- For temperatures below 50°F (later versions use the new wind chill formula result here (calculate the wind chill increment using the difference between the air temperature and wind chill)):
    - For the earlier display console versions and WeatherLink version 5.0 or 5.1: use the wind chill calculation as the base temperature.
    - For the WeatherLink software (versions 5.2 through 5.5.1): use the new heat index formula (as described in the heat index section) as the base temperature and calculate the wind chill increment using the difference between the air temperature and wind chill (which is always a negative number).

The resulting value is the wind term, which will be added to the humidity term and subsequently the sun term as indicated below.
Note: The WeatherLink software (version 5.2 through 5.5.1) offers a variable does not include the sun term in its calculation. It shows the result as the "THW Index" or Temperature-Humidity-Wind Index. This value indicates the "apparent" temperature in the shade due to these factors.

SUN FACTOR

The third term is sun. This term, *Qg*, is actually a combination of four terms (direct incoming solar, indirect incoming solar, terrestrial, and sky radiation). The term depends upon wind speed to determine how strong an effect it is. The value is limited to between −20 and +130 W/m^2 in the Vantage Pro2 console firmware and WeatherLink software versions 5.6 or later.

REFERENCES

Steadman, R.G., 1979: The Assessment of Sultriness, Part II: Effects of Wind, Extra Radiation and Barometric Pressure on Apparent Temperature. *Journal of Applied Meteorology, July 1979.*

"Media Guide to NWS Products and Services", National Weather Service Forecast Office, Monterey, CA, 1995.

Quayle, R.G. and Steadman, R.G., 1998: The Steadman Wind Chill: An Improvement over Present Scales. *Weather and Forecasting, December 1998*

BAROMETRIC PRESSURE

What is it:
The weight of the air that makes up our atmosphere exerts a pressure on the surface of the earth. This pressure is known as atmospheric pressure. Generally, the more air above an area, the higher the atmospheric pressure, this, in turn, means that atmospheric pressure changes with altitude. For example, atmospheric pressure is greater at sea-level than on a mountaintop. To compensate for this difference and facilitate comparison between locations with different altitudes, atmospheric pressure is generally adjusted to the equivalent sea-level pressure. This adjusted pressure is known as barometric pressure. In reality, the Vantage Pro and Vantage Pro2 measures atmospheric pressure. When entering the location's altitude in Setup Mode, the Vantage Pro and Vantage Pro2 calculates the necessary correction factor to consistently translate atmospheric pressure into barometric pressure.

Barometric pressure also changes with local weather conditions, making barometric pressure an extremely important and useful weather forecasting tool. High pressure zones are generally associated with fair weather while low pressure zones are generally associated with poor weather. For forecasting purposes, however, the absolute barometric pressure value is generally less important than the change in barometric pressure. In general, rising pressure indicates improving weather conditions while falling pressure indicates deteriorating weather conditions.

The following section applies to Vantage Pro and Vantage Pro2 systems only:

Parameters Used: Outside Air Temperature, Outside Humidity, Elevation, Atmospheric Pressure

Formula:
Simply,

$P_{SL} = P_S * (R)$,

where P_{SL} is sea level pressure, P_S is the unadjusted reading sensed by the Davis barometer, and R is the reduction ratio, which is determined as follows:

First, Tv (virtual temperature in the "fictitious column of air" extending down to sea-level) can be determined as follows. The result is in degrees Rankine, which is similar to Kelvin except it uses a Fahrenheit scale divisions rather than Celsius scale divisions:

$Tv = T + 460 + L + C$,

where T is the average between the current outdoor temperature and the temperature 12 hours ago (in Fahrenheit) in whole degrees. L is the typical lapse rate, or decrease in temperature with height (of the "fictitious column of air"), as calculated by:

$L = 11\ Z/8000$,

where L is a constant value with units in °F. Z is elevation, which must be entered in feet.

The current dewpoint value and the station elevation are necessary to compute C. C is the correction for the humidity in the "fictitious column of air". It is determined from a lookup table (provided in the attached table). The table consists of dewpoints in °F every 4°F and elevations in feet every 1500 feet. Linear interpolation is performed to obtain the correct reduced pressure value. For dewpoints below –76°F, C = 0; for dewpoints above 92°F, a dewpoint of 92°F is assumed.

Now, Tv can be determined. From this, the following can be computed:

Exponent = $[Z/(122.8943111*Tv)]$

Once this exponent is computed, R can be computed from the following:

R = 10^[Exponent].

Thus, $P_{SL} = P_S * (R)$ can be calculated. Pressure can be in any units (R is dimensionless) and still yield the correct value.

This procedure is designed to produce the correct reduced sea-level pressure as displayed. This requires the user to know their elevation to at least ±10 feet to be accurate to every .01" Hg or ±3 feet to be accurate to every 0.1 mb/hPa.

This is a simplified version of the official U.S. version in place now. The accepted method is to use lookup tables of ratio reduction values keyed to station temperature. These are based on station climatology. These values are unavailable for every possible location where a Davis user may have a station, thus this approach is not suitable.

It should be noted that if a sensor's pressure readings require adjustment, the user can adjust either the uncorrected or the final reading to match the user's reference, as appropriate. If the user chooses to measure uncorrected atmospheric pressure or use another reduction method, they should set their elevation to zero. Subsequently, output data using the VantageLink can be read by or exported to another application and converted as desired.

The calibration of the sensor is a separate one time function performed on the unit during the manufacturing process. It is a completely independent operation from the calculation the Vantage Pro and Vantage Pro2 console makes to display a reading corrected to sea-level. The calibration is done to ensure the sensor reads uncorrected or raw atmospheric pressure (not barometric pressure) properly. Any properly functioning unit will read the uncorrected atmospheric pressure within specifications. However, limits in the displayable range of the bar value may prevent the user from setting an incorrect elevation for their location. That is, a user at sea-level, may see a dashed reading if they set their unit to 5000' elevation or vice-versa. So, the best way to tell if a unit is functioning properly, is:

- use a reference that has been adjusted to indicate sea-level pressure and setting the Vantage Pro and Vantage Pro2 console to the proper elevation or
- use a reference that is reading the raw, uncorrected atmospheric pressure and set the Vantage Pro and Vantage Pro2 console elevation to zero

and verify that these readings are comparable.

ALTIMETER SETTING and CWOP APRS

The CWOP program in NOAA prefers to receive altimeter setting data rather than barometric pressure. This feature in WeatherLink 5.7 automatically calculates the correct altimeter setting using the user-specified elevation. Monitor II and Perception II users should set their barometer reading to match the altimeter setting of the nearest National Weather Service (NWS) weather station. Simply enter your zip code on the NWS home page to get the nearest observation. This is usually found at the "2 Day History" (detailed observation section) link under Current Conditions section. http://www.nws.noaa.gov/ . For users outside the United States, contact your country's national meteorological service.

Altimeter Formula, *A*:

$A = (P^N + K*Z)^(1/N)$, where *P* is the raw station pressure (in. Hg), $N = 0.1903$, $K = 1.313E-5$, *Z* is elevation (feet).

REFERENCE

"Smithsonian Meteorological Tables". Smithsonian Institution Press, Washington, DC, 4th Ed. 1968.

"Federal Standard Algorithms for Automated Weather Observing Systems used for Aviation Purposes". Office of the Federal Coordinator for Meteorological Services and Supporting Research, Washington, DC, 1988

RAINFALL

RAINFALL TOTAL

Unlike previous Davis systems, the Vantage Pro and Vantage Pro2 comes with only one type of rain collector. It is equipped with a 0.01" rain collector. All Vantage Pro and Vantage Pro2s physically measure in increments of 0.01 in. The system has a prevision for other types should they be added in the future.

The Vantage Pro and Vantage Pro2 is pre-configured for this type of rain collector. In the series of "Setup Screens", there is one for "Rain Collector". Simply press the DONE key to move to the next screen. By default, it should be set to ".01" Rain Collector". If it isn't, use the "+" and "-" arrow keys to select this type.

The rain display's units may be changed from inches to millimeters by pressing 2ND, then the UNITS key while in "Current Screen" mode with one of the rain fields selected. If millimeters is displayed, the console converts from inches to mm. If display millimeters is displayed, the counter will occasionally skip a reading due to rounding.

RAINFALL RATE

Parameters Used: Rain Total (actually, rain rate is a measured variable in the sense that it is measured by the ISS and transmitted to the display console, whereas all other calculated variables are determined by the console from data received from the ISS.)

Formula:

Under normal conditions, rain rate data is sent with a nominal interval of 10 to 12 seconds. Every time a rain tip or click occurs, a new rain rate value is computed (from the timer values) and the rate timers are reset to zero.

Rain rate is calculated based on the time between successive tips of the rain collector. The rain rate value is the highest rate since the last transmitted rain rate data packet. (Under most conditions, however, a rain tip will not occur every 10 to 12 seconds.)

If there have been no rain tips since the last rain rate data transmission, then the rain rate based on the time since that last tip is indicated. This results in slowly decaying rate values as a rain storm ends, instead of showing a rain rate which abruptly drops to zero. This results in a more realistic representation of the actual rain event.

If this time exceeds roughly 15 minutes, than the rain rate value is reset to zero. This period of time was chosen because 15 minutes is defined by the U.S. National Weather Service as intervening time upon which one rain "event" is considered separate from another rain "event". This is also the shortest period of time that the Umbrella will be seen on the display console after the onset of rain.

REFERENCES

"Surface Weather Observations and Reports ". Office of the Federal Coordinator for Meteorological Services and Supporting Research, Washington, DC, 1998

MOON PHASE (Vantage Pro, Vantage Pro2, and WeatherLink 5.X+ only)

Parameters Used: Latitude, Longitude, Time and Date, Time Zone, Daylight Savings Time Setting

Sufficient accuracy is obtained from the following formula for i, the phase angle:

$$i = 180° - D - 6.289° \sin M' + 2.1° \sin M - 1.274° \sin (2D - M') - 0.658° \sin 2D$$

where

- D is the mean elongation of the moon (the maximum angular distance between the earth and the moon)
- M' is the moon's mean anomaly (angular distance, measured from where the moon is closest to the earth in its orbit, if it moved around the earth at a constant angular velocity)
- M is the sun's mean anomaly (angular distance, measured from where the earth is closest to the sun in its orbit, if it moved around the earth at a constant angular velocity)

and the terms in the equation provide increasing amounts of mean accuracy to calculate the phase angle as follows (hr:min):

- D = 20:57
- $6.289° \sin M'$ = 8:35
- $2.1° \sin M$ = 4:26
- $1.274° \sin (2D - M')$ = 1:56
- $0.658° \sin 2D$ = 0:38

Note: these equations assume that the sun and moon both revolve around the earth, for simplicity. However, when addressing the positions in orbit, it is actually the earth revolving around the sun, so this should be understood when trying to understand the physical meaning described in the definitions.

The equations for D, M' and M are as follows:

$D = 297.8501921 + 12.19074911 * days$
$M' = 134.9633964 + 13.06499295 * days$
$M = 357.52911 + 0.985600281 * days$,

Where *days* (in days and fractions of days) is the number of days since Jan 1st, 2000 at 12:00 UTC

Local time needs to be converted to UTC in order to be used in the formulas:

UTC = Local Time - Time Zone Offset (including adding one hour for daylight savings if and when in use)

The phase angle is modified so that it can be used to determine whether the moon is waxing (illuminated portion increasing in size) or waning (decreasing in size):

If $i >= 180°$, then $k = 1 - (k / 2)$

Now, the phase angle can be used to determine which phase the moon is in:

$i = (i * 8) + 0.5$

The result is interpreted as follows:
0 = New Moon, 1 = Waxing Crescent, 2 = First Quarter, 3 = Waxing Gibbous, 4 = Full Moon, 5 = Waning Gibbous, 6 = Last Quarter, 7 = Waning Crescent

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k is the fraction of the moon's disk that is illuminated. It is used to draw the moon phase icon in the Bulletin.

$k = (1 + \cos i)/2$

k is a number between zero and one that indicates how much of the moon's disk should be drawn as lit. It indicates the "terminator's" (boundary between light and dark face) position on the observed face of the moon.

k can also be interpreted as listed below
0.00 = New Moon
0.25 = First Quarter
0.50 = Full Moon
0.75 = Last Quarter

REFERENCE

Meeus, Jean: "Astronomical Algorithms". Willman-Bell, Richmond, VA, 2nd Ed. 1998.

DESCRIPTION OF EVAPOTRANSPIRATION (ET), REFERENCE ET, AND THE CROP COEFFICIENT

Evapotranspiration (ET) is the amount of water that moves from the ground (and plants on the ground) to the atmosphere through both evaporation and transpiration. It is primarily important to people who are monitoring plant growth and associated water usage.

Measuring actual ET for a given location requires the measurement of weather variables at different heights at the same location and is beyond the capabilities of the current Davis weather stations. Instead, a single set of weather data measurements (described in detail below) are used to calculate a Reference ET (ET_0). ET_0 is the amount of ET that is expected at a location with specified reference conditions under the actual weather conditions. The two most common reference conditions used for agricultural purposes are the grass reference – well watered grass that completely shades the ground, is uniformly clipped to a few inches in height – and the alfalfa reference – similar to the grass reference with alfalfa instead of grass, and a different height. The Davis ET calculations all calculate ET_0 for a grass reference.

To determine actual ET from a reference ET_0, multiply the ET_0 by a crop coefficient (K_c). The crop coefficient accounts for the type of plant, the maturity of the plant, and may include local factors such as soil type. Davis Instruments does not supply crop coefficients. It is up to the individual user to determine what K_c is appropriate. See below for a list of some sources. It is very important, when selecting K_c to make sure that the coefficient is for use with a grass reference. Do not use coefficients that were derived from alfalfa referenced ET_0.

THE DIFFERENT DAVIS ET_0 CALCULATIONS

There are three ways that ET is calculated by Davis weather stations. They differ in how the weather data values are gathered and in how Net Radiation is calculated. The three methods are: GroWeather calculated on the console, GroWeather calculated on a PC, and Vantage Pro and Vantage Pro2 (calculated on the console). In all methods, hourly ET values are calculated from hourly averages of weather variables. The differences arise from differences in the computational abilities of the GroWeather station, Vantage Pro and Vantage Pro2 station and a PC.

DATA SAMPLING AND VARIABLES REQUIRED FOR CALCULATION

The GroWeather console calculated ET_0 samples Temperature, Humidity, Wind Speed, Solar Radiation over a one hour period. This sampling is independent of sampling undertaken for the creation of archived data records. At the end of the hour, the arithmetic mean is calculated for each value by dividing the sum of the sampled data values by the number of samples taken. The number of samples is tracked for each sensor independently in case some sensors are not connected for some part of the period. In addition, the raw Barometer value (i.e. not corrected for altitude) at the end of the hour is read.

