9	.0	.00
275	84.0 43.0	26.2	239.	9.2	.0	.00
276	57.9 44.1	42.4	200.	11.9	.0	.20
277	59.0 37.9	43.2	324.	6.9	.0	.00
278	63.0 36.0	39.2	412.	3.6	.0	.00
279	57.9 30.0	27.1	418.	8.1	.0	.00
280	57.9 18.0	19.0	419.	4.5	.0	.00
281	55.0 32.0	20.5	366.	4.0	.0	.00
282	64.0 28.9	25.9	208.	7.2	.0	.00
283	68.0 28.0	28.4	163.	4.0	.0	.00
284	73.9 26.1	29.5	267.	4.5	.0	.00
285	78.1 30.9	26.8	325.	11.2	.0	.00
286	70.0 37.9	26.6	364.	15.7	.0	.00
287	57.0 23.0	18.0	377.	11.2	.0	.00
288	52.0 19.0	10.2	222.	6.5	.0	.00
289	62.1 23.0	10.0	241.	7.2	.0	.00
290	64.9 30.0	20.7	317.	6.9	.0	.00
291	66.0 23.0	22.6	235.	4.9	.0	.00
292	71.1 27.0	24.1	363.	4.9	.0	.00
293	75.9 23.0	24.1	357.	4.7	.0	.00

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
294	73.9 27.0	27.1	340.	8.7	.0	.00
295	64.9 37.0	34.9	277.	8.5	.0	.00
296	66.0 19.9	24.6	287.	5.4	.0	.00
297	75.0 25.0	26.4	287.	5.6	.0	.00
298	73.0 30.0	29.8	111.	4.9	.0	.00
299	68.0 28.9	36.0	173.	7.4	.0	.00
300	69.1 30.9	32.4	237.	4.3	.0	.00
301	64.0 33.1	35.6	65.	5.1	.0	.10
302	48.9 39.9	43.3	114.	10.1	.0	.10
303	51.1 34.0	37.6	185.	12.3	.0	.00
304	50.0 27.0	29.8	252.	8.5	.0	.00
305	48.9 33.1	35.8	242.	11.2	.0	.00
306	46.9 30.0	3.4	221.	12.3	.0	.00
307	43.0 14.0	17.2	153.	6.9	.0	.00
308	35.1 9.0	19.6	264.	4.0	.0	.00
309	42.1 19.9	28.0	294.	7.4	.0	.00
310	35.1 28.0	28.6	290.	3.4	.0	.00
311	51.1 27.0	30.9	287.	5.4	.0	.00
312	37.0 28.9	28.9	183.	13.6	.0	.00
313	39.9 17.1	24.8	280.	10.3	.0	.00
314	35.1 6.1	17.8	220.	6.3	.0	.00
315	32.0 18.0	19.6	274.	4.3	.0	.00
316	33.1 18.0	20.7	271.	2.5	.0	.00
317	33.1 19.9	24.4	268.	3.6	.0	.00
318	46.0 19.0	26.2	225.	4.0	.0	.00
319	48.9 14.0	24.1	256.	4.0	.0	.00
320	50.0 16.0	23.7	156.	3.6	.0	.00
321	46.9 21.9	27.9	236.	3.6	.0	.00
322	37.0 32.0	32.0	58.	3.8	.0	.00
323	37.0 30.0	30.4	204.	4.0	.0	.00
324	37.9 17.1	19.2	153.	13.2	.0	.00
325	27.0 12.0	17.1	246.	3.4	.0	.00
326	33.1 3.0	20.8	112.	4.3	.0	.00
327	32.0 -2.9	11.5	168.	5.8	.0	.00
328	25.0-11.9	-3.1	86.	3.6	.0	.00
329	21.0-16.1	-7.2	120.	4.3	.0	.00
330	21.0-17.0	-5.8	155.	4.5	.0	.00
331	21.9-15.0	1.2	188.	3.6	.0	.00
332	28.9 -2.9	6.3	69.	2.9	.0	.00
333	17.1 -6.0	4.8	108.	3.4	.0	.00
334	28.0 12.9	16.7	160.	3.4	.0	.00
335	21.9 1.9	13.8	155.	6.0	.0	.00
336	30.9 19.0	23.7	45.	3.4	.0	.00
337	26.1-16.1	5.4	224.	9.4	.0	.00
338	6.1-27.9-18.4	208.	4.9	.0	.00	
339	19.9-25.1	-6.3	133.	3.6	.0	.00
340	15.1-16.1	-4.2	123.	4.7	.0	.00
341	24.1-15.0	7.7	86.	5.6	.0	.00
342	35.1 24.1	27.9	71.	11.9	.0	.00
343	35.1 26.1	28.6	217.	17.7	.0	.00
344	28.9 12.0	19.0	204.	2.9	.0	.00
345	36.0 14.0	27.9	48.	10.1	.0	.00
346	30.9 -9.9	8.4	168.	7.4	.0	.00
347	24.1-13.0	2.3	136.	7.4	.0	.00
348	15.1 5.0	9.1	130.	7.4	.0	.00
349	28.0-11.0	4.1	190.	4.7	.0	.00
350	12.0 -7.1	3.2	143.	3.1	.0	.00
351	17.1 7.0	12.0	142.	5.6	.0	.00
352	12.0-15.0	-6.0	43.	3.8	.0	.00

