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USE OF THE CREAMS MODEL TO REPRESENT SOIL MOISTURE UNDER VARIOUS TRENCH COVER DESIGNS FOR WASTE BURIAL

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INTRODUCTION

The ability to simulate the hydrologic performance of shallow-land burial facilities is useful in designing, monitoring and closing these facilities. In particular, 10 CFR Part 61 requires that modeling analyses provide a reasonable assurance that the disposal site will meet Nuclear Regulatory Commission performance objectives. In practice this means that hydrologic models must be used to compute a water balance for the surface and near-surface areas of shallow-land burial facilities, often under conditions where little or no field data are available.

The scarcity of available site characterization data, particularly for soil properties, often means that tabular values will have to be used in site assessment. Parameter values are available[1] for application of the CREAMS model (A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems)[2] to shallow-land burial sites in semiarid areas. The key soil hydrologic parameters are given as average, minimum and maximum values for soil texture classes, e.g., sands, silts or clays. Often, the average value is selected because it is assumed to represent the expected behavior.

The objective of this study is to evaluate the application of CREAMS in conjunction with the tabular values for predicting soil water behavior in trench covers at semiarid sites. Two approaches are presented: the first approach uses the parameters for a given texture class; and the second approach bounds system behavior using a combination of maximum and minimum suggested parameters for a given texture class. In this case, the predicted water content values are expected to envelop the observed values, thus providing the user with upper and lower limits for predictive purposes.

THE CREAMS MODEL

The CREAMS model was originally developed by the U.S. Department of Agriculture to evaluate nonpoint source pollution from agricultural lands. It has been applied to predict water balance and erosion in a variety of trench cover designs for arid and semiarid areas of the western United States.[1,3,4,5]

The CREAMS model is a continuous simulation model with components for hydrology, erosion, and chemistry. The discussions herein are limited to the hydrologic component of CREAMS, which calculates vertical transport of water in the soil column on a daily basis. The water balance is described by the equation

$$ds/dt = P - Q - ET - L$$

where
ds/dt = change in soil moisture with time (L/T)
P = precipitation (L/T)
Q = runoff (L/T)
ET = evapotranspiration (L/T)
L = seepage or percolation (L/T)
t = time (T)

The soil profile is represented by seven layers, extending from the soil surface to the plant rooting depth. Parameters used to describe the soil profile are: thickness, water storage capacity, saturated hydraulic conductivity, porosity, field capacity, wilting point, soil evaporation parameter, pore space fraction filled at field capacity, and the plant-available soil water storage capacity. Additional required model inputs are: curve number, daily precipitation, leaf area index, plant rooting depth, a winter cover factor (a measure of cover material affecting soil evaporation), mean monthly temperatures and mean monthly solar radiation.

DATA

Field experiments were performed at experimental facilities, at scales ranging from 305 cm diameter columns to 1000 m^2 field plots, located at Los Alamos National Laboratory, Los Alamos, New Mexico.[6,7] Only results from 6 m by 12 m plots at low level waste disposal Area G are shown herein. The terms experimental and control refer to the soil-gravel/cobble design and the conventional soil/crushed tuff design, respectively. The control plot consisted of 100 cm of crushed tuff, covered with 15 cm of topsoil. The experimental plot consisted of 70 cm cobble, covered with 80 cm of gravel, covered with 15 cm of topsoil.

Parameter values for application of CREAMS to shallow-land burial in semiarid areas[1] were used as input parameters in the simulations. Soil moisture data for each trench cover design were obtained using a neutron probe. Actual daily precipitation totals, and average monthly air temperature and solar radiation, for 20 years of data from Los Alamos, were used in the simulations. A rooting depth of 61 cm was assumed for the control plot, based on measurements of plant rooting depth on low-level waste disposal sites. Only the topsoil layer of the experimental plot was modeled.[8,9]

RESULTS AND DISCUSSION

Observed soil moisture averaged over the rooting depth and CREAMS-predicted soil moisture are presented for Area G in Figure 1. Results are representative of those obtained for all three sites. Although overprediction reduces model accuracy in terms of the statistics from a design viewpoint, overprediction is more conservative in terms of potential cap failure or percolation of water into waste.

Fig. 1. CREAMS simulation of volumetric soil water content of 61 cm topsoil/crushed tuff profile for Area G.

Maximum and minimum ranges of soil properties as determined by soil texture were used to bound observed soil moisture data for both control (Figure 2) and experimental cover

Fig. 2. CREAMS-predicted bounding curves for observed soil moisture at Area G.

designs (Figure 3). Although some observed values in these figures are below the predicted lower boundary, this is not as important for evaluation of trench cap performance as the upper bound. The ability to determine an upper bound on soil moisture is important to predict trench cover failure and water percolation into waste.

Fig. 3. CREAMS-predicted bounding curves for observed soil moisture at Area G experimental plot.

CONCLUSIONS

Despite the short period of record, general lack of available data at waste burial sites, and lack of field-determined model parameter inputs, the ability to bound observed soil moisture values using recommended parameter values for application to shallow-land burial in semiarid areas is encouraging. However, limitations of CREAMS must be recognized. Increased measurement of CREAMS parameter inputs and required state variables and fluxes will enhance model application. For advanced designs such as cobble/gravel barriers, our current understanding is limited and application of any model is suspect.

Using the CREAMS model in conjunction with parameters to bound the syst n performance is a more appropriate use of the model and parameter values at this time. Further data collection will allow substantiation of this approach and improve our knowledge of cap performance in arid/semiarid environments.

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