The temperature is calculated in tenths of a degree F, the humidity is calculated in tenths of a percent, wind speed is calculated in miles per hour, solar radiation is calculated in watts per square meter, and atmospheric pressure is read in thousandths of an inch of mercury. All arithmetic is in integers. Values that use fractions are represented by multiplying by an appropriate value. The formulas given below that use functions more complicated than addition, subtraction, multiplication, and division are calculated with table lookups with linear interpolation where appropriate.

The GroWeather PC calculated ET_o uses data from the historical archived data to calculate the average temperature, humidity, wind speed, solar radiation; and the final atmospheric pressure. In addition, the software uses the latitude, longitude, and time zone settings set in the Station Configuration dialog.

The Vantage calculated ET_o takes samples of Temperature, Wind Speed, and Solar Radiation over a one hour period and derives an average value in a manner similar to the GroWeather console. Instead of sampling the humidity and deriving an "average humidity" for the hour, each time the temperature is sampled, the value of the saturation vapor pressure and actual water vapor pressure are calculated from the current values of temperature and humidity and sampled. These vapor pressure values (in kPa) are used to compute the average saturation vapor pressure and the average water vapor pressure for the hour. The Vantage has the capability to perform floating point arithmetic.

GENERAL ET_O CALCULATION

For the most part, these equations are applicable to all 3 calculation methods. Where they differ they are marked as follows: (GWc) applies to the GroWeather Console calculation, (GWpc) applies to the GroWeather PC calculation, and (VP) applies to the Vantage calculation

Measured Variables

T_F mean air temperature in tenths of a degree Fahrenheit
U_{MPH} mean wind speed in whole miles per hour
R_s mean solar radiation in whole Watts per square meter
H mean humidity in percent (value is between 0 and 100). (GWc and GWpc only)
P_{in} atmospheric air pressure (not corrected for elevation) at the end of the hour; thousandths of inches of mercury.

Calculated Values
(unit conversions)

T_C mean temperature in Celsius

$$T_c = (T_F - 32) * 5/9$$

T_K mean temperature in Kelvin

$$T_K = T_C + 273.16$$

P_{kPa} atmospheric pressure in kPa

$$P_{kPa} = P_{in} * 33.864$$

$U_{m/s}$ mean wind speed in meters per second

$$U_{m/s} = U_{MPH} * 0.44704$$

R_n average net radiation over the hour as described in the next section. Watts per square meter

e_a saturation water vapor pressure in kPa

$$e_a = 0.6108 * e^{\left(\frac{17.27 * T_C}{T_C + 237.3}\right)}$$

e_d actual water vapor present

$$e_d = e_a * \frac{H}{100}$$

Δ slope of the saturation vapor curve at T_C

$$\Delta = \frac{e_a}{T_K} * \left(\frac{6790.4985}{T_K} - 5.02808\right)$$

γ psychometric constant

$$\gamma = 0.000646 * (1 + 0.000946 * T_C) * P_{kPa}$$

W weighting factor that expresses the relative contribution of the radiation component

$$W = \frac{\Delta}{\Delta + \gamma}$$

F the wind function indicates the amount of energy that the wind contributes towards ET. There are two functions, one for day (solar radiation > 0) and one for night.

$$F_d = 0.030 + 0.0576 * U_{m/s}$$

$$F_n = 0.125 + 0.0439 * U_{m/s}$$

λ latent heat of vaporization. Used to convert net radiation in Watts per square meter into the amount of water evaporated in mm

$$\lambda = 694.5 * (1 - 0.000946 * T_C)$$

ET_o the hourly potential ET in mm

$$ET_o = W * \frac{R_n}{\lambda} + (1 - W) * (e_a - e_d) * F$$

NET RADIATION

Solar radiation is the primary source of energy that drives evapotranspiration, but what is important is the net radiation, incoming radiation minus outgoing radiation, at all wavelengths.

The Davis solar radiation sensor measures incoming radiation in the visible portion of the spectrum. From this we must subtract out the component that is reflected off the plant leaves. This value is called the albedo.

In addition to the radiation in the visible spectrum, we must also take account of the longer wavelength thermal radiation. This is modeled as black-body radiation coming from three sources at the measured air temperature. The first source is the portion of the sky that does not contain clouds, the second source is the portion of the sky containing clouds, and the third source is the ground radiating into the sky. The first two sources are incoming radiation and the third is outgoing radiation. In order to determine the relative contributions of source one and two, we need to calculate the percentage of the sky that is covered by clouds.

The cloud cover fraction is estimated by comparing the actual mean solar radiation received against the amount we would have received if the sky was clear. In order to calculate the clear sky radiation, it is necessary to calculate the height of the sun above the horizon (solar altitude angle). The altitude of the sun depends, in turn, on the latitude, longitude, day of the year, and time of the day.

The net radiation equation cited in the reference section does not represent the exact method that Davis weather stations use to calculate net radiation.

ACCURACY

These equations were modeled after the ones used by the California Irrigation Management Information System (CIMIS), a program run by the California Department of Water Resources. Therefore, the accuracy of the Davis ET_0 calculations are made against the ET_0 calculations made by CIMIS. Some of the differences between Davis and CIMIS ET_0 calculated values are due to differences in resolution, rather than accuracy.

There are two major factors that cause differences between Davis and CIMIS ET_0 calculations: differences in sensor measurements, and differences in net radiation values.

On the GroWeather, all wind averages are in one mile per hour increments, whereas CIMIS data has a higher resolution. The Vantage Pro and Vantage Pro2 measures wind speed in one mile per hour increments, but maintains a higher resolution for hourly averages.

As explained above, there are several different ways to calculate a hourly average vapor pressure and saturation vapor pressure values. The CIMIS method is to calculate and sample the vapor pressure value as described for the Vantage Pro and Vantage Pro2. However, the saturation vapor pressure is calculated from the average temperature. This method will produce a saturation vapor pressure that is equal or lower than the average of the sampled saturation pressures.

The net radiation formula given above are all approximations of the formula CIMIS uses. CIMIS either directly measures net radiation, or uses a formula that includes a provision for an empirically derived cloud cover factor. CIMIS determines this factor either from data collected at the site over a four year period, or from other sites in the same region. Twelve factors are determined, one for each month.

REFERENCES

General reference on ET
Jensen, M .E., Burman, R. D., Allen, R. G., Editors (1990) "*Evapotranspiration and irrigation water requirements.*" ASCE Manuals and Reports on Engineering Practice No 70.

Paper describing CIMIS' equations and methodology:
Snyder, R. L., Pruitt, W. O. (1992). "Evapotranspiration Data Management in California" *Irrigation & Drainage Session Proceedings/Water Forum '92 EE, HY, IR, WR, div/ASCE*

Paper describing net radiation:
Dong, A, Grattan, S. R., Carroll, J. J., Prashar, C. R. K. (1992). "Estimation of net radiation over well-watered grass." *J. of Irrigation and Drainage Engineering*, Vol. 118, No. 3 ASCE

Web sites with useful information
CIMIS home page
http://wwwdpla.water.ca.gov/cgi-bin/cimis/cimis/hq/main.pl

Provides some guidelines for water requirements for growing landscape plants in California
http://wwwdpla.water.ca.gov/urban/conservation/landscape/wucols/index.html

SUNRISE/SUNSET (Vantage Pro, Vantage Pro2, and WeatherLink only)

Parameters Used: Latitude, Longitude, Time and Date, Time Zone, Daylight Savings Time Setting

Sunrise and sunset is a matter of finding when, local time, the sun is on the horizon. The following equations describe the position of the sun in the sky:

Solar altitude, α, is the angular distance of the sun above the horizon, given by:

$$\sin \alpha = \sin \phi \sin \delta + \cos \phi \cos \delta \cos h$$

ϕ is latitude, δ is the declination angle of the sun, h is the hour angle

declination angle is the latitude on the earth at which the sun is directly overhead (south latitudes are indicated as a negative number)

hour angle is the non-negative angular distance east or west from directly overhead

These formulas indicate the true geometric position of the sun. When the sun is on the horizon (as in the case of sunrise and sunset), refraction by the atmosphere will alter the apparent position of the sun. Under average conditions, the sun will appear at the horizon when it is actually 34' (0.567°) below the horizon. Since sunrise and sunset is defined as when the upper half of the sun is visible on the horizon, and the radius of the sun when on the horizon is 16' (0.267°), sunrise and sunset are defined when the geometric position of the sun is 50' (0.833°) below the horizon. This is especially critical in polar regions.

The report also generates twilight times. There are three separate twilight times listed for both morning and evening:

Astronomical Twilight (Astro) is defined as the time at which the center of the sun is 18° below the horizon. At this time, stars and planets of sixth magnitude are visible directly above and generally there is no trace of twilight glow on the horizon. It's the time of complete darkness without an artificial light source.

Nautical Twilight (Naut) is defined as the time at which the center of the sun is 12° below the horizon. Distinguishing the outlines of objects on the ground is impossible past this point toward darkness, thus it marks the point at which navigation is impossible without an artificial light source.

Civil Twilight (Civil) is defined as the time at which the center of the sun is 6° below the horizon. At this time, stars and planets of first magnitude are visible and suspension of outdoor activities is required (on a clear day) without artificial lighting. Civil twilight is roughly 30 minutes long during the equinox.

The procedure to calculate any of these parameters is as follows. Details on the equations used and time convention and unit conversions follow this brief description:

1. First assume that a sunrise event occurred at 6:00 am local time, a sunset event at 6:00 pm local time. The equations used to describe the position of the sun already require a time, so we must make a first "guess" as to when the event will be.

2. Convert this local time to UTC time. The equations used to define the position of the sun (in this case, on the horizon) use UTC time.
3. Calculate the **declination** and subsequently the **hour angle** of the sun using this UTC time and the specified solar altitude of the given event.
4. Convert the resultant **hour angle** (which is in geometric coordinates) to UTC time.
5. Take the resultant UTC time to again *recalculate* the **declination** and subsequently the **hour angle** using this more accurate indication of the position of the sun.
6. Convert the resultant **hour angle** (which is in geometric coordinates) to UTC time.

To calculate the **hour angle** of the sun, *h*, at the given altitude (which is defined by sunrise/sunset or the twilight parameters), so rearranging the equation for the sun's altitude above for the hour angle, we get:

$$\cos h = \frac{\sin \alpha - \sin \phi \sin \delta}{\cos \phi \cos \delta}$$

If the result of this equation is undefined, that is, cos $h > 1$ or $h < 1$, then the event did not occur.

Otherwise, we can solve for $\cos^{-1}(h)$. The value of *h* here is an angle, which must be converted to a 24 hour time base. The procedure is as follows:
Convention: h = 0 = midnight, *h* = 90 = 6:00 am, *h* = 180 = noon, *h* = 270 = 6:00 pm
If h is determined to be a sunrise, then (180 – *h*)/15 is the value in hours (and fractions of hours), otherwise
If *h* is determined to be a sunset, then (180 + *h*)/15 is the value in hours (and fractions of hours)
The result is in **solar time**, which, in this convention, at Noon, the **mean sun** is at its highest point in the sky for the day, which can differ considerably from local time.

The sun's **declination** angle, δ, is determined as follows:

$\delta = \sin^{-1} (\sin T \sin \epsilon)$

$T = L + C$

L = (280.46646 + 0.98564736**days*)

C = ((1.914602-0.00000013188**days*)*sin *M* +
(0.019993-0.000000002765*days)*sin 2*M*)

$\epsilon = 23.43929°$

M = (357.52911 + 0.985600281**days*)

where *days* (including fractional days) is the number of days since Jan 1st, 2000, 12:00 UTC in UTC

T is the true anomaly of the sun (the angular distance between where the earth is closest to the sun is its orbit and the actual position in orbit)

L is the mean longitude of the sun (mean angular distance measured around the earth's orbit from the position at the time of equinox)

C is the center of the sun or the difference between the true, T, and mean, M, anomalies of the sun (determines the location of the sun resolving the differences between the actual position of the sun and the position the sun would have if the earth's angular motion were uniform)

M is the mean anomaly of the sun (same as true anomaly except it assumes the earth moves around the sun at a constant angular velocity), same as mean anomaly of the earth

ϵ is the obliquity of the earth (the amount the earth is tilted on its axis), which is constant for a century or so (It has an error in the year 2100 of only 0.013° when this constant is used.)

Note: these equations assume that the sun revolves around the earth, for simplicity. However, when addressing the positions in orbit, it is actually the earth revolving around the sun, so this should be understood when trying to understand the physical meaning described in the definitions.

Time Conversions

First, convert local mean solar time to local actual solar time. (Note: When calculating sunrise and sunset, the 6:00 am or 6:00 pm local time is considered actual solar time for simplicity. In the second iteration, when higher precision is needed, the result, local mean solar time, is corrected to actual solar time):

Actual Solar Time = Local Mean Solar Time – E

$E = y \sin 2L - 2e \sin M + 4ey \sin M \cos 2L$

where e is eccentricity of the earth's orbit (how much of an elliptical shape it has) as described below, and M is the sun's mean anomaly and L is the sun's mean longitude as described earlier

$e = 0.016708634 - 0.0000000011509 * days$

$y = \tan^2 (\epsilon / 2)$

where ϵ is obliquity as described earlier

The equation of time must be taken into account in order to determine the exact local time (as opposed to the local mean time). This specifies the difference between apparent time and mean time. Stated another way, it is the difference between the true position of the sun and the mean position of the sun. The mean sun assumes that its motion across the sky is uniform.

Then to convert to actual local solar time to local civil time (local civil time is refers to the time convention used by the public at large within a given time zone), take into account how far west or east of the "standard meridian" for their particular time zone. Fractions of minutes must be incorporated to avoid rounding errors. The **standard meridian** is determined as follows:

Standard Meridian = |(UTC Offset)| * 15

UTC Offset should include whether or not Daylight Savings Time is currently in use and be the absolute value or always positive value of the offset in this case.

Then, determine the offset from the standard meridian in hours:

Local Offset = (Standard Meridian - Longitude) / 15

Summarized, the formula for determining sunrise and sunset in local civil time:

Local Civil Time = Mean Solar Time – E + Local Offset

The Davis software further converts the results into UTC so a standard time base is used and thus, it is much easier to use any combination of Time Zone and latitude/longitude coordinates. Some may prefer to have the sunrise/sunset times in UTC. Others, for example, may want to determine what time it is in San Francisco when the sunrise in Tokyo occurs. Here is the relationship between UTC and local civil time:

UTC = Local Civil Time – UTC Offset

In general, UTC offsets are negative if the longitude is west, positive if east. The UTC Offset includes any corrections for Daylight Savings Time (if specified) and must be converted into hours and minutes as needed.

REFERENCES

Meeus, Jean: "Astronomical Algorithms". Willman-Bell, Richmond, VA, 2nd Ed. 1998.