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
353	10.9 -6.0	-9	213.	2.9	.0	.00
354	17.1 1.0	8.2	213.	3.1	.0	.00
355	30.0 10.9	17.4	164.	8.3	.0	.00
356	27.0 9.0	20.3	124.	19.9	.0	.00
357	33.1 18.0	23.2	185.	9.8	.0	.00
358	30.0 10.0	18.7	198.	4.7	.0	.00
359	21.9 -9.9	13.1	215.	1.6	.0	.00
360	19.0 -2.9	4.8	189.	1.6	.0	.00
361	35.1 6.1	21.2	216.	10.5	.0	.00
362	33.1 3.9	14.7	217.	4.3	.0	.00
363	34.0 26.1	30.0	53.	9.6	.0	.00
364	26.1 10.0	17.6	164.	11.2	.0	.00
365	18.0-11.0	6.1	63.	4.9	.0	.00

Year 1993

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
1	30.9 17.1	23.7	170.	5.1	.0	.00
2	30.9 -2.9	10.0	177.	13.0	.0	.00
3	6.1 -9.9	-5.1	222.	1.8	.0	.00
4	12.9-20.0	-5.1	103.	2.9	.0	.00
5	9.0-18.0	-17.3	148.	2.7	.0	.00
6	6.1-14.1	-9.4	143.	3.8	.0	.00
7	12.0-26.0	-9.2	183.	4.5	.0	.00
8	23.0 10.9	16.0	46.	4.5	.0	.00
9	19.0 -5.1	8.4	196.	8.3	.0	.00
10	21.0 .0	9.1	138.	4.3	.0	.00
11	24.1 10.9	15.1	47.	18.1	.0	.00
12	15.1-18.0	-9	153.	4.9	.0	.00
13	18.0-18.9	5.0	70.	6.0	.0	.00
14	28.0 17.1	23.7	60.	4.0	.0	.00
15	30.0 10.0	21.2	189.	9.6	.0	.00
16	30.9 17.1	22.6	49.	3.1	.0	.00
17	27.0 -2.9	13.3	98.	5.6	.0	.00
18	25.0 .0	14.0	120.	5.8	.0	.00
19	30.0 7.0	18.7	151.	8.3	.0	.00
20	35.1 12.9	25.2	83.	7.6	.0	.00
21	34.0 21.0	24.6	75.	14.1	.0	.00
22	35.1 14.0	26.6	52.	17.9	.0	.00
23	17.1 -2.9	2.1	193.	4.9	.0	.00
24	18.0 -9.0	3.2	144.	3.8	.0	.00
25	21.0 -2.9	7.9	234.	3.8	.0	.00
26	19.9 -5.1	.9	232.	1.6	.0	.00
27	19.0-11.9	-2.7	276.	1.8	.0	.00
28	23.0 -8.0	5.4	279.	2.5	.0	.00
29	21.0 -6.0	5.5	256.	2.7	.0	.00
30	16.0-11.9	-3.6	162.	2.9	.0	.00
31	23.0-11.0	.7	128.	3.4	.0	.00
32	16.0 -8.0	-2	197.	4.0	.0	.00
33	19.9 -9.0	-8	226.	3.4	.0	.00
34	12.9-14.1	-5.8	214.	2.7	.0	.00
35	25.0-11.9	-4.7	172.	2.5	.0	.00
36	21.0-14.1	-3.8	213.	3.1	.0	.00
37	25.0 -9.9	10.0	273.	2.9	.0	.00
38	33.1 3.9	18.1	315.	3.1	.0	.00
39	28.9 .0	7.0	238.	3.6	.0	.00
40	34.0 27.0	31.3	65.	5.6	.0	.00

