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MASTER

THE PRESTO LOW-LEVEL WASTE TRANSPORT AND RISK ASSESSMENT CODE*

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ABSTRACT

PRESTO (Prediction of Radiation Effects from Shallow Trench Operations) is a computer code developed under U.S. Environmental Protection Agency (EPA) funding to evaluate possible health effects from shallow land burial trenches. The model is intended to be generic and to assess radionuclide transport, ensuing exposure, and health impact to a static local population for a 1000-y period following the end of burial operations. Human exposure scenarios considered by the model include normal releases (including leaching and operational spillage), human intrusion, and site farming or reclamation. Pathways and processes of transit from the trench to an individual or population include: groundwater transport, overland flow, erosion, surface water dilution, resuspension, atmospheric transport, deposition, inhalation, and ingestion of contaminated beef, milk, crops, and water. Both population doses and individual doses are calculated as well as doses to the intruder

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and farmer. Cumulative health effects in terms of deaths from cancer are calculated for the population over the thousand-year period using a life-table approach. Data bases are being developed for three extant shallow land burial sites: Barnwell, South Carolina; Beatty, Nevada; and West Valley, New York.

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is developing an environmental standard for the disposal of low-level radioactive waste (LLW) to support the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE) in constructing a national radioactive waste management system. This standard is to be issued during 1982. The PRESTO code (Prediction of Radiation Effects from Shallow Trench Operations) is designed to allow the EPA to assess the impacts of shallow land burial under numerous situations in support of the standard development activities.

PRESTO is modular in construction to allow for more sophisticated submodels or subroutines to be substituted at later dates, if desirable. The code is generic and will be supplied with data bases for three specific locations of shallow land burial operations: Barnwell, South Carolina; Beatty, Nevada; and West Valley, New York. Many of the submodels included in PRESTO were developed elsewhere, and we have adapted them for use.

PROBLEM DESCRIPTION AND MAJOR MODELING ASSUMPTIONS

PRESTO is to be run numerous times for the purpose of assessing the relative effects of the various scenarios and input parameters on the public health impacts in support of the developing EPA standard. Because of this, the code has been kept relatively simple and easy to operate. Four basic scenarios (Table I) are considered: normal function with operational spillage; human intrusion; site reclamation or farming; and suspension of radionuclides from an eroded trench. Pathways considered by PRESTO are shown in Figs. 1 and 2. Depending on the scenario chosen by the user, a given pathway may not be followed or may be "short circuited."

For the normal scenario, doses and risks to populations are calculated assuming site-specific population centers characterized by geographic centroid location and number of persons. Annual average meteorology for the modeled site is input. All population centroids utilize common sources of drinking and irrigation water

Table I. Types of Doses and Risks Calculated for Populations and Individuals by Scenario

Scenario	For Population	For Individual
Normal	Ingests off-site water	Ingests site-boundary water
	Ingests off-site foods	Ingests site-boundary foods
	Inhales downwind air	Inhales site-boundary air
Intrusion	None	Ingests trench well water Direct exposure from residency
Farming	Ingests on-site foods Ingests off-site water	Ingests on-site foods Ingests off-site water Inhales suspended soil
Eroded Trench	Inhales suspended material at centroid Direct exposure from plume	Inhales suspended material at boundary Direct exposure to exposed trench

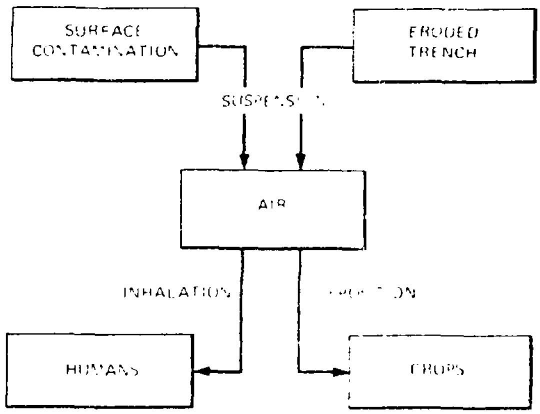

Fig. 1. Pathways of air transport considered in PRESTO.