"Smithsonian Meteorological Tables". Smithsonian Institution Press, Washington, DC, 4th Ed. 1968.

Davis Instruments
3465 Diablo Avenue, Hayward, CA 94545 U.S.A.
Phone: 510-732-9229 • Fax: 510-732-9188
sales@davisnet.com • http://www.davisnet.com

ATTACHMENT 2

UNSAT-H MODELING ANALYSIS INPUT AND OUTPUT DATA

UNSAT-H MODEL INPUTS

A.1 Options, Constraints & Limits

Record	Format	Variables	Selection
1	A	TITLE,	entral Maui Landfill, Maximum Rainfa
2	2I	**IPLANT, NGRAV** IPLANT = 0, no plants = 1, plants NGRAV = 0, horizontal = 1, vertical	1, 1,
3	3I	**IFDEND, IDTBEG,IDTEND.** IFDEND = Last day of last year IDTBEG = first day of first year IDTEND = last day of last year	365,1,365,
4	5I	**IYS,NYEARS,ISTEAD,IFLIST,NFLIST** IYS = Year of simultation NYEARS = no. of years ISTED = 0, transient solution IFLIST = 0, met. data in input file NFLIST = no. of file names	1,1,1,0,1,
5	2I	**NPRINT,STOPHR** NPRINT = 0, daily & end-of-year summaries STOPHR = stopping time	0,24.0
6	3I,R	**ISMETH,INMAX,ISWDIF,DMAXBA,** ISMETH = 0, standard method of solution INMAX = No. of iterations to solve water flow ISWDIF = option for time step control DMAXBA = time step control parameter	0,2,1,0.001
7	3R	**DELMAX,DELMIN,OUTTIM,** DELMAX = Maximum time step (hr) DELMIN = minimum time step (hr) OUTTIM = normal time step (hr)	0.15,1.0E-07,0.0,
8	5R	**RFACT,RAINIF,DHOTL,DHMAX,DHFACT,** RFACT = maximum time step factor RAINIF = rainfall time step factor DHOTL = iteration control parameter DHMAX = iteration control parameter DHFACT = time step reduction if HDMAX >0	2.0,1.0E-06,0.0,0.0,0.0,
9	2I,R	**KOPT,KEST,WTF** KOPT = 4, Van Genuchten properties used KEST = 3, geometric mean used to estimate liquid conductivity WTF = weighting factor (not used)	4,3,0.0,
10	4I	**ITOPBC,IEVOPT,NFHOUR,LOWER,** ITOPBC = 0, surface boundary condition = flux IEVOPT = 1, evaporation allowed NFHOUR = 2, program distributes daily PET LOWER = 1, unit gradientlower boundary	0,1,2,1,
11	4R	**HIRRI,HDRY,HTOP,RHA,** HIRRI = minimum head to which soil can wet up (cm) HDRY = maximum head to whch soil can dry out (cm) HTOP = constant head value of the surface whenITOPBC = 1 (cm) RHA = relative humidity of air (not used)	0.0,1.0E+06,0.0,0.99,
12	3I	**IETOPT,ICLOUD,ISHOPT** IETOPT = 0, PET data used ICLOUD = 0, no cloud cover data used ISHOPT = 0, constant head surface	0,0,0,
13	I,R	**IRAIN,HPR,** IRAIN = 0, hourly computations of rainfall HPR = 0, hourly rate if IETOPT = 1	0,0.0,
14	I,3R,A	**IHYS,AIRTOL,HYSTOL,HYSMAX,HYFILE** IHYS = 0 - no hysteresis; all others = 0	0,0.0,0.0,0.0,0,

15	2I,R	**IHEAT,ICONVH,DMAXHE** IHEAT = 0, no heat calculations, others = 0	0,0,0.0,
16	I,3R,A	**UPPERH,TSMEAN,TSAMP,QHCTOP** All = 0 (no heat flow)	0,0.0,0.0,0.0,
17	1,2R	**LOWERH,QHLEAK,TGRAD** All = 0 (no heat flow)	0.0.0,0.0,
18	1,3R	**IVAPOR,TORT,TSOIL,VAPDIF** IVAPOR = 1, vapor flow allowed TORT = tortuosity factor for soil = 0.66 TSOIL = average soil temp = 77 F = 298 K VAPDIF = diffusion coeffiecient = 0.24 cm2/sec	1,0.66,298.0,0.24,
19	2I	**MATN, NPT** MATN = 3 = no. of different soil materials NPT = number of nodes 40 + 20+ 20	4, 84,
20	4(I,R) per line	**MAT,Z** I = Material No. 1 = vegetative layer, 0.5 ft = 15.2 cm 2 = final cover soil, 3 feet = 91.5 cm 3 = waste, 2 ft = 61.0 cm Z = depth below surface, cm	See separate listing

A.1 Options, Constraints & Limits

Record	Format	Variables	Selection
1A	A	**DUMMY = Soil Type title**	Compost Soil Water Retention Properties,
2A	4R	**THET,THETR,VGA,VGN,** THET = saturated water content THTR = residual water content VGA = van Genuchten alpha coefficient VGN = van Genuchten n coefficient	0.3464,0.0130,0.0299,1.2403,
3A	A	**DUMMY = Soil Type title, HC Data to follow**	Compost Soil Hydraulic Conductivity,
4A	5R	**RKMOD,SK,VGA,VGN,EPIT,** RKMOD = 2, Mualem conductivity model SK = Sat. hydraulic conductivity, cm/hr VGA = van Genuchten alpha coefficient VGN = van Genuchten n coefficient EPIT = 0.5, standard exponsnt for Mualem	2,1.8,0.0299,1.2403,0.5, (Note: 1.8 cm/hr =5.0E-04 cm/sec)
1B	A	**DUMMY = Soil Type title**	ET Cover Soil Water Retention Properties,
2B	4R	**THET,THETR,VGA,VGN,** THET = saturated water content THTR = residual water content VGA = van Genuchten alpha coefficient VGN = van Genuchten n coefficient	0.3464,0.0130,0.0299,1.2403,
3B	A	**DUMMY = Soil Type title, HC Data to follow**	ET Cover Soil Hydraulic Conductivity,
4B	5R	**RKMOD,SK,VGA,VGN,EPIT,,** RKMOD = 2, Mualem conductivity model SK = Sat. hydraulic conductivity, cm/hr VGA = van Genuchten alpha coefficient VGN = van Genuchten n coefficient EPIT = 0.5, standard exponsnt for Mualem	2,0.994,0.036,1.2403,0.5, (Note: 0.036 cm/hr =1.0E-05 cm/sec)
1C	A	**DUMMY = Soil Type title**	Foundation Layer Soil Water Retention Properties,
2C	4R	**THET,THETR,VGA,VGN,** THET = saturated water content THTR = residual water content VGA = van Genuchten alpha coefficient VGN = van Genuchten n coefficient	0.3464,0.0130,0.0299,1.2403,
3C	A	**DUMMY = Soil Type title, HC Data to follow**	ndation Layer Soil Hydrauiic Conducti
4C	5R	**RKMOD,SK,VGA,VGN,EPIT,,** RKMOD = 2, Mualem conductivity model SK = Sat. hydraulic conductivity, cm/hr VGA = van Genuchten alpha coefficient	2,0.994,0.036,1.2403,0.5, (Note: 0.036 cm/hr =1.0E-05 cm/sec)

		VGN = van Genuchten n coefficient EPIT = 0.5, standard exponsnt for Mualem	
1D	A	**DUMMY = Soil Type title**	Refuse Water Retention Properties,
2D	4R	THET,THETR,VGA,VGN, THET = saturated water content THTR = residual water content VGA = van Genuchten alpha coefficient VGN = van Genuchten n coefficient	0.53,0.11,0.26,2.22,
3D	A	**DUMMY = Soil Type title, HC Data to follow**	Refuse Hydraulic Conductivity,
4D	5R	RKMOD,SK,VGA,VGN,EPIT,, RKMOD = 2, Mualem conductivity model SK = Sat. hydraulic conductivity, cm/hr VGA = van Genuchten alpha coefficient VGN = van Genuchten n coefficient EPIT = 0.5, standard exponsnt for Mualem	2.0,0.36,0.26,2.22,0.5, ote: 1.00E-04 cm/sec = 3.6E-01 cm/h

A.3 INITIAL CONDITIONS

Record	Format	Variables	Selection
1	i	**NDAY** = day for which end-of-day suction head values are specified as initial conditions	0,
2	4R per line	H(1....npt Hh(1. . . . NPT) = initial suction head for each node, cm	500 for soil, 300 for waste (Repeat 20 times for assumed constant initial 100 cm throughout profile of 80 nodes

A.4 Plant Information

Record	Format	Variables	Selection
1A	6I	**LEAF,NFROOT,NUPTAK,NFPET,NSOW,NHRVST,** LEAF = 1, leaf area index values supplied NFROOT = 1, exponential relationship for root growth NUPTAK = 1, default for plant water uptake NFPET = 1, method of partitioning PET NSOW = day of year seeds germinate NRVST = day of year when plants stop transpiring	1,1,1,1,1,365, Assume vegetation active year around
2A	R	**BARE = fraction of soil bare of plants**	0.10,
1B	I	**NDLAI = No. of changes in LAI**	4,
2B	4(I,R) per line	IDLAI,VLAI IDLAI = day of year next LAI begins VLAI = LAI corresponding to corresponding day	1,1.0,90,1.5,180,0.5,300,1.0
1C	3R	**AA,B1,B2** AA = coefficient a in eq'n RLD=a exp(-bz) +C B1 = coefficient b B2 = coefficient c	1.163,0.129,0.03 ote: used default values for cheatgra:
2C	10I	**NTROOT** = growth day on which roots reach each node	See Separate data file
1D	3R	**HW,HD,HN** (repeat for each soil material HW = head corresponding to wilting point (cm) HD = head corresponding to transpiration beginning to decrease HN = head corresponding to anaerobic conditions	15000.0,1500.0,10.0, 15000.0,1500.0,10.0, 15000.0,1500.0,10.0,
1E	5R	**PCA,PCB,PCC,PCD,PCE** PCA = coeff. A in T=PET)(a+b*LAEexp(c) PCB = coeff. B PCE = coeff. C PCD = Lower limit PCE = upper limit	0.0,0.52,0.5,0.0,3.7, (default values)

A.5 Boundary Conditions

Record	Format	Variables	Selection
1A	8R per line	**PET(1:IDEND)** PET values for each day of year	See separate data file

1B	I	**NWATER** = total number of days of rain	61,
2B	3I,R	**IRDAY,IRTYPE,NP,EFICEN** IRDAY = day on which rain occurs IRTYPE = 1 = rainfall event NP = number of times during day when water application changes EFICEN = efficiency of water application	See separate data file
2B	2R per line	**RTIME,AMOUNT,** RTIME = time of day when water rate changes AMOUNT = the amount (cm) that falls until the next rate change	See separate data file

Nodes Analysis – Vegetative Layer

Soil Thickness 1 ft
30.48 cm

No. of Nodes 20

Equation $D = D_{n-1} + Ke^{c(n-1)}$

K = 0.1 cm

c = 0.392665

1/2 thickness depth = 7.62

Bottom depth = 30.48

Node n	Depth D	Spacing	Rounded Depth
1	0.00	0.1	0.0
2	0.15	0.15	0.15
3	0.37	0.22	0.37
4	0.69	0.32	0.69
5	1.17	0.48	1.17
6	1.89	0.71	1.89
7	2.94	1.05	2.94
8	4.50	1.56	4.50
9	6.82	2.31	6.82
10	10.24	3.43	10.24
11	15.32	5.07	15.32
12	20.39	5.07	20.39
13	23.82	3.43	23.82
14	26.13	2.31	26.13
15	27.69	1.56	27.69
16	28.75	1.05	28.75
17	29.46	0.71	29.46
18	29.94	0.48	29.94
19	30.26	0.32	30.26
20	30.48	0.22	30.48

1,	0.00 ,1,	0.15 ,1,	0.37 ,1,	0.69 ,
1,	1.17 ,1,	1.89 ,1,	2.94 ,1,	4.50 ,
1,	6.82 ,1,	10.24 ,1,	15.32 ,1,	20.39 ,
1,	23.82 ,1,	26.13 ,1,	27.69 ,1,	28.75 ,
1,	29.46 ,1,	29.94 ,1,	30.26 ,1,	30.48 ,

Nodes Analysis – ET Cover Soil

Soil Thickness	2	ft
	60.96	cm
No. of Nodes	40	
Equation	$D = D_{n-1} + Ke^{c(n-1)}$	
K =	0.2	cm
c =	0.1685232	

1/2 thickness depth	60.96	cm
Bottom depth	91.44	cm

Node n	Depth D	Spacing	Rounded Depth
1	30.52	0.1	30.52
2	30.76	0.24	30.76
3	31.04	0.28	31.04
4	31.37	0.33	31.37
5	31.76	0.39	31.76
6	32.23	0.46	32.23
7	32.78	0.55	32.78
8	33.43	0.65	33.43
9	34.20	0.77	34.20
10	35.11	0.91	35.11
11	36.19	1.08	36.19
12	37.46	1.28	37.46
13	38.97	1.51	38.97
14	40.76	1.79	40.76
15	42.88	2.12	42.88
16	45.38	2.51	45.38
17	48.35	2.97	48.35
18	51.86	3.51	51.86
19	56.01	4.15	56.01
20	60.93	4.92	60.93
21	65.84	4.92	65.84
22	70.00	4.15	70.00
23	73.51	3.51	73.51
24	76.47	2.97	76.47
25	78.98	2.51	78.98
26	81.10	2.12	81.10
27	82.88	1.79	82.88
28	84.39	1.51	84.39
29	85.67	1.28	85.67
30	86.75	1.08	86.75
31	87.66	0.91	87.66
32	88.43	0.77	88.43
33	89.08	0.65	89.08
34	89.63	0.55	89.63
35	90.10	0.46	90.10
36	90.49	0.39	90.49
37	90.82	0.33	90.82
38	91.10	0.28	91.10
39	91.34	0.24	91.34
40	91.44	0.10	91.44

2,	15.28 ,2,	30.76 ,2,	31.04 ,2,	31.37 ,
2,	31.76 ,2,	32.23 ,2,	32.78 ,2,	33.43 ,
2,	34.20 ,2,	35.11 ,2,	36.19 ,2,	37.46 ,
2,	38.97 ,2,	40.76 ,2,	42.88 ,2,	45.38 ,
2,	48.35 ,2,	51.86 ,2,	56.01 ,2,	60.93 ,
2,	65.84 ,2,	70.00 ,2,	73.51 ,2,	76.47 ,
2,	78.98 ,2,	81.10 ,2,	82.88 ,2,	84.39 ,
2,	85.67 ,2,	86.75 ,2,	87.66 ,2,	88.43 ,
2,	89.08 ,2,	89.63 ,2,	90.10 ,2,	90.49 ,
2,	90.82 ,2,	91.10 ,2,	91.34 ,2,	91.44 ,