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
41	32.0 28.0	31.1	122.	5.8	.0	.00
42	33.1 26.1	29.1	332.	6.5	.0	.00
43	28.0 17.1	22.3	310.	14.1	.0	.00
44	24.1 12.0	17.1	256.	2.7	.0	.00
45	25.0 6.1	14.0	327.	4.3	.0	.00
46	15.1 5.0	10.4	168.	13.0	.0	.00
47	7.0-24.0	-8.7	203.	10.1	.0	.00
48	10.0-27.0	-24.5	246.	3.1	.0	.00
49	24.1 9.0	17.2	135.	5.6	.0	.00
50	37.0 23.0	30.4	178.	7.8	.0	.00
51	33.1 10.9	25.0	74.	22.4	.0	.00
52	21.9 12.9	18.7	376.	19.5	.0	.00
53	21.9 3.0	11.1	198.	11.6	.0	.00
54	21.0 .0	12.6	112.	7.4	.0	.00
55	26.1 10.0	18.3	143.	5.4	.0	.00
56	25.0 1.0	12.9	202.	5.4	.0	.00
57	12.9-16.1	-5.8	257.	5.4	.0	.00
58	10.9-23.1	-13.9	322.	5.4	.0	.00
59	21.0-22.0	-8.0	249.	5.4	.0	.00
60	14.0-11.9	-5.6	301.	3.6	.0	.00
61	19.0 -9.9	-3.1	323.	4.0	.0	.00
62	28.0 -5.1	9.5	397.	5.1	.0	.00
63	21.9 -2.9	9.7	253.	4.0	.0	.00
64	30.9 9.0	19.0	435.	4.0	.0	.00
65	30.0 21.9	25.2	205.	4.9	.0	.00
66	34.0 21.9	27.5	272.	3.6	.0	.00
67	35.1 27.0	29.1	451.	3.1	.0	.00
68	35.1 27.0	29.7	405.	5.8	.0	.00
69	34.0 23.0	25.7	399.	4.7	.0	.00
70	30.0 12.0	16.9	345.	6.3	.0	.00
71	19.9 -.9	7.0	282.	6.0	.0	.00
72	32.0 9.0	12.6	157.	5.1	.0	.00
73	33.1 10.0	21.4	465.	4.0	.0	.00
74	39.9 19.0	30.2	401.	23.0	.0	.00
75	39.0 30.9	32.4	338.	12.5	.0	.18
76	41.0 32.0	33.4	99.	3.6	.0	.37
77	42.1 28.9	33.6	283.	5.8	.0	.21
78	41.0 28.0	30.0	485.	4.7	.0	.15
79	42.1 26.1	29.8	307.	9.2	.0	.13
80	41.0 24.1	24.8	202.	5.4	.0	.03
81	41.0 15.1	23.0	479.	4.9	.0	.00
82	46.0 15.1	25.7	529.	4.3	.0	.00
83	43.0 24.1	32.0	434.	5.4	.0	.19
84	45.0 34.0	37.4	245.	6.9	.0	.75
85	51.1 33.1	39.0	296.	7.2	.0	.71
86	52.0 30.0	36.3	271.	6.0	.0	.54
87	51.1 35.1	38.7	436.	6.7	.0	.67
88	51.1 33.1	33.8	542.	9.4	.0	.61
89	52.0 30.0	28.9	471.	5.8	.0	.07
90	55.0 24.1	29.3	417.	4.3	.0	.00
91	53.1 28.0	31.8	337.	11.2	.0	.00
92	48.9 30.9	32.0	184.	7.6	.0	.20
93	48.9 27.0	33.4	436.	3.8	.0	.00
94	48.0 34.0	38.7	396.	10.3	.0	.20
95	50.0 30.9	29.8	550.	12.1	.0	.00
96	48.9 26.1	23.5	300.	4.5	.0	.00
97	55.9 19.9	24.8	385.	5.4	.0	.00
98	59.0 28.9	30.6	249.	8.5	.0	.00
99	52.0 30.9	31.6	394.	17.7	.0	.00