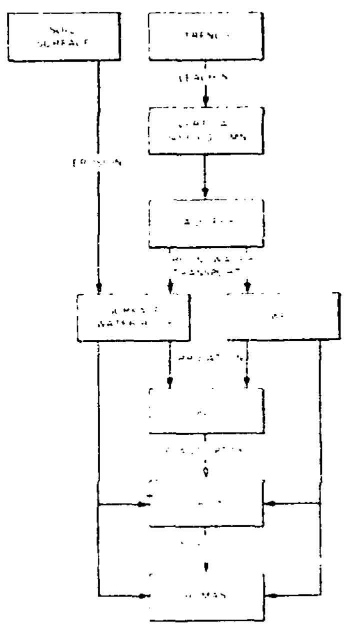

Fig. 2. Major pathways of water transport in PRESTO.

contaminated from trench seepage or overflow. The population age distribution and size is held constant over the simulation period. Individual dose calculations for atmospheric releases under the normal scenario will be for a person at the site boundary in the prevailing downwind direction. Individual doses for water-borne effluents will be calculated at the site boundary also.

For the intrusion scenario, no population dose or risk calculations are made. Individual calculations assume that the intruder (1) receives an internal dose from drinking water from a well drilled into the trench, and (2) receives an external dose from excavating and residing in a basement on the trench location; the time of onset and duration of exposure are user-specified for both calculations.

For the farming or reclamation scenario, the on-site farmer grows and eats his or her own vegetables, beef, and milk produced on land irrigated by trench water, but drinks off-site water equal in concentration to the normal scenario population intake. The farmer also inhales suspended contaminated soil from the residual operational spillage. Population dose and risk calculations under the farming scenario assume that the food products grown on-site are ingested by the population at-large rather than the farmer alone.

The eroded trench scenario provides for suspension and atmospheric transport of trench contents and resulting inhalation by an individual or the specified population. An individual may also be directly exposed to trench contents and thus receive an external dose. Populations may receive an external dose from immersion in the suspended plume.

Important modeling assumptions are as follows. Daughter products of decay are not calculated because, for the most part, the inventory of commercial low-level waste burial grounds includes no radionuclides that are part of long chains. Chemical reactions are not modeled, with the exception of the use of such factors as the distribution coefficient, k_d. Waste material in the trench is considered to be effectively homogeneous in terms of radionuclide distribution and type of material; i.e., no canister containment will be modeled. An alternative assumption about waste packaging may be considered by modification or replacement of the intra-trench subroutine, TRENCH. Groundwater transport is one-dimensional through a "tube" from the point of radionuclide input below the trench directly to a surface water body or well. A correction factor is calculated and applied to account for the combined effects of radioactive decay and dispersion in the groundwater pathway.

CODE DESCRIPTION

The PRESTO code is structured in a modular form to permit simple upgrading or replacement of given submodels without rewriting the entire code. The code is written for an IBM 360 computer system to be operated in batch mode. The MAIN program accepts initialization and input data from an input subroutine and calls all of the process subprograms as needed. Different submodels are invoked or called in changed order for scenarios other than the normal scenario. Three classes of submodels are used in PRESTO: unit response submodels; scheduled event or bookkeeping submodels; and risk evaluation submodels. Unit response submodels simulate processes such as rainwater infiltration into the trench, erosion of soil overburden from the trench cover, and atmospheric transport. Such submodels are likely accessed only once during a model run and generate parameters used elsewhere in the simulation. Scheduled event and bookkeeping submodels are those that estimate the time of trench cap failure, water balance in the trench, radionuclide concentration in the aquifer outflow, etc. Such submodels are iterated annually for the 1000-y simulation period. Risk evaluation submodels accept the cumulative or mean output from the iterated submodels and generate doses and population risks. These codes are accessed only once and output the tabular results of the codes. Figure 3 illustrates the flow of information between submodels.

During a model run, the MAIN program may access the following submodels:

EVAPO. This unit response submodel is an adaptation of Morton's model[1,2] for calculation of evapotranspiration and net infiltration as a function of continental location, precipitation, temperature, barometric pressure, and cloudiness. The output is infiltration rate into the trench or soil (TRENCH). The status of the trench cap modifies the rate and amount of infiltration. We assume that the breached portion of the cap results in no evapotranspiration; all precipitation falling on the breached region of the trench becomes available for leaching. Infiltration rates are also fed into the soluble surface component subroutine, SURSOL.

ERORF. This unit response subroutine calculates the rate of erosion of soil from the trench cap and surrounding surfaces. Erosion by rainfall is calculated using an adaptation of the universal soil loss equation as described by the U.S. Department of Agriculture[3] and parameterized by McElroy et al.[4] ERORF feeds information to the cap status algorithm that changes the relative rates of infiltration and evapotranspiration. ERORF also provides the amount of eroded soil into the INSOL subroutine.