Nodes Analysis -- Foundation Layer

Soil Thickness 1 ft

30.48 cm

No. of Nodes 20

1/2 thickness depth = 106.68 cm

Equation $D = D_{n-1} + Ke^{c(n-1)}$

Bottom depth = 121.92 cm

K = 0.2 cm

c = 0.738134

Node n	Depth D	Spacing	Rounded Depth
1	91.48	0.5	91.48
2	91.90	0.42	91.90
3	92.77	0.88	92.77
4	94.60	1.83	94.60
5	98.44	3.83	98.44
6	106.45	8.01	106.45
7	114.46	8.01	114.46
8	118.30	3.83	118.30
9	120.13	1.83	120.13
10	121.00	0.88	121.00
11	121.42	0.42	121.42
12	121.92	0.50	121.92

3,	91.48 ,3,	91.90 ,3,	92.77 ,3,	94.60 ,
3,	98.44 ,3,	106.45 ,3,	114.46 ,3,	118.30 ,
3,	120.13 ,3,	121.00 ,3,	121.42 ,3,	121.92 ,

Nodes Analysis -- Upper Waste Layer

Soil Thickness		1 ft												
		30.48 cm												
No. of Nodes		20		1/2 thickness depth =			137.16 cm							
Equation	$D = D_{n-1} + Ke^{c(n-1)}$			Bottom depth =			152.40 cm							
	K =	0.2 cm												
	c =	0.738134												
Node n	Depth D	Spacing	ɔunded Depth											
1	121.96	0.5	121.96											
2	122.38	0.42	122.38											
3	123.25	0.88	123.25											
4	125.08	1.83	125.08											
5	128.92	3.83	128.92											
6	136.93	8.01	136.93											
7	144.94	8.01	144.94	4,	121.96	4,	122.38	4,	123.25	4,	125.08	,		
8	148.78	3.83	148.78	4,	128.92	4,	136.93	4,	144.94	4,	148.78	,		
9	150.61	1.83	150.61	4,	150.61	4,	151.48	4,	151.90	4,	152.40	,		
10	151.48	0.88	151.48											
11	151.90	0.42	151.90											
12	152.40	0.50	152.40											

PROCESED INPUT

PROCESSED INPUT

```
-----------------------------------------------------------------------------
!                            Program DATAINH                                !
!                             Version 3.01                                  !
-----------------------------------------------------------------------------
 Input Filename: J:\Central Maui Landfill\Phase IV Closure\UNSAT-H\cmlrun5e.i
 Date Processed: 18 Jun 2012
 Time Processed: 13:58:49.96
 Title:
Central Maui LF - 5 Year -  Maximum Rainfall

 General options:

 IPLANT =    1        NGRAV  =    1
 IFDEND =  365        IDTBEG =    1        IDTEND =  365
    IYS =    1        NYEARS =    5        ISTEAD =    1
 IFLIST =    0        NFLIST =    1
 NPRINT =    0        STOPHR = 2.400E-15
 ISMETH =    1        INMAX  =    2        ISWDIF =    1       DMAXBA = 0.100E-02
 DELMAX = 1.500E-01   DELMIN = 1.000E-07   OUTTIM = 1.500E-01
  RFACT = 2.000E+00   RAINIF = 1.000E-06    DHTOL = 0.000E+00
  DHMAX = 0.000E+00   DHFACT = 0.000E+00
   KOPT =    4          KEST =    3          WTF = 0.000E+00
 ITOPBC =    0        IEVOPT =    1       NFHOUR =    2         LOWER =    1
  HIRRI = 3.000E+00     HDRY = 1.000E+06    HTOP = 0.000E+00      RHA = 8.000E-01
 IETOPT =    0        ICLOUD =    0       ISHOPT =    0
  IRAIN =    0           HPR = 1.000E+00

 Hysteresis options:

   IHYS =    0        AIRTOL = 0.000E+00  HYSTOL = 0.000E+00  HYSMXH = 0.000E+00

 Heat flow options:

  IHEAT =    0        ICONVH =    0       DMAXHE = 0.000E+00
 UPPERH =    0        TSMEAN = 0.000E+00   TSAMP = 0.000E+00  QHCTOP = 0.000E+00
 LOWERH =    0        QHLEAK = 0.000E+00   TGRAD = 0.000E+00

 Vapor flow options:

 IVAPOR =    0          TORT = 6.600E-01   TSOIL = 2.980E+02  VAPDIF = 2.400E-01

 Grid options:

   MATN =    4           NPT =   84

 Soil hydraulic properties:

   KOPT = 4: van Genuchten hydraulic functions
```

SK = SATURATED HYDRAULIC CONDUCTIVITY, CM/HOUR

Material No. 1
THETA = f(H), Compost Soil Water Retention Properties,
THET = 0.47000 THTR = 4.40000E-02 ALPHA = 2.64000E-02
N = 1.2800 M = 0.21875
K =f(H), Compost Soil Hydraulic Conductivity,
RKMOD = 2.0000 SK = 0.36000 A = 2.64000E-02
N = 1.2800 M = 0.21875 EPIT = 0.50000

Material No. 2
THETA = f(H), ET Cover Soil Water Retention Properties,
THET = 0.34640 THTR = 1.30000E-02 ALPHA = 2.99000E-02
N = 1.2403 M = 0.19374
K =f(H), ET Cover Soil Hydraulic Conductivity,
RKMOD = 2.0000 SK = 1.80000E-02 A = 2.99000E-02
N = 1.2403 M = 0.19374 EPIT = 0.50000

Material No. 3
THETA = f(H), Foundation Layer Soil Water Retention Properties,
THET = 0.34640 THTR = 1.30000E-02 ALPHA = 2.99000E-02
N = 1.2403 M = 0.19374
K =f(H), Foundation Layer Soil Hydraulic Conductivity,
RKMOD = 2.0000 SK = 0.36000 A = 2.99000E-02
N = 1.2403 M = 0.19374 EPIT = 0.50000

Material No. 4
THETA = f(H), Refuse Water Retention Properties
THET = 0.53000 THTR = 0.11000 ALPHA = 0.26000
N = 2.2200 M = 0.54955
K =f(H), Refuse Hydraulic Conductivity,
RKMOD = 2.0000 SK = 0.36000 A = 0.26000
N = 2.2200 M = 0.54955 EPIT = 0.50000

Surface node bounding values:

HIRRI = 3.000E+00 THETA = 4.665E-01 K = 9.415E-02 C =-1.478E-03
HDRY = 1.000E+06 THETA = 6.862E-02 K = 1.985E-14 C =-6.895E-09

Initial Conditions:

NDAY = 0

NODE	Z	MAT	HEAD	CONDUCTIVITY	CAPACITY	THETA	TEMP
1	0.00	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0
2	0.15	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0
3	0.37	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0
4	0.69	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0
5	1.17	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0
6	1.89	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0

7	2.94	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
8	4.50	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
9	6.82	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
10	10.24	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
11	15.32	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
12	20.39	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
13	23.82	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
14	26.13	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
15	27.69	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	VEG.
16	28.75	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	LAYER
17	29.46	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
18	29.94	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
19	30.26	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
20	30.48	1	1.0000E+03	2.4501E-06	-4.6834E-05	0.2138	298.0	
21	30.52	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
22	30.76	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
23	31.04	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
24	31.37	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
25	31.76	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
26	32.23	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	INFILTRATION
27	32.78	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	LAYER
28	33.43	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
29	34.20	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
30	35.11	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
31	36.19	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
32	37.46	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
33	38.97	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
34	40.76	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
35	42.88	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
36	45.38	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
37	48.35	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
38	51.86	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
39	56.01	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
40	60.93	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
41	65.84	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
42	70.00	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
43	73.51	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
44	76.47	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
45	78.98	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
46	81.10	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
47	82.88	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
48	84.39	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
49	85.67	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
50	86.75	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
51	87.66	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
52	88.43	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
53	89.08	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
54	89.63	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
55	90.10	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	

56	90.49	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	INFILTRATION
57	90.82	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	LAYER
58	91.10	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
59	91.34	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
60	91.44	2	1.0000E+03	9.6304E-08	-3.4794E-05	0.1599	298.0	
61	91.48	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
62	91.90	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
63	92.77	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
64	94.60	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
65	98.44	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	FOUNDATION
66	106.45	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	LAYER
67	114.46	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
68	118.30	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
69	120.13	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
70	121.00	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
71	121.42	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
72	121.92	3	1.0000E+02	5.8024E-04	-4.6861E-04	0.2581	298.0	
73	121.96	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	
74	122.38	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	
75	123.25	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	
76	125.08	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	SOLID
77	128.92	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	WASTE
78	136.93	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	
79	144.94	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	
80	148.78	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	
81	150.61	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	
82	151.48	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	
83	151.90	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	
84	152.40	4	1.0000E+02	7.7648E-09	-9.6129E-05	0.1179	298.0	

Total Initial Storage (cm) = 2.772937E+01

Plant parameters:

LEAF= 1, NFROOT= 1, NUPTAK= 1, NFPET= 1, NSOW= 1, NHRVST=365, BARE=0.100

Number of Growth Day (NDLAI) - Leaf Area Index (VLAI) pairs 3

NDLAI	VLAI
1	1.000
180	1.500
364	1.000

DAY	LAI	DAY	LAI	DAY	LAI	DAY	LAI	DAY	LAI	DAY	LAI
1	1.000	2	1.003	3	1.006	4	1.008	5	1.011	6	1.014
7	1.017	8	1.020	9	1.022	10	1.025	11	1.028	12	1.031
13	1.034	14	1.036	15	1.039	16	1.042	17	1.045	18	1.047

19	1.050	20	1.053	21	1.056	22	1.059	23	1.061	24	1.064
25	1.067	26	1.070	27	1.073	28	1.075	29	1.078	30	1.081
31	1.084	32	1.087	33	1.089	34	1.092	35	1.095	36	1.098
37	1.101	38	1.103	39	1.106	40	1.109	41	1.112	42	1.115
43	1.117	44	1.120	45	1.123	46	1.126	47	1.128	48	1.131
49	1.134	50	1.137	51	1.140	52	1.142	53	1.145	54	1.148
55	1.151	56	1.154	57	1.156	58	1.159	59	1.162	60	1.165
61	1.168	62	1.170	63	1.173	64	1.176	65	1.179	66	1.182
67	1.184	68	1.187	69	1.190	70	1.193	71	1.196	72	1.198
73	1.201	74	1.204	75	1.207	76	1.209	77	1.212	78	1.215
79	1.218	80	1.221	81	1.223	82	1.226	83	1.229	84	1.232
85	1.235	86	1.237	87	1.240	88	1.243	89	1.246	90	1.249
91	1.251	92	1.254	93	1.257	94	1.260	95	1.263	96	1.265
97	1.268	98	1.271	99	1.274	100	1.277	101	1.279	102	1.282
103	1.285	104	1.288	105	1.291	106	1.293	107	1.296	108	1.299
109	1.302	110	1.304	111	1.307	112	1.310	113	1.313	114	1.316
115	1.318	116	1.321	117	1.324	118	1.327	119	1.330	120	1.332
121	1.335	122	1.338	123	1.341	124	1.344	125	1.346	126	1.349
127	1.352	128	1.355	129	1.358	130	1.360	131	1.363	132	1.366
133	1.369	134	1.372	135	1.374	136	1.377	137	1.380	138	1.383
139	1.385	140	1.388	141	1.391	142	1.394	143	1.397	144	1.399
145	1.402	146	1.405	147	1.408	148	1.411	149	1.413	150	1.416
151	1.419	152	1.422	153	1.425	154	1.427	155	1.430	156	1.433
157	1.436	158	1.439	159	1.441	160	1.444	161	1.447	162	1.450
163	1.453	164	1.455	165	1.458	166	1.461	167	1.464	168	1.466
169	1.469	170	1.472	171	1.475	172	1.478	173	1.480	174	1.483
175	1.486	176	1.489	177	1.492	178	1.494	179	1.497	180	1.500
181	1.497	182	1.495	183	1.492	184	1.489	185	1.486	186	1.484
187	1.481	188	1.478	189	1.476	190	1.473	191	1.470	192	1.467
193	1.465	194	1.462	195	1.459	196	1.457	197	1.454	198	1.451
199	1.448	200	1.446	201	1.443	202	1.440	203	1.438	204	1.435
205	1.432	206	1.429	207	1.427	208	1.424	209	1.421	210	1.418
211	1.416	212	1.413	213	1.410	214	1.408	215	1.405	216	1.402
217	1.399	218	1.397	219	1.394	220	1.391	221	1.389	222	1.386
223	1.383	224	1.380	225	1.378	226	1.375	227	1.372	228	1.370
229	1.367	230	1.364	231	1.361	232	1.359	233	1.356	234	1.353
235	1.351	236	1.348	237	1.345	238	1.342	239	1.340	240	1.337
241	1.334	242	1.332	243	1.329	244	1.326	245	1.323	246	1.321
247	1.318	248	1.315	249	1.312	250	1.310	251	1.307	252	1.304
253	1.302	254	1.299	255	1.296	256	1.293	257	1.291	258	1.288
259	1.285	260	1.283	261	1.280	262	1.277	263	1.274	264	1.272
265	1.269	266	1.266	267	1.264	268	1.261	269	1.258	270	1.255
271	1.253	272	1.250	273	1.247	274	1.245	275	1.242	276	1.239
277	1.236	278	1.234	279	1.231	280	1.228	281	1.226	282	1.223
283	1.220	284	1.217	285	1.215	286	1.212	287	1.209	288	1.207
289	1.204	290	1.201	291	1.198	292	1.196	293	1.193	294	1.190
295	1.188	296	1.185	297	1.182	298	1.179	299	1.177	300	1.174
301	1.171	302	1.168	303	1.166	304	1.163	305	1.160	306	1.158
307	1.155	308	1.152	309	1.149	310	1.147	311	1.144	312	1.141

313	1.139	314	1.136	315	1.133	316	1.130	317	1.128	318	1.125
319	1.122	320	1.120	321	1.117	322	1.114	323	1.111	324	1.109
325	1.106	326	1.103	327	1.101	328	1.098	329	1.095	330	1.092
331	1.090	332	1.087	333	1.084	334	1.082	335	1.079	336	1.076
337	1.073	338	1.071	339	1.068	340	1.065	341	1.062	342	1.060
343	1.057	344	1.054	345	1.052	346	1.049	347	1.046	348	1.043
349	1.041	350	1.038	351	1.035	352	1.033	353	1.030	354	1.027
355	1.024	356	1.022	357	1.019	358	1.016	359	1.014	360	1.011
361	1.008	362	1.005	363	1.003	364	1.000	365	0.000		