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
100	48.9 23.0	29.5	326.	11.2	.0	.10
101	45.0 23.0	27.0	479.	5.6	.0	.10
102	45.0 23.0	29.3	297.	4.7	.0	.20
103	52.0 18.0	24.4	568.	5.6	.0	.00
104	51.1 23.0	25.9	379.	7.8	.0	.00
105	55.0 19.9	30.2	394.	8.3	.0	.00
106	59.0 33.1	28.8	504.	8.7	.0	.00
107	60.1 36.0	30.7	592.	11.4	.0	.00
108	50.0 32.0	30.0	155.	17.2	.0	.10
109	54.0 25.0	20.8	512.	6.7	.0	.00
110	57.0 19.9	22.8	620.	6.3	.0	.00
111	68.0 28.9	22.6	620.	11.6	.0	.00
112	53.1 39.9	36.9	385.	10.5	.0	.10
113	55.9 33.1	27.7	483.	14.1	.0	.00
114	53.1 34.0	34.7	560.	8.9	.0	.10
115	55.9 30.0	32.5	483.	7.4	.0	.00
116	57.9 33.1	29.8	607.	14.5	.0	.20
117	57.0 21.0	22.6	564.	6.3	.0	.10
118	64.0 24.1	24.1	649.	8.7	.0	.00
119	57.9 36.0	34.2	698.	11.2	.0	.00
120	54.0 30.0	34.5	451.	6.7	.0	.00
121	62.1 28.9	29.7	337.	7.8	.0	.00
122	66.9 44.1	34.0	459.	14.3	.0	.00
123	62.1 33.1	39.2	279.	9.6	.0	.50
124	46.0 34.0	36.3	446.	8.3	.0	.40
125	48.9 35.1	41.2	229.	9.6	.0	.10
126	46.0 37.0	41.7	573.	6.7	.0	.30
127	53.1 34.0	35.4	690.	12.8	.0	.30
128	50.0 28.9	31.8	439.	5.6	.0	.10
129	60.1 25.0	30.6	731.	5.6	.0	.00
130	72.0 32.0	35.4	734.	8.3	.0	.00
131	79.0 37.9	36.1	546.	8.3	.0	.00
132	79.0 39.9	35.4	733.	8.7	.0	.00
133	81.0 46.0	42.8	743.	5.8	.0	.00
134	75.9 43.0	44.8	601.	7.4	.0	.00
135	78.1 44.1	46.4	645.	6.3	.0	.10
136	73.9 44.1	47.1	493.	6.3	.0	.20
137	75.9 37.9	45.0	593.	4.5	.0	.00
138	79.0 42.1	42.1	543.	8.1	.0	.00
139	80.1 46.9	46.6	758.	5.8	.0	.00
140	82.0 46.9	46.4	579.	9.4	.0	.00
141	70.0 51.1	45.5	533.	11.2	.0	.10
142	63.0 41.0	39.9	765.	7.2	.0	.00
143	66.9 41.0	37.0	767.	8.3	.0	.00
144	72.0 43.0	37.9	657.	9.2	.0	.00
145	80.1 46.0	37.9	721.	10.3	.0	.00
146	78.1 46.0	41.4	538.	8.5	.0	.00
147	78.1 45.0	38.8	641.	9.8	.0	.00
148	79.0 45.0	37.6	553.	9.8	.0	.00
149	73.0 46.9	36.0	633.	11.4	.0	.00
150	77.0 34.0	35.8	779.	5.6	.0	.00
151	79.0 51.1	39.9	611.	12.3	.0	.00
152	70.0 45.0	38.5	726.	17.0	.0	.00
153	66.0 34.0	39.6	590.	10.3	.0	.20
154	53.1 43.0	45.7	500.	6.9	.0	.30
155	57.9 36.0	43.5	582.	5.6	.0	.00
156	52.0 46.9	49.5	266.	10.1	.0	.80
157	55.0 43.0	46.0	379.	10.5	.0	.80
158	60.1 42.1	44.2	158.	7.6	.0	.10