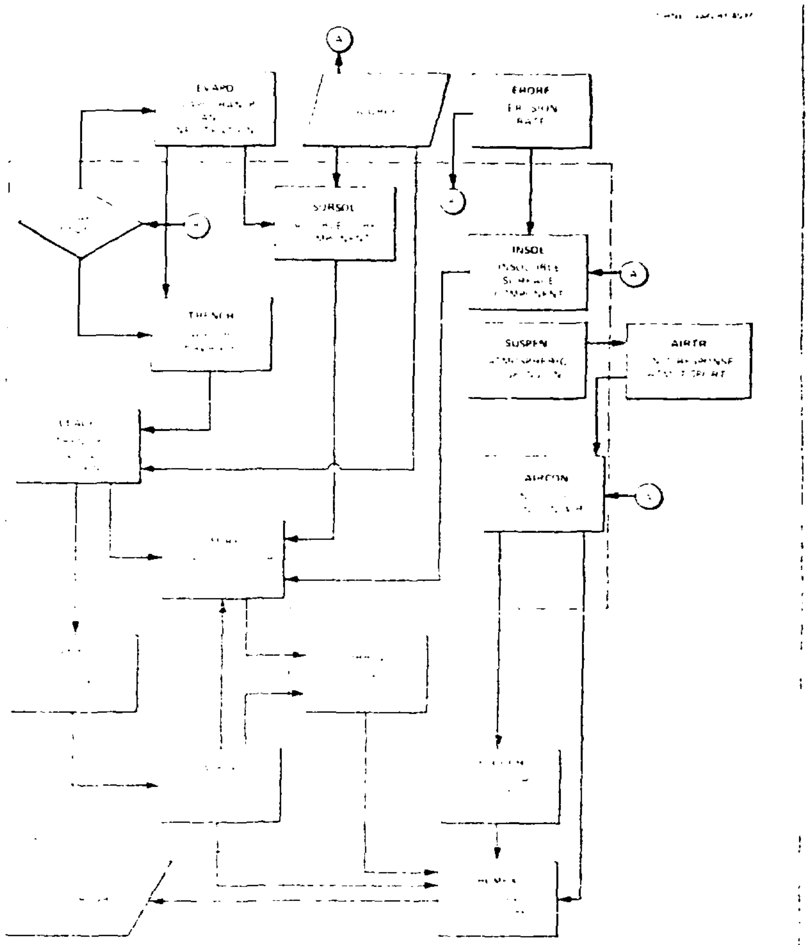

Fig. 3. Information flow between submodels in the PRESTO code.

AIRTR. This group of subroutines calculates the unit response of the Gaussian plume model. AIRTR is an adaptation of the interactive code DWNWND[5] and accepts both user input data and the suspended mass load to calculate a χ/Q value for each impacted population.

SUSPEN. This submodel calculates the rate of suspension of soil from the ground surface as a time dependent factor. The model equation as parameterized by Anspaugh et al.[7] was used for this code. For the farming scenario, SUSPEN will calculate mass loading of the atmosphere from mechanical tillage of the soil.

TRENCH. This subroutine maintains a trench water budget and feeds the water content of the stored material into the LEACH code. As mentioned above, the water budget of the trench is affected by both cap status and precipitation or infiltration.

LEACH. The leaching subroutine accepts information about the annual water budget from TRENCH and the radionuclide inventory from the source input to calculate the rate of dissolution of materials within the trench. Depending on the conditions of loss from the trench, either downward leaching or trench overflow, the information is passed to either the VERT or SURF codes. LEACH is formulated to contend with homogenized trench contents, but may ultimately be upgraded to consider canistered waste.

VERT. The VERT subroutine accepts user information about soil characteristics and depth of aquifer as well as the radionuclide concentrations and hydrologic data calculated by the LEACH code. Output from VERT is the annual amount of each nuclide added to the aquifer, the total water added to the aquifer from the vertical column, and the transit time of vertical radionuclide movement.

AQUIF. The AQUIF subroutine accepts user input about groundwater velocity, distribution coefficient (retardation coefficient), porosity, etc. Input from VERT includes the annual trench contribution to the aquifer water balance and the annual radionuclide contribution to the aquifer. AQUIF output is the annual amount of water and radionuclide concentration to appropriate wells and groundwater-fed surface water used for irrigation or drinking. The synergism between dispersion and decay is accounted for using an adaptation of the dispersion correction factor devised by Hung.[8] This factor corrects for the fact that more activity is output from the aquifer when dispersion occurs than when no dispersion occurs.

SURF. User input to the SURF subroutine includes the annual rate of stream flow and location of the stream. Information flow into SURF from the other codes includes annual water input and radionuclide concentration from LEACH, SURSOL, and INSOL. SURF output is annual water budget and radionuclide concentration for that portion of irrigation water taken from surface sources.