NFROOT = 1: Negative exponential representation of root growth

AA (intersection of curve at z=0 with abscissa) = 1.163
B1 (coefficient defining degree of curvature) = 0.129
B2 (coefficient determining the value of asymptote = 0.030

Root depth, density, and weight/node versus depth

DAY	MAX ROOT DEPTH	ROOT DENSITY (cm/cm)	NORMALIZED DENSITY (1/cm)
1	0.00	0.000	0.0000
1	0.15	1.171	0.1087
1	0.37	1.139	0.1058
1	0.69	1.094	0.1016
1	1.17	1.030	0.0957
1	1.89	0.941	0.0874
1	2.94	0.826	0.0767
1	4.50	0.681	0.0632
1	6.82	0.512	0.0476
1	10.24	0.340	0.0316
1	15.32	0.191	0.0178
1	20.39	0.114	0.0106
1	23.82	0.084	0.0078
1	26.13	0.070	0.0065
1	27.69	0.063	0.0058
1	28.75	0.059	0.0054
1	29.46	0.056	0.0052
1	29.94	0.054	0.0051
1	30.26	0.053	0.0050
1	30.48	0.053	0.0049
1	30.52	0.053	0.0049
1	30.76	0.052	0.0048
1	31.04	0.051	0.0048
1	31.37	0.050	0.0047
1	31.76	0.049	0.0046
1	32.23	0.048	0.0045
1	32.78	0.047	0.0044
1	33.43	0.046	0.0042

1	34.20	0.044	0.0041
1	35.11	0.043	0.0040
1	36.19	0.041	0.0038
1	37.46	0.039	0.0036
1	38.97	0.038	0.0035
1	40.76	0.036	0.0033
1	42.88	0.035	0.0032
1	45.38	0.033	0.0031
1	48.35	0.032	0.0030
1	51.86	0.031	0.0029
1	56.01	0.031	0.0029
1	60.93	0.030	0.0028

MXROOT (deepest node that roots penetrate) = 40

NUPTAK = 1: Feddes et al. 1975 moisture dependent sink term

For Material No. 1
THETAW (wilting point moisture content) = 0.1238
THETAD (lower limit of optimum moisture content) = 0.1958
THETAN (upper limit of optimum moisture content) = 0.4691

For Material No. 2
THETAW (wilting point moisture content) = 0.0899
THETAD (lower limit of optimum moisture content) = 0.1464
THETAN (upper limit of optimum moisture content) = 0.3456

For Material No. 3
THETAW (wilting point moisture content) = 0.0899
THETAD (lower limit of optimum moisture content) = 0.1464
THETAN (upper limit of optimum moisture content) = 0.3456

For Material No. 4
THETAW (wilting point moisture content) = 0.1100
THETAD (lower limit of optimum moisture content) = 0.1103
THETAN (upper limit of optimum moisture content) = 0.5188

ET parameters:

NFHOUR = 2: User subroutine for hourly PET provided

0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0150	0.0440
0.0699	0.0911	0.1061	0.1139	0.1139	0.1061	0.0911	0.0699
0.0440	0.0150	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100

Lower Boundary Option:

LOWER = 1: unit gradient

PET partitioning:

NFPET = 1:

PET is partitioned into PT and PE according to the relationship developed by Ritchie (1972)

The user-specified coefficients are:

a = 0.000
b = 0.520
c = 0.500
d = 0.000 (below this LAI, PT is zero)
e = 3.700 (above this LAI, PT=f(e))

DAY	PET	PTRANS	PEVAPO	DAY	PET	PTRANS	PEVAPO
1	0.1500	0.0702	0.0798	2	0.0800	0.0375	0.0425
3	0.0300	0.0141	0.0159	4	0.0000	0.0000	0.0000
5	0.1300	0.0612	0.0688	6	0.1500	0.0707	0.0793
7	0.0000	0.0000	0.0000	8	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	10	0.0300	0.0142	0.0158
11	0.1000	0.0474	0.0526	12	0.1800	0.0855	0.0945
13	0.1300	0.0619	0.0681	14	0.1800	0.0858	0.0942
15	0.2000	0.0954	0.1046	16	0.2000	0.0955	0.1045
17	0.2500	0.1196	0.1304	18	0.3600	0.1724	0.1876
19	0.4800	0.2302	0.2498	20	0.1500	0.0720	0.0780
21	0.2000	0.0962	0.1038	22	0.2000	0.0963	0.1037
23	0.2500	0.1205	0.1295	24	0.1300	0.0628	0.0672
25	0.1500	0.0725	0.0775	26	0.0800	0.0387	0.0413
27	0.1300	0.0630	0.0670	28	0.0800	0.0388	0.0412
29	0.2000	0.0972	0.1028	30	0.2300	0.1119	0.1181
31	0.2500	0.1218	0.1282	32	0.2500	0.1220	0.1280
33	0.3300	0.1612	0.1688	34	0.4100	0.2005	0.2095
35	0.2800	0.1371	0.1429	36	0.1500	0.0736	0.0764
37	0.0300	0.0147	0.0153	38	0.0500	0.0246	0.0254
39	0.2500	0.1231	0.1269	40	0.3000	0.1478	0.1522
41	0.1800	0.0888	0.0912	42	0.0500	0.0247	0.0253
43	0.0300	0.0148	0.0152	44	0.1500	0.0743	0.0757
45	0.1000	0.0496	0.0504	46	0.1300	0.0646	0.0654
47	0.2800	0.1392	0.1408	48	0.0800	0.0398	0.0402
49	0.1500	0.0748	0.0752	50	0.1000	0.0499	0.0501
51	0.1300	0.0649	0.0651	52	0.0300	0.0150	0.0150
53	0.1000	0.0501	0.0499	54	0.1300	0.0652	0.0648
55	0.2800	0.1406	0.1394	56	0.2300	0.1156	0.1144
57	0.1500	0.0755	0.0745	58	0.2300	0.1159	0.1141
59	0.2800	0.1413	0.1387	60	0.2300	0.1162	0.1138
61	0.2500	0.1264	0.1236	62	0.2000	0.1013	0.0987
63	0.1000	0.0507	0.0493	64	0.2500	0.1269	0.1231
65	0.2800	0.1423	0.1377	66	0.3300	0.1679	0.1621
67	0.2300	0.1171	0.1129	68	0.3300	0.1683	0.1617
69	0.3300	0.1685	0.1615	70	0.3000	0.1533	0.1467

71	0.2500	0.1279	0.1221	72	0.1800	0.0922	0.0878
73	0.3000	0.1539	0.1461	74	0.5100	0.2619	0.2481
75	0.4300	0.2211	0.2089	76	0.3000	0.1544	0.1456
77	0.1300	0.0670	0.0630	78	0.1800	0.0929	0.0871
79	0.3800	0.1963	0.1837	80	0.3800	0.1965	0.1835
81	0.3300	0.1708	0.1592	82	0.2300	0.1192	0.1108
83	0.0500	0.0259	0.0241	84	0.3800	0.1974	0.1826
85	0.4100	0.2132	0.1968	86	0.4100	0.2134	0.1966
87	0.3000	0.1564	0.1436	88	0.4100	0.2139	0.1961
89	0.4300	0.2246	0.2054	90	0.6900	0.3608	0.3292
91	0.7100	0.3717	0.3383	92	0.5100	0.2673	0.2427
93	0.4300	0.2256	0.2044	94	0.3600	0.1891	0.1709
95	0.5100	0.2682	0.2418	96	0.4800	0.2527	0.2273
97	0.4300	0.2266	0.2034	98	0.4100	0.2163	0.1937
99	0.4300	0.2271	0.2029	100	0.4800	0.2538	0.2262
101	0.5100	0.2700	0.2400	102	0.5100	0.2703	0.2397
103	0.4600	0.2440	0.2160	104	0.4800	0.2549	0.2251
105	0.4600	0.2446	0.2154	106	0.5100	0.2714	0.2386
107	0.4600	0.2451	0.2149	108	0.3000	0.1600	0.1400
109	0.3800	0.2029	0.1771	110	0.4800	0.2566	0.2234
111	0.5300	0.2836	0.2464	112	0.1000	0.0536	0.0464
113	0.3000	0.1609	0.1391	114	0.1800	0.0966	0.0834
115	0.3600	0.1935	0.1665	116	0.4100	0.2206	0.1894
117	0.3600	0.1939	0.1661	118	0.2500	0.1348	0.1152
119	0.4100	0.2213	0.1887	120	0.5100	0.2755	0.2345
121	0.4600	0.2488	0.2112	122	0.4800	0.2598	0.2202
123	0.4600	0.2493	0.2107	124	0.4100	0.2224	0.1876
125	0.1000	0.0543	0.0457	126	0.3600	0.1957	0.1643
127	0.4100	0.2231	0.1869	128	0.4600	0.2506	0.2094
129	0.4100	0.2236	0.1864	130	0.4800	0.2620	0.2180
131	0.5300	0.2896	0.2404	132	0.6100	0.3336	0.2764
133	0.5800	0.3176	0.2624	134	0.6100	0.3343	0.2757
135	0.5800	0.3182	0.2618	136	0.3300	0.1812	0.1488
137	0.4800	0.2639	0.2161	138	0.4800	0.2641	0.2159
139	0.5300	0.2920	0.2380	140	0.5600	0.3088	0.2512
141	0.6600	0.3643	0.2957	142	0.6400	0.3536	0.2864
143	0.5600	0.3097	0.2503	144	0.4800	0.2657	0.2143
145	0.5300	0.2937	0.2363	146	0.5100	0.2829	0.2271
147	0.5100	0.2832	0.2268	148	0.4600	0.2557	0.2043
149	0.5100	0.2838	0.2262	150	0.5300	0.2952	0.2348
151	0.5100	0.2843	0.2257	152	0.5100	0.2846	0.2254
153	0.1300	0.0726	0.0574	154	0.5300	0.2963	0.2337
155	0.5100	0.2854	0.2246	156	0.1800	0.1008	0.0792
157	0.5600	0.3140	0.2460	158	0.6100	0.3424	0.2676
159	0.6100	0.3427	0.2673	160	0.2800	0.1575	0.1225
161	0.3000	0.1689	0.1311	162	0.1300	0.0733	0.0567
163	0.4800	0.2707	0.2093	164	0.5600	0.3162	0.2438
165	0.4800	0.2713	0.2087	166	0.4100	0.2319	0.1781
167	0.3800	0.2152	0.1648	168	0.5800	0.3287	0.2513

169	0.6100	0.3460	0.2640	170	0.6400	0.3634	0.2766
171	0.6400	0.3637	0.2763	172	0.6600	0.3755	0.2845
173	0.6900	0.3929	0.2971	174	0.6100	0.3477	0.2623
175	0.6400	0.3651	0.2749	176	0.5800	0.3312	0.2488
177	0.5800	0.3315	0.2485	178	0.5800	0.3318	0.2482
179	0.6100	0.3493	0.2607	180	0.6100	0.3496	0.2604
181	0.6100	0.3493	0.2607	182	0.6100	0.3490	0.2610
183	0.6100	0.3487	0.2613	184	0.6400	0.3655	0.2745
185	0.6100	0.3481	0.2619	186	0.6100	0.3477	0.2623
187	0.6400	0.3645	0.2755	188	0.6400	0.3642	0.2758
189	0.6100	0.3468	0.2632	190	0.6100	0.3465	0.2635
191	0.6100	0.3461	0.2639	192	0.6100	0.3458	0.2642
193	0.6400	0.3625	0.2775	194	0.6400	0.3622	0.2778
195	0.5800	0.3279	0.2521	196	0.5600	0.3163	0.2437
197	0.6100	0.3442	0.2658	198	0.6400	0.3608	0.2792
199	0.6100	0.3436	0.2664	200	0.5600	0.3151	0.2449
201	0.4600	0.2586	0.2014	202	0.6900	0.3875	0.3025
203	0.6600	0.3703	0.2897	204	0.4800	0.2691	0.2109
205	0.5300	0.2968	0.2332	206	0.6100	0.3413	0.2687
207	0.6400	0.3578	0.2822	208	0.6100	0.3407	0.2693
209	0.6100	0.3403	0.2697	210	0.5800	0.3233	0.2567
211	0.5800	0.3230	0.2570	212	0.5800	0.3227	0.2573
213	0.5800	0.3224	0.2576	214	0.5800	0.3220	0.2580
215	0.5800	0.3217	0.2583	216	0.6400	0.3547	0.2853
217	0.6100	0.3377	0.2723	218	0.5800	0.3208	0.2592
219	0.5100	0.2818	0.2282	220	0.3800	0.2098	0.1702
221	0.5300	0.2923	0.2377	222	0.4600	0.2534	0.2066
223	0.5600	0.3082	0.2518	224	0.5100	0.2804	0.2296
225	0.4800	0.2637	0.2163	226	0.3800	0.2085	0.1715
227	0.4300	0.2357	0.1943	228	0.5100	0.2793	0.2307
229	0.4800	0.2626	0.2174	230	0.5100	0.2788	0.2312
231	0.5600	0.3058	0.2542	232	0.5600	0.3055	0.2545
233	0.5300	0.2888	0.2412	234	0.5600	0.3049	0.2551
235	0.4800	0.2611	0.2189	236	0.6100	0.3314	0.2786
237	0.6600	0.3582	0.3018	238	0.6400	0.3470	0.2930
239	0.6400	0.3467	0.2933	240	0.6400	0.3463	0.2937
241	0.6400	0.3460	0.2940	242	0.5800	0.3132	0.2668
243	0.5300	0.2859	0.2441	244	0.5300	0.2856	0.2444
245	0.5300	0.2853	0.2447	246	0.5300	0.2850	0.2450
247	0.5300	0.2848	0.2452	248	0.5800	0.3113	0.2687
249	0.5800	0.3110	0.2690	250	0.5600	0.2999	0.2601
251	0.4600	0.2461	0.2139	252	0.2300	0.1229	0.1071
253	0.3000	0.1602	0.1398	254	0.4600	0.2454	0.2146
255	0.4600	0.2451	0.2149	256	0.4600	0.2448	0.2152
257	0.4300	0.2286	0.2014	258	0.3600	0.1912	0.1688
259	0.4300	0.2282	0.2018	260	0.4300	0.2279	0.2021
261	0.4300	0.2277	0.2023	262	0.3600	0.1904	0.1696
263	0.2500	0.1321	0.1179	264	0.4300	0.2269	0.2031
265	0.5100	0.2689	0.2411	266	0.4300	0.2265	0.2035