Day	Temp.	Dew	Solar	Wind	Cloud	Precip
	Max. Min.	Pt	Rad	Speed	Cover	
159	61.0 41.0	43.0	537.	9.8	.0	.10
160	68.0 36.0	39.0	595.	6.7	.0	.00
161	69.1 41.0	45.0	174.	8.5	.0	.10
162	68.0 39.9	39.2	485.	12.8	.0	.00
163	59.0 32.0	31.6	645.	11.4	.0	.00
164	68.0 28.9	32.5	793.	4.7	.0	.00
165	79.0 35.1	40.1	687.	6.3	.0	.00
166	75.9 48.9	44.4	692.	11.4	.0	.10
167	68.0 37.9	43.2	438.	7.2	.0	.10
168	68.0 46.0	40.8	680.	15.2	.0	.00
169	75.9 36.0	38.1	598.	6.5	.0	.00
170	82.0 43.0	45.1	612.	6.0	.0	.00
171	86.0 45.0	47.1	538.	5.8	.0	.00
172	77.0 43.0	48.4	788.	8.9	.0	.10
173	63.0 45.0	38.7	794.	19.5	.0	.00
174	61.0 37.0	27.9	692.	8.7	.0	.00
175	71.1 34.0	34.5	793.	8.5	.0	.00
176	78.1 35.1	40.6	771.	5.8	.0	.00
177	87.1 39.9	43.9	773.	6.5	.0	.00
178	84.9 46.9	46.4	784.	9.4	.0	.00
179	79.0 53.1	48.7	791.	8.5	.0	.00
180	68.0 44.1	40.1	619.	8.7	.0	.00
181	73.9 32.0	31.6	790.	9.2	.0	.00
182	78.1 36.0	34.2	789.	9.6	.0	.00
183	78.1 37.9	39.4	764.	12.1	.0	.00
184	66.9 43.0	40.1	611.	11.6	.0	.00
185	69.1 45.0	41.9	518.	6.3	.0	.10
186	72.0 42.1	40.5	540.	6.7	.0	.00
187	73.9 35.1	37.4	783.	6.7	.0	.00
188	73.9 34.0	33.8	686.	11.9	.0	.00
189	73.9 44.1	37.2	570.	8.7	.0	.00
190	82.9 33.1	36.0	638.	9.4	.0	.00
191	80.1 43.0	34.2	709.	12.1	.0	.00
192	82.9 37.9	34.2	776.	9.6	.0	.00
193	75.0 48.0	34.2	775.	18.8	.0	.00
194	79.0 32.0	34.2	753.	6.7	.0	.00
195	75.9 35.1	34.2	760.	13.2	.0	.00
196	73.9 52.0	32.4	714.	9.8	.0	.00
197	73.0 46.9	34.9	767.	11.6	.0	.00
198	77.0 36.0	36.0	709.	11.2	.0	.00
199	78.1 28.9	36.0	458.	5.8	.0	.00
200	87.1 39.9	36.0	589.	7.6	.0	.00
201	77.0 48.0	37.2	653.	14.3	.0	.00
202	72.0 53.1	42.3	512.	9.2	.0	.00
203	64.0 41.0	42.8	701.	7.6	.0	.00
204	55.9 42.1	48.4	611.	5.6	.0	.00
205	68.0 48.9	46.0	634.	10.3	.0	.00
206	75.0 46.0	41.5	747.	8.9	.0	.00
207	71.1 46.0	45.0	670.	9.8	.0	.00
208	79.0 37.9	46.0	493.	4.9	.0	.00
209	91.0 42.1	46.0	560.	8.1	.0	.00
210	84.0 50.0	47.1	715.	9.2	.0	.00
211	84.9 54.0	36.7	605.	14.5	.0	.00
212	86.0 44.1	36.7	730.	7.4	.0	.00
213	87.1 42.1	39.4	727.	6.9	.0	.00
214	84.9 44.1	40.6	657.	9.6	.0	.00
215	84.0 54.0	39.6	665.	10.5	.0	.00
216	84.0 48.9	48.2	626.	7.8	.0	.00
217	81.0 44.1	49.3	383.	7.2	.0	.10

Day	Temp.		Dew	Solar	Wind	Cloud	Precip
	Max.	Min.	Pt	Rad	Speed	Cover	
218	84.9	48.0	47.1	465.	7.8	.0	.00
219	79.0	48.9	48.4	537.	9.2	.0	.00
220	82.9	39.9	37.0	549.	9.8	.0	.00
221	90.0	43.0	37.2	459.	9.6	.0	.00
222	88.0	52.0	43.3	187.	8.5	.0	.10
223	78.1	53.1	51.1	189.	7.2	.0	.10
224	81.0	48.0	45.9	465.	8.9	.0	.00
225	79.0	46.0	44.2	448.	9.6	.0	.00
226	82.0	37.9	44.4	453.	7.2	.0	.00
227	80.1	42.1	41.9	651.	10.1	.0	.00
228	66.9	46.9	43.9	454.	11.9	.0	.20
229	75.0	37.9	39.9	670.	6.5	.0	.00
230	82.0	37.0	39.4	666.	6.3	.0	.00
231	88.0	52.0	43.5	612.	11.0	.0	.00
232	81.0	55.9	48.0	471.	10.7	.0	.00
233	72.0	48.0	50.7	501.	9.8	.0	.20
234	75.9	43.0	44.2	537.	6.0	.0	.00
235	86.0	43.0	40.1	645.	9.4	.0	.00
236	75.9	48.9	38.1	543.	16.6	.0	.00
237	70.0	45.0	27.1	406.	6.9	.0	.00
238	73.0	36.0	26.1	632.	6.3	.0	.00
239	79.0	28.9	26.6	608.	9.6	.0	.00
240	81.0	35.1	27.9	456.	13.0	.0	.00
241	66.9	42.1	29.5	618.	9.2	.0	.00
242	72.0	34.0	22.8	614.	7.6	.0	.00
243	81.0	26.1	20.1	573.	9.4	.0	.00

Appendix B

UNSAT-H Simulation Input Data Decks

16	441.0000	16	441.3076	16	441.7691	16	442.4613
16	443.4995	16	445.0569	16	447.3930	16	450.8972
16	456.1534	16	464.0378	16	475.8643	16	493.6040
16	520.2137	16	560.1282	16	619.9999		

Soil Number 1

.5000	.0600	.0100	1.6000	
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Soil Number 1

2.0000	.9000	.0100	1.6000	.5000
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Soil Number 2