SURSOL. The soluble component of operational spillage is transported to surface water bodies in SURSOL. Surface contamination (operational spillage) is assumed never to reach the aquifer. Input includes the radionuclide contamination of the soil surface and the rate of infiltration into the active soil exchange region (from EVAPO).

INSOL. The insoluble component of operational spillage may be transported to the surface water via INSOL. The annual rate of soil erosion is input to INSOL by ERORF along with the radionuclide concentrations of the surface soil.

AIRCON. This subroutine combines the unit response χ/Q, generated by AIRTR for each pertinent location, with radionuclides suspended in the air from the surface soil by SUSPEN to calculate the downwind radionuclide concentrations in air. AIRCON will output these data for use as deposition terms into the foodchain (FOODCH) and human inhalation (HUMEX).

IRRIG. Foods may be irrigated with contaminated water from either surface or groundwater sources. Input to IRRIG consists of the necessary user inputs and either the integrated or time-averaged radionuclide concentration in the water used for irrigation. IRRIG, which in function is similar to FOODCH, calculates the integrated or time-averaged radionuclide concentration from both deposition and root uptake in foodcrops, milk, and meat for human consumption.

FOODCH. Foods may be contaminated by atmospheric deposition and root uptake. FOODCH accepts user input and radionuclide concentration in air calculated by AIRCON to calculate nuclide concentrations in crops, meat, and milk for use by HUMEX. The equations used are basically those of the USNRC *Regulatory Guide* 1.109.

HUMEX. The human exposure subroutine accepts user input and time-integrated or averaged data from AIRCON, FOODCH, IRRIG, and AQUIF. AIRCON will provide radionuclide concentrations in air for inhalation calculations. FOODCH and IRRIG will furnish radionuclide concentrations in foodstuffs for ingestion calculations.

DARTAB. This large routine accepts output from HUMEX and, using the RADRISK methodology, calculates and outputs risk and dose estimates according to numerous user-specific options for table format. RADRISK[10] is a life-table approach to calculating the human health risk to a cohort of 10[illegible] people from a constant input of 1 pCi/y (0.037 Bq/y) for a lifetime (70.7 y). RADRISK is called by DARTAB, not by the user. DARTAB[11] categorizes data and [illegible] numerous tabular output options.

DATA BASES AND USER INPUT

We are currently compiling data for each of three burial grounds: Barnwell, Beatty, and West Valley. Some of the data for each site are readily available, and others will need to be estimated from other sites. Easily available data include site location (latitude), precipitation rate, mean temperature, mean barometric pressure, soil porosity, soil bulk density, depth of aquifer, trench dimensions, depth of overburden, location and flow of surface water bodies and wells, topography, average meteorology, location of population centers, etc. Data about which considerable uncertainty exists include groundwater flow velocity both vertically and horizontally, element-specific retardation as a function of the distribution coefficient (k_d) and the activity inventory by nuclide of each site. Estimates of the aquifer flow velocity are available from USGS investigations or other sources[12-14] such as site operators. A recent survey of k_d values for agricultural soils[15] will be a prominent source of k_d information, but will likely be supplemented by both further literature searches and laboratory measurements of k_d. Due to the dearth of data it is doubtful that site-specific values of k_d will be used in the ultimate form of the code. The activity inventories may be the least accessible of the necessary information. The Barnwell staff have compiled the listed activity from incoming radionuclide receipts for about the past year onto a computerized data base. The West Valley facility radionuclide inventory was described by EPA in 1977.[13] Virtually no data on activity inventory exist for Beatty; inventory input for that site may have to be estimated from other facilities.

The necessary data for the food chain, irrigation, human exposure, dose, and risk portions of PRESTO are generic in nature. Transfer coefficients for crops, meat and milk and human ingestion and inhalation rates are taken from USNRC *Regulatory Guide* 1.109[9] or other accepted assessment literature. If a user needs to change any of these data to meet some site-specific situation, that option is available.

The user also inputs a series of specifications that select the scenario under which doses and risks are to be calculated. Other data entered by the user refer to the individual dose calculation and include such variables as location, residency factor following excavation for an intruder, etc. All user-selected variables will be specified with a default value for input in the data deck if the user does not have overriding information.

CODE AVAILABILITY

As of February 1981, about eighty percent of the coding on PRESTO is completed. An interim code and report will be issued during April 1981. A draft user's manual including job control language, a complete code listing, operating experience and a sample problem will be available in late 1981.

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