267	0.4300	0.2262	0.2038	268	0.4600	0.2417	0.2183
269	0.4600	0.2415	0.2185	270	0.4800	0.2517	0.2283
271	0.5300	0.2776	0.2524	272	0.5600	0.2930	0.2670
273	0.3600	0.1882	0.1718	274	0.4600	0.2402	0.2198
275	0.4100	0.2138	0.1962	276	0.4100	0.2136	0.1964
277	0.4100	0.2134	0.1966	278	0.5300	0.2755	0.2545
279	0.4800	0.2492	0.2308	280	0.4600	0.2386	0.2214
281	0.3600	0.1865	0.1735	282	0.3300	0.1708	0.1592
283	0.4100	0.2119	0.1981	284	0.3600	0.1859	0.1741
285	0.3600	0.1857	0.1743	286	0.4300	0.2215	0.2085
287	0.4600	0.2367	0.2233	288	0.3600	0.1851	0.1749
289	0.1800	0.0924	0.0876	290	0.0500	0.0256	0.0244
291	0.1000	0.0512	0.0488	292	0.3000	0.1535	0.1465
293	0.2800	0.1431	0.1369	294	0.1300	0.0664	0.0636
295	0.0300	0.0153	0.0147	296	0.1500	0.0764	0.0736
297	0.0000	0.0000	0.0000	298	0.1000	0.0508	0.0492
299	0.2500	0.1269	0.1231	300	0.2500	0.1268	0.1232
301	0.2800	0.1418	0.1382	302	0.2800	0.1416	0.1384
303	0.3000	0.1516	0.1484	304	0.4300	0.2170	0.2130
305	0.3300	0.1664	0.1636	306	0.2800	0.1410	0.1390
307	0.2500	0.1257	0.1243	308	0.2000	0.1005	0.0995
309	0.2500	0.1254	0.1246	310	0.1800	0.0902	0.0898
311	0.1500	0.0751	0.0749	312	0.1300	0.0650	0.0650
313	0.0500	0.0250	0.0250	314	0.1000	0.0499	0.0501
315	0.1500	0.0747	0.0753	316	0.2300	0.1144	0.1156
317	0.2500	0.1242	0.1258	318	0.2800	0.1390	0.1410
319	0.4800	0.2380	0.2420	320	0.3800	0.1882	0.1918
321	0.2800	0.1385	0.1415	322	0.5100	0.2519	0.2581
323	0.2800	0.1381	0.1419	324	0.5100	0.2513	0.2587
325	0.3600	0.1772	0.1828	326	0.2000	0.0983	0.1017
327	0.1300	0.0638	0.0662	328	0.2000	0.0981	0.1019
329	0.1500	0.0735	0.0765	330	0.1300	0.0636	0.0664
331	0.2300	0.1124	0.1176	332	0.2500	0.1220	0.1280
333	0.2000	0.0975	0.1025	334	0.1800	0.0876	0.0924
335	0.2000	0.0972	0.1028	336	0.1500	0.0728	0.0772
337	0.1800	0.0873	0.0927	338	0.2800	0.1356	0.1444
339	0.2000	0.0967	0.1033	340	0.2300	0.1111	0.1189
341	0.2300	0.1110	0.1190	342	0.2000	0.0964	0.1036
343	0.3600	0.1732	0.1868	344	0.2000	0.0961	0.1039
345	0.2800	0.1344	0.1456	346	0.1800	0.0863	0.0937
347	0.1500	0.0718	0.0782	348	0.1500	0.0717	0.0783
349	0.1300	0.0621	0.0679	350	0.1300	0.0620	0.0680
351	0.0500	0.0238	0.0262	352	0.1000	0.0476	0.0524
353	0.2000	0.0950	0.1050	354	0.2000	0.0949	0.1051
355	0.1500	0.0711	0.0789	356	0.1800	0.0852	0.0948
357	0.1500	0.0709	0.0791	358	0.2500	0.1179	0.1321
359	0.1300	0.0613	0.0687	360	0.1000	0.0471	0.0529
361	0.1500	0.0705	0.0795	362	0.1000	0.0469	0.0531
363	0.1000	0.0469	0.0531	364	0.1300	0.0608	0.0692

365 0.0800 0.0000 0.0800

Totals: PET = 133.4200
PTRANS = 71.2862
PEVAPO = 62.1338

Precipitation/irrigation parameters:

IRAIN = 0: precipitation data provided

NWATER (number of days of rain/irrigation) = 61

Rainfall/Irrigation Details

Day	Time (hr)	Amount (cm)	Application Type	Efficiency	Changes In Rate/Head
7	16.000	0.1030	1	1.000	2
	17.000	0.0000			
9	7.000	0.2570	1	1.000	2
	12.000	0.0000			
27	21.000	0.0510	1	1.000	2
	22.000	0.0000			
28	5.000	0.0510	1	1.000	2
	6.000	0.0000			
29	8.000	1.7440	1	1.000	2
	18.000	0.0000			
31	18.000	3.8990	1	1.000	2
	22.000	0.0000			
34	2.000	0.2570	1	1.000	2
	4.000	0.0000			
42	2.000	0.0510	1	1.000	2
	3.000	0.0000			
49	21.000	0.1030	1	1.000	2
	23.000	0.0000			
51	7.000	0.0510	1	1.000	2
	8.000	0.0000			
59	7.000	0.5130	1	1.000	2
	12.000	0.0000			
68	3.000	0.0510	1	1.000	2
	4.000	0.0000			
69	2.000	5.1820	1	1.000	2
	17.000	0.0000			
72	11.000	0.5640	1	1.000	2
	18.000	0.0000			
73	2.000	5.3870	1	1.000	2
	14.000	0.0000			
74	9.000	0.9750	1	1.000	2
	23.000	0.0000			

75	10.000	0.0510	1	1.000	2
	11.000	0.0000			
76	4.000	0.0510	1	1.000	2
	5.000	0.0000			
77	1.000	1.3340	1	1.000	2
	24.000	0.0000			
78	1.000	0.3080	1	1.000	2
	22.000	0.0000			
79	3.000	0.1030	1	1.000	2
	4.000	0.0000			
88	18.000	0.0510	1	1.000	2
	19.000	0.0000			
91	19.000	1.3850	1	1.000	2
	21.000	0.0000			
111	5.000	0.2050	1	1.000	2
	7.000	0.0000			
113	7.000	0.5640	1	1.000	2
	24.000	0.0000			
120	1.000	0.0510	1	1.000	2
	2.000	0.0000			
129	23.000	0.0510	1	1.000	2
	24.000	0.0000			
139	2.000	0.0510	1	1.000	2
	3.000	0.0000			
196	7.000	0.0510	1	1.000	2
	8.000	0.0000			
233	1.000	0.0510	1	1.000	2
	2.000	0.0000			
237	13.000	6.0540	1	1.000	2
	16.000	0.0000			
243	15.000	0.1030	1	1.000	2
	16.000	0.0000			
247	4.000	0.0510	1	1.000	2
	5.000	0.0000			
279	19.000	0.2570	1	1.000	2
	21.000	0.0000			
300	23.000	0.0510	1	1.000	2
	24.000	0.0000			
304	18.000	0.3080	1	1.000	2
	24.000	0.0000			
305	1.000	0.2570	1	1.000	2
	2.000	0.0000			
308	10.000	2.3600	1	1.000	2
	23.000	0.0000			
324	1.000	1.0770	1	1.000	2
	2.000	0.0000			
325	1.000	1.7960	1	1.000	2
	23.000	0.0000			
326	1.000	0.9240	1	1.000	2

	20.000	0.0000			
327	22.000	0.0510	1	1.000	2
	23.000	0.0000			
328	3.000	0.0510	1	1.000	2
	4.000	0.0000			
332	10.000	1.7440	1	1.000	2
	15.000	0.0000			
335	16.000	1.0770	1	1.000	2
	24.000	0.0000			
336	1.000	3.3350	1	1.000	2
	17.000	0.0000			
337	1.000	5.7460	1	1.000	2
	24.000	0.0000			
338	18.000	2.5650	1	1.000	2
	24.000	0.0000			
339	1.000	6.9260	1	1.000	2
	18.000	0.0000			
340	6.000	5.5920	1	1.000	2
	24.000	0.0000			
341	1.000	8.5170	1	1.000	2
	22.000	0.0000			
342	2.000	0.4100	1	1.000	2
	11.000	0.0000			
343	3.000	0.0510	1	1.000	2
	4.000	0.0000			
347	3.000	0.2570	1	1.000	2
	9.000	0.0000			
348	2.000	0.7700	1	1.000	2
	20.000	0.0000			
349	12.000	0.1030	1	1.000	2
	20.000	0.0000			
350	1.000	0.1540	1	1.000	2
	21.000	0.0000			
351	6.000	0.0510	1	1.000	2
	7.000	0.0000			
352	3.000	0.1030	1	1.000	2
	8.000	0.0000			
364	23.000	0.1030	1	1.000	2
	24.000	0.0000			
365	1.000	2.6680	1	1.000	2
	21.000	0.0000			

Total Water Applied (cm) = 7.705800E+01 cm.

Program DATAINH terminated normally.

FIFTH YEAR OUTPUT

FIFTH-YEAR OUTPUT

UNSAT-H Version 3.01
INITIAL CONDITIONS

Input File: J:\Central Maui Landfill\Phase IV Closure\UNSAT-H\cmlrun5e.inp
Results File: J:\Central Maui Landfill\Phase IV Closure\UNSAT-H\cmlrun5e0005.re
Date of Run: 18 Jun 2012
Time of Run: 13:59:20.98
Title:
Central Maui LF - 5 Year - Maximum Rainfall

Initial Conditions					Initial Conditions				
NODE	DEPTH (cm)	HEAD (cm)	THETA (vol.)	TEMP (K)	NODE	DEPTH (cm)	HEAD (cm)	THETA (vol.)	TEMP (K)
1	0.000E+00	1.522E+01	0.4455	298.00	2	1.500E-01	1.541E+01	0.4452	298.00
3	3.700E-01	1.528E+01	0.4454	298.00	4	6.900E-01	1.491E+01	0.4460	298.00
5	1.170E+00	1.443E+01	0.4469	298.00	6	1.890E+00	1.382E+01	0.4479	298.00
7	2.940E+00	1.300E+01	0.4494	298.00	8	4.500E+00	1.195E+01	0.4512	298.00
9	6.820E+00	1.069E+01	0.4535	298.00	10	1.024E+01	9.300E+00	0.4559	298.00
11	1.532E+01	7.933E+00	0.4583	298.00	12	2.039E+01	6.769E+00	0.4604	298.00
13	2.382E+01	5.605E+00	0.4623	298.00	14	2.613E+01	4.480E+00	0.4642	298.00
15	2.769E+01	3.533E+00	0.4657	298.00	16	2.875E+01	2.803E+00	0.4667	298.00
17	2.946E+01	2.275E+00	0.4675	298.00	18	2.994E+01	1.901E+00	0.4680	298.00
19	3.026E+01	1.645E+00	0.4683	298.00	20	3.048E+01	1.466E+00	0.4686	298.00
21	3.052E+01	1.462E+00	0.3451	298.00	22	3.076E+01	2.436E+00	0.3439	

298.00
23 3.104E+01 3.933E+00 0.3420 298.00 24 3.137E+01 6.300E+00 0.3388
298.00
25 3.176E+01 1.013E+01 0.3334 298.00 26 3.223E+01 1.635E+01 0.3249
298.00
27 3.278E+01 2.458E+01 0.3144 298.00 28 3.343E+01 3.118E+01 0.3069
298.00
29 3.420E+01 3.365E+01 0.3043 298.00 30 3.511E+01 3.365E+01 0.3043
298.00
31 3.619E+01 3.290E+01 0.3051 298.00 32 3.746E+01 3.213E+01 0.3059
298.00
33 3.897E+01 3.167E+01 0.3064 298.00 34 4.076E+01 3.183E+01 0.3062
298.00
35 4.288E+01 3.318E+01 0.3048 298.00 36 4.538E+01 3.715E+01 0.3007
298.00
37 4.835E+01 4.915E+01 0.2898 298.00 38 5.186E+01 3.301E+02 0.2032
298.00
39 5.601E+01 6.348E+03 0.1075 298.00 40 6.093E+01 7.032E+03 0.1052
298.00
41 6.584E+01 7.398E+02 0.1708 298.00 42 7.000E+01 5.389E+02 0.1829
298.00
43 7.351E+01 4.484E+02 0.1903 298.00 44 7.647E+01 3.967E+02 0.1954
298.00
45 7.898E+01 3.634E+02 0.1991 298.00 46 8.110E+01 3.404E+02 0.2019
298.00
47 8.288E+01 3.240E+02 0.2040 298.00 48 8.439E+01 3.117E+02 0.2057
298.00
49 8.567E+01 3.022E+02 0.2071 298.00 50 8.675E+01 2.949E+02 0.2081
298.00
51 8.766E+01 2.891E+02 0.2090 298.00 52 8.843E+01 2.844E+02 0.2097
298.00
53 8.908E+01 2.807E+02 0.2103 298.00 54 8.963E+01 2.776E+02 0.2108
298.00
55 9.010E+01 2.751E+02 0.2112 298.00 56 9.049E+01 2.731E+02 0.2115
298.00
57 9.082E+01 2.714E+02 0.2118 298.00 58 9.110E+01 2.700E+02 0.2120
298.00
59 9.134E+01 2.688E+02 0.2122 298.00 60 9.144E+01 2.683E+02 0.2123
298.00
61 9.148E+01 2.682E+02 0.2123 298.00 62 9.190E+01 2.677E+02 0.2124
298.00
63 9.277E+01 2.667E+02 0.2126 298.00 64 9.460E+01 2.645E+02 0.2129
298.00
65 9.844E+01 2.601E+02 0.2137 298.00 66 1.065E+02 2.512E+02 0.2153
298.00
67 1.145E+02 2.427E+02 0.2168 298.00 68 1.183E+02 2.387E+02 0.2176

```
298.00
    69 1.201E+02 2.369E+02 0.2179 298.00    70 1.210E+02 2.360E+02 0.2181
298.00
    71 1.214E+02 2.356E+02 0.2182 298.00    72 1.219E+02 2.351E+02 0.2183
298.00
    73 1.220E+02 2.350E+02 0.1128 298.00    74 1.224E+02 1.432E+02 0.1151
298.00
    75 1.232E+02 1.163E+02 0.1166 298.00    76 1.251E+02 1.029E+02 0.1176
298.00
    77 1.289E+02 1.001E+02 0.1179 298.00    78 1.369E+02 1.000E+02 0.1179
298.00
    79 1.449E+02 1.000E+02 0.1179 298.00    80 1.488E+02 1.000E+02 0.1179
298.00
    81 1.506E+02 1.000E+02 0.1179 298.00    82 1.515E+02 1.000E+02 0.1179
298.00
    83 1.519E+02 1.000E+02 0.1179 298.00    84 1.524E+02 1.000E+02 0.1179
298.00

 Initial Water Storage =  37.3358 cm

 NOTE:  There are no temperature data when plants are modelled.


---------------------------------------------------------------------------
-----


 DAILY SUMMARY:  Day =   1, Simulated Time = 24.0000 hr
 -------------
 Node Number        =      1          20          40          60
72
 Depth (cm)         =    0.00000    30.48000    60.93000    91.44000
121.92000
 Water (cm3/cm3)    =    0.42054     0.46837     0.10526     0.21230
0.21824
 Head (cm)          = 3.05061E+01 1.61961E+00 7.00976E+03 2.68357E+02
2.35112E+02
 LiqWater Flow (cm)=-7.79704E-02
3.17621E-01-3.48313E-04-2.54444E-04-2.04924E-06
 Plant Sink (cm)    = 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
0.00000E+00


                                                    LIQUID
  PRESTOR    INFIL   RUNOFF    EVAPO    TRANS      DRAIN      NEWSTOR
STORAGE
  37.3358+ 0.0000+ 0.0000 - 0.0798- 0.0000-   0.0000 =   37.2559 vs.
```