.4850	.0545	.0175	1.8375	
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Soil Number 2

2.0000	6.7050	.0175	1.8375	.5000
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Soil Number 3

.4700	.0490	.0250	2.0750	
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Soil Number 3

2.0000	12.5100	.0250	2.0750	.5000
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Soil Number 4

.4550	.0435	.0325	2.3125	
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Soil Number 4

2.0000	18.3150	.0325	2.3125	.5000
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Soil Number 5

.4400	.0380	.0400	2.5500	
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Soil Number 5

2.0000	24.1200	.0400	2.5500	.5000
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Soil Number 6

.4633	.0653	.0350	2.2300	
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Soil Number 6

2.0000	16.7000	.0350	2.2300	.5000
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Soil Number 7

.4867	.0927	.0300	1.9100	
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Soil Number 7

2.0000	9.2800	.0300	1.9100	.5000
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Soil Number 8

.5100	.1200	.0250	1.5900	
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Soil Number 8

2.0000	1.8600	.0250	1.5900	.5000
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Soil Number 9

.4550	.0635	.0309	2.3075	
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Soil Number 9

2.0000	18.2475	.0309	2.3075	.5000
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Soil Number 10

.4700	.0890	.0218	2.0650	
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Soil Number 10

2.0000	12.3750	.0218	2.0650	.5000
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Soil Number 11

.4850	.1145	.0127	1.8225	
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Soil Number 11

2.0000	6.5025	.0127	1.8225	.5000
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Soil Number 12

.5000	.1400	.0036	1.5800	
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Soil Number 12

2.0000	.6300	.0036	1.5800	.5000
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Soil Number 13

.5033	.1333	.0054	1.5833	
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Soil Number 13

2.0000	.7700	.0054	1.5833	.5000
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Soil Number 14

.5067	.1267	.0072	1.5867	
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Soil Number 14

2.0000	.9100	.0072	1.5867	.5000
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Soil Number 15

.5100	.1200	.0090	1.5900	
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Soil Number 15

2.0000	1.0500	.0090	1.5900	.5000
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Soil Number 16 (VESICULAR BASALT: from Bishop, 1991)

0.23	0.015	0.03840	1.47410	
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Soil Number 16

2.000	2.00	0.03840	1.47410	0.5
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0	(TOSS.OUT file for day	3.65000E+02)		
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7.79343E+02	7.78786E+02	7.77915E+02	7.76530E+02	
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7.74277E+02	7.70516E+02	7.64065E+02	7.52790E+02	
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7.33196E+02	7.01047E+02	6.70310E+02	6.52139E+02	
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6.41220E+02	6.34486E+02	6.30237E+02	6.27511E+02	
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6.25741E+02	6.24581E+02	6.23691E+02	6.21428E+02	
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6.18142E+02	6.13452E+02	6.09043E+02	6.06255E+02	
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NDAY (UNSAT-H V2.01)
Head Values

6.03219E+02	5.99452E+02	5.94086E+02	5.86630E+02
5.76645E+02	5.67929E+02	5.62741E+02	5.59533E+02
5.54461E+02	5.40827E+02	5.23528E+02	5.02650E+02
4.78815E+02	4.60716E+02	4.50813E+02	4.44948E+02
4.34948E+02	3.87661E+02	3.50126E+02	3.18328E+02
2.90285E+02	2.71981E+02	2.62559E+02	2.57093E+02
2.54865E+02	2.53954E+02	2.52602E+02	2.50601E+02
2.48633E+02	2.47337E+02	2.46516E+02	2.44992E+02
2.42718E+02	2.40458E+02	2.38959E+02	2.38756E+02
2.38453E+02	2.37998E+02	2.37317E+02	2.36299E+02
2.34776E+02	2.32504E+02	2.29122E+02	2.25768E+02
2.23547E+02	2.22072E+02	2.21092E+02	2.20439E+02
2.20005E+02	2.19715E+02	2.19522E+02	2.17338E+02
2.14071E+02	2.10814E+02	2.08776E+02	2.08227E+02
2.07403E+02	2.06166E+02	2.04312E+02	2.02456E+02
2.01218E+02	2.00392E+02	2.00065E+02	2.00264E+02
2.00583E+02	2.01109E+02	2.02014E+02	2.03671E+02
2.07005E+02	2.14894E+02	2.29342E+02	2.47327E+02
2.69026E+02	2.95215E+02	3.27795E+02	3.71586E+02
3.84081E+02	3.88451E+02	3.95692E+02	4.08478E+02
4.34049E+02	4.73632E+02	5.16836E+02	5.63122E+02
5.72769E+02	5.73264E+02	5.74012E+02	5.75148E+02
5.76884E+02	5.79560E+02	5.83745E+02	5.90432E+02
5.97652E+02	6.02788E+02	6.06365E+02	6.08821E+02
6.10492E+02	6.11621E+02	6.11654E+02	6.11427E+02
6.11086E+02	6.10574E+02	6.09803E+02	6.08644E+02
6.06897E+02	6.05139E+02	6.03961E+02	6.03173E+02
6.02647E+02	6.02296E+02	6.02003E+02	5.98685E+02
5.93703E+02	5.86219E+02	5.74970E+02	5.58048E+02
5.41072E+02	5.29728E+02	5.22153E+02	5.17098E+02
5.13753E+02	5.13157E+02	5.12263E+02	5.10921E+02
5.08908E+02	5.06892E+02	5.05548E+02	5.04651E+02
5.04061E+02	5.03070E+02	5.01582E+02	4.99347E+02
4.97108E+02	4.95613E+02	4.94635E+02	4.92880E+02
4.90239E+02	4.86259E+02	4.80248E+02	4.71144E+02
4.61939E+02	4.55750E+02	4.51601E+02	4.48827E+02
4.47324E+02	4.47384E+02	4.47473E+02	4.47606E+02
4.47801E+02	4.48087E+02	4.48500E+02	4.49080E+02
4.49866E+02	4.50854E+02	4.51923E+02	4.52704E+02
4.52567E+02	4.51358E+02	4.50354E+02	
0.2000	1500.0	6.0	845.0

B.2 NAT W06 Input Deck

SDA COVER BARRIER PROFILE: soil cover 1.4 m, Gravel 6 in, Cobbles 2.5 ft

0	1	1	1	0	1	1	IPLANT, LOWER, NGRAV, ISWDIF, IHEAT, UPPERH, LOWERH
0	365	365	1	1	0	1.0	NPRINT, DAYEND, NDAYS, NYEARS, IRAIN, ICONVH, OUTTIM
1	2	0	1	1			NSURPE, NFHOUR, ITOPBC, ET_OPT, ICLOUD
4	3	1	0	5	5		KOPT, KEST, IVAPOR, SH_OPT, INMAX, INHMAX
0.000E+00	2.500E+04	50.0			5.0E+1		HIRRI, HDRY, HTOP, DHMAX
1.000E-04	1.00	1.E-04			24.0		DMAXBA, DELMAX, DELMIN, STOPHR
0.66	283.00	.24			0.0		TORT, TSOIL, VAPDIF, QHTOP
-1.E-4	283.00	10.00E+00			0.0		TGRAD, TSMEAN, TSAMP, QHLEAK
0.5	2.00	1.000E-03			5.0E-1	1.	WTF, RFACT, RAINIF, DHFACT, isnow
12	123						MATN, NPT
1	.0000	1	.0583	1	.1456	1	.2767
1	.4733	1	.7682	1	1.2106	1	1.8741
1	2.8695	1	4.3625	1	6.6019	1	9.9612
1	15.0000	1	20.0388	1	23.3981	1	25.6375
1	27.1305	1	28.1259	1	28.7894	1	29.2318
1	29.5267	1	29.7233	1	29.8544	1	29.9417
2	30.0000	2	31.4032	2	33.5079	2	36.6650
2	39.8221	2	41.9268	3	43.3300	3	44.7332
3	46.8379	3	49.9950	3	53.1521	3	55.2568
4	56.6600	4	58.0642	4	60.1705	4	63.3300
4	66.4895	4	68.5958	5	70.0000	5	70.7218
5	71.8045	5	73.4286	5	75.8647	5	79.5188
5	85.0000	5	90.4812	5	94.1353	5	96.5714
5	98.1955	5	99.2782	6	100.0000	6	101.0526
6	102.6316	6	105.0000	6	107.3684	6	108.9474
7	110.0000	7	111.0526	7	112.6316	7	115.0000
7	117.3684	7	118.9474	8	120.0000	8	120.7105
8	121.7764	8	123.3751	8	125.7732	8	129.3703
8	134.7661	8	142.8596	8	155.0000	8	167.1404

8	175.2339	8	180.6297	8	184.2268	8	186.6249
8	188.2236	8	189.2895	9	190.0000	9	192.1053
9	195.2632	9	200.0000	9	204.7369	9	207.8948
10	210.0000	10	212.1053	10	215.2632	10	220.0000
10	224.7369	10	227.8948	11	230.0000	11	230.9136
11	232.2839	11	234.3394	11	237.4227	11	242.0476
11	248.9849	11	259.3910	11	275.0000	11	290.6090
11	301.0151	11	307.9524	11	312.5773	11	315.6606
11	317.7161	11	319.0864	12	320.0000	12	320.8544
12	322.1360	12	324.0584	12	326.9420	12	331.2673
12	337.7554	12	347.4875	12	362.0856	12	383.9827
12	416.8285	12	466.0971	12	540.0000		