37.2541

Mass Balance = 1.8010E-03 cm; Time step attempts = 160 and successes =
160
Evaporation: Potential = 0.0798 cm, Actual = 0.0798 cm
Transpiration: Potential = 0.0702 cm, Actual = 0.0000 cm

DAILY SUMMARY: Day = 365, Simulated Time = 24.0000 hr

Node Number = 1 20 40 60
72
Depth (cm) = 0.00000 30.48000 60.93000 91.44000
121.92000
Water (cm3/cm3) = 0.44548 0.46856 0.10519 0.20971
0.21525
Head (cm) = 1.52205E+01 1.46556E+00 7.03204E+03 2.84509E+02
2.51256E+02
LiqWater Flow (cm)= 2.34997E+00
8.11226E-02-3.43818E-04-2.19800E-04-1.80846E-06
Plant Sink (cm) = 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
0.00000E+00

PRESTOR	INFIL	RUNOFF	EVAPO	TRANS	LIQUID DRAIN	NEWSTOR	STORAGE
34.8515+	2.3556+	0.3057 -	0.0032-	0.0000-	0.0000 =	37.2039 vs.	37.2041

Mass Balance = -1.8478E-04 cm; Time step attempts = 183 and successes =
183
Evaporation: Potential = 0.0800 cm, Actual = 0.0032 cm
Transpiration: Potential = 0.0000 cm, Actual = 0.0000 cm
1

UNSAT-H Version 3.01
SIMULATION SUMMARY

Title:
- 5 Year - Maximum Rainfall

Transpiration Scheme is:	=	1	
Potential Evapotranspiration	=	1.3342E+02	[cm]
Potential Transpiration	=	7.1323E+01	[cm]
Actual Transpiration	=	2.6347E+01	[cm]
Potential Evaporation	=	6.2166E+01	[cm]
Actual Evaporation	=	1.2138E+01	[cm]
Evaporation during Growth	=	1.2138E+01	[cm]
Total Runoff	=	3.8840E+01	[cm]
Total Infiltration	=	3.8236E+01	[cm]
Total Basal Liquid Flux (drainage)	=	6.8019E-05	[cm]
Total Basal Vapor Flux (temp-grad)	=	0.0000E+00	[cm]
Total Applied Water	=	7.7058E+01	[cm]
Actual Rainfall	=	7.7076E+01	[cm]
Actual Irrigation	=	0.0000E+00	[cm]
Total Final Moisture Storage	=	3.7204E+01	[cm]
Mass Balance Error	=	-1.1700E-01	[cm]
Total Successful Time Steps	=	60195	
Total Attempted Time Steps	=	60545	
Total Time Step Reductions (DHMAX)	=	0	
Total Changes in Surface Boundary	=	36733	
Total Time Actually Simulated	=	3.6500E+02	[days]

Total liquid water flow (cm) across different depths at the end of 3.6500E+02 days:

DEPTH	FLOW	DEPTH	FLOW	DEPTH	FLOW
0.000	2.6098E+01	0.075	2.6237E+01	0.260	2.5871E+01
0.530	2.5304E+01	0.930	2.4485E+01	1.530	2.3334E+01
2.415	2.1794E+01	3.720	1.9774E+01	5.660	1.7242E+01
8.530	1.4343E+01	12.780	1.1371E+01	17.855	9.0729E+00
22.105	7.6889E+00	24.975	6.9162E+00	26.910	6.4509E+00
28.220	6.1588E+00	29.105	5.9713E+00	29.700	5.8498E+00
30.100	5.7704E+00	30.370	5.7178E+00	30.500	5.6929E+00
30.640	5.6661E+00	30.900	5.6149E+00	31.205	5.5540E+00
31.565	5.4812E+00	31.995	5.3922E+00	32.505	5.2854E+00
33.105	5.1598E+00	33.815	5.0077E+00	34.655	4.8269E+00
35.650	4.6160E+00	36.825	4.3728E+00	38.215	4.0961E+00
39.865	3.7696E+00	41.820	3.3898E+00	44.130	2.9463E+00
46.865	2.4368E+00	50.105	1.8490E+00	53.935	1.1821E+00
58.470	4.3658E-01	63.385	-1.2798E-01	67.920	-1.2649E-01
71.755	-1.2348E-01	74.990	-1.1967E-01	77.725	-1.1562E-01

80.040	-1.1165E-01	81.990	-1.0794E-01	83.635	-1.0458E-01
85.030	-1.0156E-01	86.210	-9.8911E-02	87.205	-9.6600E-02
88.045	-9.4600E-02	88.755	-9.2876E-02	89.355	-9.1395E-02
89.865	-9.0120E-02	90.295	-8.9034E-02	90.655	-8.8116E-02
90.960	-8.7334E-02	91.220	-8.6662E-02	91.390	-8.6221E-02
91.460	-8.6039E-02	91.690	-8.5441E-02	92.335	-8.3760E-02
93.685	-8.0227E-02	96.520	-7.2741E-02	102.445	-5.6801E-02
110.455	-3.4413E-02	116.380	-1.7218E-02	119.215	-8.8431E-03
120.565	-4.8209E-03	121.210	-2.8914E-03	121.670	-1.5127E-03
121.940	-7.0156E-04	122.170	-6.5164E-04	122.815	-5.3816E-04
124.165	-2.8104E-04	127.000	8.8228E-06	132.925	6.6238E-05
140.935	6.7992E-05	146.860	6.8019E-05	149.695	6.8019E-05
151.045	6.8019E-05	151.690	6.8019E-05	152.150	6.8019E-05
152.400	6.8019E-05				

BOTTOM of FOUNDATION LAYER FLOW ≠ 0

Total plant water uptake (cm) at different depths:

DEPTH	WATER UPTAKE	DEPTH	WATER UPTAKE	DEPTH	WATER UPTAKE
0.000	0.0000E+00	0.150	3.8556E-01	0.370	5.7565E-01
0.690	8.2358E-01	1.170	1.1520E+00	1.890	1.5492E+00
2.940	2.0246E+00	4.500	2.5300E+00	6.820	2.8959E+00
10.240	2.9700E+00	15.320	2.2964E+00	20.390	1.3825E+00
23.820	7.7194E-01	26.130	4.6486E-01	27.690	2.9220E-01
28.750	1.8761E-01	29.460	1.2173E-01	29.940	7.9675E-02
30.260	5.2870E-02	30.480	2.5159E-02	30.520	2.7235E-02
30.760	5.1013E-02	31.040	6.0359E-02	31.370	7.1757E-02
31.760	8.6262E-02	32.230	1.0290E-01	32.780	1.2150E-01
33.430	1.4396E-01	34.200	1.7010E-01	35.110	2.0070E-01
36.190	2.3543E-01	37.460	2.7614E-01	38.970	3.2369E-01
40.760	3.7762E-01	42.880	4.3859E-01	45.380	5.0948E-01
48.350	5.8766E-01	51.860	6.7014E-01	56.010	7.4608E-01
60.930	5.6455E-01	65.840	0.0000E+00	70.000	0.0000E+00
73.510	0.0000E+00	76.470	0.0000E+00	78.980	0.0000E+00
81.100	0.0000E+00	82.880	0.0000E+00	84.390	0.0000E+00
85.670	0.0000E+00	86.750	0.0000E+00	87.660	0.0000E+00
88.430	0.0000E+00	89.080	0.0000E+00	89.630	0.0000E+00
90.100	0.0000E+00	90.490	0.0000E+00	90.820	0.0000E+00
91.100	0.0000E+00	91.340	0.0000E+00	91.440	0.0000E+00
91.480	0.0000E+00	91.900	0.0000E+00	92.770	0.0000E+00
94.600	0.0000E+00	98.440	0.0000E+00	106.450	0.0000E+00
114.460	0.0000E+00	118.300	0.0000E+00	120.130	0.0000E+00
121.000	0.0000E+00	121.420	0.0000E+00	121.920	0.0000E+00
121.960	0.0000E+00	122.380	0.0000E+00	123.250	0.0000E+00

125.080	0.0000E+00	128.920	0.0000E+00	136.930	0.0000E+00
144.940	0.0000E+00	148.780	0.0000E+00	150.610	0.0000E+00
151.480	0.0000E+00	151.900	0.0000E+00	152.400	0.0000E+00

APPENDIX B

FINAL COVER SLOPE STABILITY ANALYSIS

(Please see Operations Plan Appendix C for Gross Slope Stability of The Liner System)

CML Landfill Cells
Final Cover Surficial Slope Stability

Static Factor of Safety

For an infinite slope (Matasovic, 1989):

$$FS = \{c/(\gamma z \cos^2 \beta) + \tan\phi[1 - \gamma_w (z - d_w)/\gamma z]\}/\tan\beta$$

Where:
FS = Static factor of safety
c = cohesion intercept of soil (psf)
γ = total unit weight of soil (pcf)
z = total depth of soil (ft)
β = slope angle (degrees)
ϕ = internal angle of friction of soil (degrees)
γ_w = unit weight of water (pcf)
d_w = depth to groundwater surface parallel to slope (ft)

Evaluate a 2-feet thick soil cover layer with water table at 0 and 2 feet below the surface, corresponding to saturated depths of 2 and 0 feet respectively.

The input values and result for each case are presented below:

Parameter	Saturated Thickness (ft)	
	0	2
c	200 psf	200 psf
γ	125 pcf	125 pcf
z	2 ft	2 ft
β	21.8^{o} (2.5:1 slope)	21.8^{o} (2.5:1 slope)
ϕ	35 ^{o}	35^{o}
γ_w	62.4 pcf	62.4 pcf
d_w	2 ft	0 ft
FS	4.1	3.2

The static factor of safety for surficial slope stability exceeds 1.5 under all conditions of cover soil saturation.

Pseudo-Static Factor of Safety (PSFS) and Yield Acceleration (K_y) for Earthquake Event

For an infinite slope (Matasovic, 1989):

$$K_y = \{c/(\gamma z \cos^2 \beta) + \tan\phi[1 - \gamma_w (z - d_w)/\gamma z] - \tan\beta\}/(1 + \tan\beta \tan\phi)$$

Where: K_y = yield acceleration (g)
c = cohesion intercept of soil (psf)
γ = unit weight of soil (pcf)
z = total depth of soil (ft)
β = slope angle (degrees)
ϕ = internal angle of friction of soil (degrees)
γ_w = unit weight of water (pcf)
d_w = depth to groundwater surface parallel to slope (ft)

Evaluate a the cover with water levels at 0 and 2 feet below the surface of the cover soil, corresponding to saturated depths of 2 and 0 feet respectively.

From the USGS earthquake hazards maps, the estimated peak horizontal ground acceleration at CML Landfill is 0.36 g, with a 2% probability of occurrence in 50 years, which is approximately equivalent to a probability of 10% in 250 years, and represents an event with an average return period of approximately 2,475 years. The seismic coefficient is one half of the peak acceleration, or about 0.18g. The maximum permanent deformation of the cover is given as a function of yield acceleration as summarized in the following table. The input values and results for each case are presented below:

Parameter	Saturated Thickness (ft)	
	0	2
c	200 psf	200 psf
γ	125 pcf	125 pcf
z	2 ft	2 ft
β	21.8° (2.5:1 slope)	21.8° (2.5:1 slope)
ϕ	35°	35°
γ_w	62.4 pcf	62.4 pcf
d_w	2 ft	0 ft
PSFS	2.8 > 1	2.2 > 1
K_y	> 0.9g > 0.18g	0.68g > 0.18g
Permanent Displacement	0 inch	0 inch

Even under fully saturated conditions, maximum permanent displacement of the slope during the design earthquake event is estimated to be negligible, which is an acceptable deformation of final cover.

APPENDIX C

CLOSURE AND POST-CLOSURE COST ESTIMATES

CENTRAL MAUI LANDFILL
CLOSURE / POST-CLOSURE PLAN
COST ESTIMATE

SITE DESCRIPTION

General Site Information

Name of Facility	Central Maui Landfill
Solid Waste Facility Permit No.	LF0072-93
Facility Operator	County of Maui
Site Owner	County of Maui
Site Address	Pulehu Road, Puunene, Hawaii
Assessors Parcel No.	TMK:(2)3-8-003 :POR. of 004
Anticipated Closure Date	Phases IV through III-A approximately 2024

Site Characteristics

Total Site Area		300 acres	
Developed Waste Footprint		Currently Closed: Phase I and II (acres):	42
		Currently Open: Phases IV, V, & V-B Ext	41
Waste Footprint to be Developed		28.1 acres in Phase III	
Type of Fill		Area	
Underlying Geology		Igneous rock	
Nearest Major Fault		N/A	
On-Site Faults		No known faults	
Depth to Groundwater	Minimum	216 to 297 feet	
Groundwater flow direction		Generally north/northwest	
Groundwater gradient		0.0001 ft./ft.	