Soil Number 1

.5540	.0385	.0155	1.8000	
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Soil Number 1

2.0000	11.4000	.0155	1.8000	.5000
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Soil Number 2

.5405	.0639	.0147	1.7625	
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Soil Number 2

2.0000	9.8000	.0147	1.7625	.5000
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Soil Number 3

.5270	.0892	.0139	1.7250	
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Soil Number 3

2.0000	8.2000	.0139	1.7250	.5000
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Soil Number 4

.5135	.1146	.0131	1.6875	
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Soil Number 4

2.0000	6.6000	.0131	1.6875	.5000
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Soil Number 5

.5000	.1400	.0123	1.6500	
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Soil Number 5

2.0000	5.0000	.0123	1.6500	.5000
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Soil Number 6

.5033	.1333	.0169	1.6300	
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Soil Number 6

2.0000	7.5000	.0169	1.6300	.5000
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Soil Number 7

.5067	.1267	.0216	1.6100	
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Soil Number 7

2.0000	10.0000	.0216	1.6100	.5000
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Soil Number 8

.5100	.1200	.0262	1.5900	
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Soil Number 8

2.0000	12.5000	.0262	1.5900	.5000
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Soil Number 9

.5067	.1267	.0216	1.6100	
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Soil Number 9

2.0000	10.0000	.0216	1.6100	.5000
--------	---------	-------	--------	-------

Soil Number 10

.5033	.1333	.0169	1.6300	
-------	-------	-------	--------	--

Soil Number 10

2.0000	7.5000	.0169	1.6300	.5000
--------	--------	-------	--------	-------

Soil Number 11

.5000	.1400	.0123	1.6500	
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Soil Number 11

2.0000	5.0000	.0123	1.6500	.5000
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Soil Number 12 (VESICULAR BASALT: from Bishop, 1991)

0.23	0.015	0.0384	1.47410	
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Soil Number 12

2.000	2.00	0.0384	1.47410	0.5
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0 (TOSS.OUT file for day 3.65000E+02)

NDAY (UNSAT-H V2.01)

Head Values

5.36048E+02	5.50805E+02	5.46987E+02	5.46068E+02
5.46173E+02	5.45853E+02	5.45413E+02	5.44755E+02
5.43770E+02	5.42301E+02	5.40116E+02	5.36875E+02
5.32089E+02	5.27370E+02	5.24247E+02	5.22171E+02
5.20788E+02	5.19866E+02	5.19252E+02	5.18842E+02
5.18568E+02	5.18386E+02	5.18264E+02	5.18183E+02
5.18129E+02	5.16809E+02	5.14827E+02	5.11845E+02
5.08848E+02	5.06838E+02	5.05488E+02	5.04130E+02
5.02084E+02	4.98996E+02	4.95881E+02	4.93788E+02
4.92385E+02	4.90976E+02	4.88852E+02	4.85643E+02
4.82404E+02	4.80228E+02	4.78772E+02	4.78021E+02
4.76893E+02	4.75194E+02	4.72633E+02	4.68760E+02
4.62882E+02	4.56923E+02	4.52907E+02	4.50211E+02
4.48406E+02	4.47199E+02	4.46361E+02	4.45070E+02

4.43126E+02	4.40197E+02	4.37250E+02	4.35276E+02
4.33881E+02	4.32386E+02	4.30136E+02	4.26749E+02
4.23350E+02	4.21077E+02	4.19466E+02	4.18301E+02
4.16554E+02	4.13932E+02	4.10001E+02	4.04114E+02
3.95323E+02	3.82289E+02	3.63241E+02	3.44986E+02
3.33305E+02	3.25734E+02	3.20782E+02	3.17522E+02
3.15367E+02	3.13938E+02	3.13030E+02	3.10450E+02
3.06610E+02	3.00914E+02	2.95293E+02	2.91585E+02
2.89207E+02	2.86898E+02	2.83450E+02	2.78308E+02
2.73202E+02	2.69817E+02	2.67607E+02	2.66661E+02
2.65244E+02	2.63121E+02	2.59941E+02	2.55185E+02
2.48075E+02	2.37463E+02	2.21644E+02	2.05918E+02
1.95473E+02	1.88524E+02	1.83897E+02	1.80813E+02
1.78759E+02	1.77390E+02	1.76490E+02	1.75866E+02
1.74948E+02	1.73606E+02	1.71672E+02	1.68940E+02
1.65190E+02	1.60252E+02	1.54105E+02	1.47005E+02
1.39544E+02	1.32618E+02	1.28942E+02	
0.2000	1500.0	6.0	845.0

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