Waste Types and Volumes

Waste Type	MSW & C&D	
Design Capacity	5,200,000	CY in Phases I & II
	6,691,075	CY in Phases IV, V, V-B Ext., & III
Thickness of Waste at Closure	Minimum	20
	Average	120
	Maximum	160

Average Height Above Surrounding Terrain	100	
Typical Grades of Side Slopes	3:1	horizontal:vertical
Quantity of Waste Received Typical	770	tons/day

Landfill Design Characteristics

Unlined Waste Area	42	acres (Phase I & II)
Lined Area at Closure Currently Active:	41	acres (Phases IV, V, & V-B Ext)
To Be Developed:	28.1	acres (Phase III)
Maximum Area Requiring Closure:	69.1	acres

Base Liner Design Section

Foundation layer	Recompacted native soil
Clay liner	GCL (Phase IV-A),
	2 ft. clay @ 10-7 cm/sec (Ph. IV-B, V, V-B Ext)
	2 ft. clay @ 10-7 cm/sec (Ph. III-A - Planned)
Geomembrane	60 mil HDPE (Phase IV-A),
	80 mil HDPE (Ph. VI-B, V, V-B Ext)
	80 mil HDPE (Ph. III-A - Planned)
Drainage layer	Geocomposite or 1 ft. gravel, geotextile above and below
Operations layer	2 ft. (3 ft. above geocomposite drainage layer) native soil

Side Slope Liner Design Section

Subgrade	Native soil/cushion layer graded and recompacted
Primary liner	GCL (Phase IV-A)
	2 ft. clay @ 10-7 cm/sec (Ph. IV-B, V, V-B Ext)
	2 ft. clay @ 10-7 cm/sec (Ph. III-A - Planned)
Geomembrane	60 mil HDPE (Phase IV-A)
	80 mil HDPE (Ph. IV-B, V, V-B Ext)
	80 mil HDPE (Ph. III-A - Planned)
Drainage layer	Geotextile
Geotextile	16 oz. nonwoven
Operations layer	2 ft. native soil

Leachate Collection and Treatment

Primary Collectors	Perforated pipes in trenches
Sumps	Phase I & II: Manhole 4
	Phase IV: Manhole in Phase IV-A;
	Phase IV-B: Internal sump
	Phase III-A: Internal sump (Planned)
Treatment	Reintroduce to landifll; transport to POTW

Landfill Gas Management

Collection	Vertical wells; horizontal trench collectors on floor of Phase V-VI cells
Treatment	Flare; potential future energy recovery

CENTRAL MAUI LANDFILL
CLOSURE PLAN

CLOSURE COST ESTIMATE
PHASES IV, V and V-B Ext.

1. Final Cover
   a. Area to be covered — 41 acres
   Computed surface area — 1,785,960 sq. ft.

   b. Grading

	Quantity	Unit Cost	Amount
s.y.	198,440	$ 4.79	$ 950,552
Total			$ 950,552

   c. Cover Soil

Foundation layer (in-place interim cover, none added during final closure)	1 ft. (existing 1 ft. intermediate cover prior to closure)	
Monolithic final cover	2.0 ft.	
Total soil thickness	2.0 ft. (in addition to existing 1 ft. intermediate cover)	
Soil volume placed under final cover contract	132,293 cu. yd.	
Percent native soil	100%	
Unit cost to place & compact	$ 15.52 per cu. yd.	
Cover soil cost		$ 2,052,642

   d. Vegetative Layer

Thickness	1 ft.	
Volume	66,147 cu. yd	
Unit cost to supply and place	$ 17.70 per cu. yd.	
		$ 1,170,970

   e. Geosynthetics

	Unit Cost	Quantity	Cost
None			$ -

   f. Engineering & Construction Quality Assurance

Total cover construction value	#########	
Engrg. & CQA as percent of construction	15%	
CQA cost		$ 483,542

   Final Cover Subtotal — $ 4,657,707

2. Revegetation

   a. Area to be revegetated by hydroseeding — 41 acres

   b. Unit costs — $ 11,400 per acre

c. Revegetation subtotal $ 467,420

3. Leachate Management

No modifications required $ -

4. Landfill Gas Monitoring & Control

a. Monitoring System

2-probe nested wells at 1000-foot spacing.
Depths of probes 10 & 40 ft.
No. of Wells to be added 0 (To be developed during operations)

Cost per well $ 5,873

Cost for monitoring wells $ -

b. Collection System

Extraction Wells, each	51	$ 11,746	$ 599,057
10" Header pipe, lin. ft.	3417	$ 35.30	$ 120,624
Misc. Joints & Fittings	1	$ 26,554	$ 26,554
Flare Station - Supplied with Phases I & II	0		$ -
Total collection system			$ 746,235

c. Subtotal Landfill Gas $ 746,235

5. Groundwater Monitoring Installation

Additional wells to install 0 well

Depth ft.

Unit cost of drilling & installation

Cost of groundwater monitoring system additions $ -

6. Drainage & Roads — Item & Units	Quantity	Unit Cost	Amount
Paved drainage road (top deck), s.y.	4,600	$ 52.07	$ 239,506
Aggregate & asphalt v-ditch on benches, l.f.	7,550	$ 41.13	$ 310,551
Misc. Improvements, l.s.	1	$ 68,000	$ 68,000

Total drainage cost $ 618,057

7. Security - no modifications required $ -

8. Removal of strucures $ -

TOTAL CLOSURE COST $ 6,489,419

Contingency 20% $ 1,297,884

TOTAL INCLUDING CONTINGENCY - 2019 Dollars **$ 7,787,303**

CENTRAL MAUI LANDFILL
CLOSURE PLAN

CLOSURE COST ESTIMATE
PHASE III

1. Final Cover

a. Area to be covered: 28.1 acres

Computed surface area: 1,224,036 sq. ft.

b. Grading

	Quantity	Unit Cost	Amount
Grading preparation for Monolithic Final Cover, s.y.	136,004	$ 4.79	$ 651,476
Total			$ 651,476

c. Cover Soil

Foundation layer (in-place interim cover, none added during final closure)	1	ft. (existing 1 ft. intermediate cover prior to clos
Monolithic final cover	2.0	ft.
Total soil thickness	2.0	ft. in addition to existing 1 ft. intermediate cove
Soil volume placed under final cover contract	90,669	cu. yd.
Percent native soil	100%	
Unit cost to place & compact	$ 15.52	per cu. yd.
Cover soil cost		$ 1,406,811

d. Vegetative Layer

Thickness	1	ft.	
Volume	45,335	cu. yd	
Unit cost to supply and place	$ 17.70	per cu. yd.	
			$ 802,543

e. Geosynthetics

	Unit Cost	Quantity	Cost
None			$ -

f. Engineering & Construction Quality Assurance

Total cover construction value	$ 2,209,354	
Engrg. & CQA as percent of construction	15%	
CQA cost		$ 331,403

Final Cover Subtotal: $ 3,192,233

2. Revegetation

a. Area to be revegetated by hydroseeding: 28.1 acres

b. Unit costs — $ 11,400 per acre

c. Revegetation subtotal — $ 320,354

3. Leachate Management

No modifications required — $ -

4. Landfill Gas Monitoring & Control

a. Monitoring System

2-probe nested wells at 1000-foot spacing.
Depths of probes 10 & 40 ft.
No. of Wells to be added — 0 (To be developed during operations)

Cost per well — $ 5,873

Cost for monitoring wells — $ -

b. Collection System

Extraction Wells, each	35	$ 11,746	$ 411,118
10" Header pipe, lin. ft.	2345	$ 35.30	$ 82,781
Misc. Joints & Fittings	1	$ 18,223	$ 18,223
Flare Station - Supplied with Phases I & II	0	$ -	$ -

Total collection system — $ 512,122

c. Subtotal Landfill Gas — $ 512,122

5. Groundwater Monitoring Installation

Additional wells to install — 0 well

Depth — ft.

Unit cost of drilling & installation

Cost of groundwater monitoring system additions — $ -

6. Drainage & Roads

Item & Units	Quantity	Unit Cost	Amount
Paved drainage road (top deck), s.y.	7,300	$ 52.07	$ 380,086
Aggregate & asphalt v-ditch on benches, l.f.	3,200	$ 41.13	$ 131,624
Misc. Improvements, l.s.	1	$ 47,770	$ 47,770

Total drainage cost — $ 559,480

7. Security - no modifications required — $ -

8. Removal of strucures — $ -

TOTAL CLOSURE COST — $ 4,584,189

Contingency — 20% — $ 916,838

TOTAL INCLUDING CONTINGENCY - 2019 Dollars — $ 5,501,027

CENTRAL MAUI LANDFILL
POST-CLOSURE MAINTENANCE PLAN

ANNUAL POST-CLOSURE COST ESTIMATE
PHASES I AND II

1. Final Cover Maintenance

   a. Earthwork Repair

Area assumed for repair	1 acre		
Unit cost for repair incl. CQA and Engr.	$ 1.25 per sq. ft.		
Annual cost of repairs		$ 54,432	

   b. Revegetation

Area assumed for repair	1 acre		
Unit cost for repair	$ 11,871 per acre		
Annual cost of repairs		$ 11,871	

c. Subtotal for Final Cover Maintenance			$ 66,304

2. Leachate Management (Monitoring)

a. Labor	1 hr/week		
b. Labor unit cost	$ 47.07 per hour		
c. Annual labor cost		$ 2,448	
d. Annual allowance for repairs & materials		$ 5,873	

   e. Leachate sampling costs

Number of samples per round	1		
Frequency of sampling per year	1		
Sampling cost per round	$ 587		
Testing cost per sample	$ 1,175		
Annual sampling and testing costs		$ 1,762	
g. Subtotal Leachate Management			$ 10,083

3. Landfill Gas Management

   a. Annual Maintenance of Flare Station

No. of flare stations	See Phases IV, V, V-B EXT., & III
Capital cost of flares and blowers	
Annual maintenance as % of capital cost	

Annual flare maintenance and repairs			$ -	
b. Collection System Maintenance				
Annual repairs / replacements		$ 35,239		
Annual system testing & balancing		$ 46,985		
Total collection system maintenance			$ 82,224	
c. Subtotal Landfill Gas Management				$ 82,224
4. Monitoring				
a. Gas Monitoring				
Quarterly Surface Emissions Monitoring		$ 27,016		
Quarterly sampling - methane & trace gases All points tested for TOC using FID/OVA 1 Bag sample collected for trace gas analysis using GC				
Sampling cost per event	$ 2,349			
Trace gas testing cost per event	$ 1,175			
Annual cost for sampling & testing		$ 14,095		
Annual cost for probe replacement		$ 587		
Gas Monitoring Subtotal			$ 41,699	
b. Groundwater Monitoring				
Number of wells	See Phases IV, V, V-B EXT., & III			
Sample events per year	$ -			
Sampling cost per event	$ -			
Testing costs per sample	$ -			
Annual sampling and testing costs		$ -		
Annual maintenance & replacement of wells		$ -		
Groundwater Monitoring Subtotal			$ -	
d. Total Monitoring Costs				$ 41,699
5. Drainage and Roads - Annual maintenance cost				$ 23,492
6. Security - Annual maintenance cost				$ 1,175
7. Inspection - Semi-annual Inspections - annual cost				$ 5,873
TOTAL ANNUAL COST (2019 Dollars)				**$ 230,849**
TOTAL COST FOR EIGHTEEN (18) YEARS OF POST-CLOSURE CARE				**$ 4,155,282**

CENTRAL MAUI LANDFILL
POST-CLOSURE MAINTENANCE PLAN

ANNUAL POST-CLOSURE COST ESTIMATE
PHASES IV, V, V-B EXT., & III

1. Final Cover Maintenance			
a. Earthwork Repair			
Area assumed for repair	1.75 acre		
Unit cost for repair incl. CQA and Engr.	$ 1.25 per sq. ft.		
Annual cost of repairs		$ 95,257	
b. Revegetation			
Area assumed for repair	1.75 acre		
Unit cost for repair	$ 11,871 per acre		
Annual cost of repairs		$ 20,775	
c. Subtotal for Final Cover Maintenance			$ 116,031
2. Leachate Management (Monitoring)			
a. Labor	13 hr/week		
b. Labor unit cost	$ 47.07 per hour		
c. Annual labor cost		$ 32,634	
d. Annual allowance for repairs & materials		$ 7,831	
e. Leachate sampling costs			
Number of samples per round	4		
Frequency of sampling per year	2		
Sampling cost per round	$ 587		
Testing cost per sample	$ 1,175		
Annual sampling and testing costs		$ 10,572	
g. Subtotal Leachate Management			$ 51,036
3. Landfill Gas Management			
a. Annual Maintenance of Flare Station			
No. of flare stations	1		
Annual flare maintenance and repairs		$ 65,129	
b. Collection System Maintenance			

Annual repairs / replacements		$ 68,081		
Annual system testing & balancing		$ 90,775		
Total collection system maintenance			$ 158,856	
c. Subtotal Landfill Gas Management				$ 223,985
4. Monitoring				
a. Gas Monitoring				
Quarterly surface emissions monitoring		$ 54,353		
Quarterly sampling - methane & trace gases All points tested for TOC using FID/OVA 1 Bag sample collected for trace gas analysis using GC				
Sampling cost per event	$ 2,349			
Trace gas testing cost per event	$ 1,175			
Annual cost for sampling & testing		$ 14,095		
Annual cost for probe replacement		$ 587		
Gas Monitoring Subtotal			$ 69,036	
b. Groundwater Monitoring				
Number of wells	9			
Sample events per year	2			
Sampling cost per event	$ 2,349			
Testing costs per sample	$ 2,643			
Annual sampling and testing costs		$ 52,271		
Annual maintenance & replacement of wells		$ 2,937		
Groundwater Monitoring Subtotal			$ 55,207	
d. Total Monitoring Costs				$ 124,243
5. Drainage and Roads - Annual maintenance cost				$ 12,408
6. Security - Annual maintenance cost				$ 1,175
7. Inspection - Semi-annual Inspections - annual cost				$ 5,873
TOTAL ANNUAL COST (2017 Dollars)				**$ 534,752**
TOTAL COST FOR THIRTY (30) YEARS OF POST-CLOSURE CARE				**$ 16,042,546**

TABLE 7-1
CENTRAL MAUI LANDFILL
CLOSURE / POST-CLOSURE COSTS

Closure	**Phase IV, V, V-B Ext & III**	**Total**
Final Cover	$ 7,849,940	$ 7,849,940
Revegetation	$ 787,774	$ 787,774
Leachate Management	$ -	$ -
Landfill Gas Monitoring & Control	$ 1,258,357	$ 1,258,357
Groundwater Monitoring Installation	$ -	$ -
Drainage Installation	$ 1,177,538	$ 1,177,538
Security Installation	$ -	$ -
Removal of Structures	$ -	$ -
Subtotal Closure	$ 11,073,609	$ 11,073,609
Contingency	$ 2,214,722	$ 2,214,722
Total Closure Cost (2019 Dollars)	**$ 13,288,331**	**$ 13,288,331**

Post-Closure Monitoring and Maintenance - Annual Cost

	Phase I & II (Closed 2007)	**Phase IV, V, V-B Ext & III (Future Costs)**	**Total**
Final Cover Maintenance	$ 66,304	$ 116,031	$ 182,335
Leachate Management	$ 10,083	$ 51,036	$ 61,119
Gas Management	$ 82,224	$ 223,985	$ 306,208
Monitoring	$ 41,699	$ 124,243	$ 165,942
Drainage	$ 23,492	$ 12,408	$ 35,900
Security	$ 1,175	$ 1,175	$ 2,349
Inspection	$ 5,873	$ 5,873	$ 11,746
Subtotal - Annual Cost - 2019 Dollars	$ 230,849	$ 534,752	$ 765,601
No. of Years Required / Remaining Responsibility	18	30	
Subtotal x years	**$ 4,155,282**	**$ 16,042,546**	**$ 20,197,829**
Total Closure and Post-Closure Cost	**$ 4,155,282**	**$ 29,330,877**	**$ 33,486,159**