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NATIONAL HIGH-LEVEL WASTE SYSTEMS ANALYSIS

Keith Kristofferson
Lockheed Martin Idaho Technologies Co.
P. O. Box 1625
Idaho Falls, Idaho 83415-2420
(208)526-9363

Thomas P. O'Holleran
Lockheed Martin Idaho Technologies Co.
P. O. Box 1625
Idaho Falls, Idaho 83415-2420
(208)526-3557

ABSTRACT

Previously, no mechanism existed that provided a systematic, interrelated view or national perspective of all high-level waste (HLW) treatment and storage systems that the U.S. Department of Energy (DOE) manages. The impacts of budgetary constraints and repository availability on storage and treatment must be assessed against existing and pending negotiated milestones for their impact on the overall HLW system. This assessment can give DOE a complex-wide view of the availability of waste treatment and help project the time required to prepare HLW for disposal.

To aid in this assessment Lockheed Martin Idaho Technologies was requested by DOE, Office of Environmental Management, to initiate a study of the DOE HLW System. To commence the study, facilities, throughputs, schedules, and milestones were modeled to ascertain the treatment and storage "systems" resource requirements at the Hanford site, Savannah River Site (SRS), Idaho National Engineering Laboratory (INEL), and West Valley Demonstration Project (WVDP). The impacts of various treatment system availabilities on schedule and throughput were compared to repository readiness to determine the prudent application of resources. To assess the various impacts, the model was exercised against a number of plausible scenarios as discussed below.

I. MODEL DESCRIPTION

The system model was constructed using detailed flow sheets[1,2,3] describing the wastes and treatment processes (existing or proposed) at each site managing HLW. The influence of qualitative factors (soft variables) can be evaluated with the model by establishing discrete sets of input variables (called scenarios) that reflect the consequences of soft variables. For example, the effects of stakeholder involvement could be modeled by manually setting certain schedule dates that are used as input by the model, and letting the model calculate detailed schedule and throughput rates needed to meet the fixed schedule. The potential need for additional resources, such as increased tank capacity, would also be estimated. Alternatively, schedule can be fixed in order to study the effects of legally binding agreements on facility size (throughput). Conversely, throughput can be fixed to examine the influence of budget constraints on the need to renegotiate existing agreements. Detailed schedules were developed from higher-level milestones, such as deadlines in Federal Facility Tri-Party Agreements, consent orders and Federal Facility Compliance Act driven consent orders.

The model uses four types of variables to track system performance: start dates, end dates, throughputs, and capacities. The user can fix various combinations of these variables as independent variables, and allow the model to calculate the remaining variables as dependent variables. The model performs calculations as an incremental function of time to correlate throughput and capacity with schedule variables.

Waste treatment at each site is modeled by three top-level functions: HLW storage, treatment, and interim storage. Transfers between the functions are characterized by throughput variables. HLW storage

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and interim storage are characterized by capacities. The treatment function is derived as a rollup of detailed flow sheets describing the entire treatment process (existing or proposed) at each site. As such, the treatment function is described entirely by inputs, outputs and schedule information. This feature allows the model to account for secondary waste streams (such as low-level waste), in addition to the primary HLW stream.

In the scenarios used for initial model development, the repository was assigned sufficient capacity to accept all HLW. Repository capacity could be reduced to study the effects of limited HLW repository space in the first repository, and to schedule and size a second repository.

II. OPERATION OF THE MODEL

A given set of independent variables represents a "scenario." Once a scenario has been defined, dependent variables are calculated to provide the output. The output includes event flags to indicate if pre-selected conditions are not satisfied by the dependent variables when a scenario is run.

Specific scenarios were examined with the model in order to efficiently develop the model and to demonstrate capabilities for further analysis.

The model is implemented using a simulation environment called Vensim,[a] running under Microsoft Windows®. Therefore, much of the operation of the model is based upon operation of the Vensim product.

Vensim allows the user to build *continuous* computer simulations (as opposed to *discrete* simulations). This means that the various treatment, storage, and disposal operations are represented in the computer as continuous flows of material.

III. SYSTEM ANALYSIS

A. Scenario 1, the Base Case

The base case scenario uses a fixed schedule defined by existing court orders[5] and agreements. Detailed waste treatment schedules were derived from site-specific plans for waste immobilization[1,2,3,4]. Process throughputs were estimated from available flow sheet data, along with interim storage requirements. Process models and accompanying data for SRS and West Valley are considered complete and very accurate, because these sites are about to begin waste form production. The models and data for Hanford and the INEL are more preliminary in nature, reflecting the current state of development at those sites.

The transportation system and repository waste receipt operation are modeled as a throughput to repository storage having a maximum rate of 572 m^3/yr. Waste from West Valley is shipped at a rate that will allow interim storage to be emptied in one year. Waste from SRS is shipped at the production rate to avoid construction of new interim storage at that site after the repository begins accepting HLW. The remaining shipping capacity (throughput) is divided between Hanford and the INEL. The original plan was to assign shipping rates based on the ratio of the production rates at the two sites. For example, the shipping capacity assigned to Hanford (S_H) is calculated as:

$$S_H = \frac{P_H}{P_I} S_R - S_S + S_W$$

where

$$P_H \quad = \quad \text{Hanford's production rate} \quad (m^3/\text{yr})$$

$$P_I \quad = \quad \text{INEL's production rate} \quad (m^3/\text{yr})$$

$$S_R \quad = \quad \text{total repository shipping} \quad \text{(receipt) rate} = 572 \, m^3/\text{yr}$$

$$S_S \quad = \quad \text{SRS's shipping rate } (m^3/\text{yr})$$

$$S_W \quad = \quad \text{WVDP's shipping rate} \quad (m^3/\text{yr})$$

However, since the production rate at the INEL is much lower that the SRS and Hanford, the glass is shipped from the INEL at the production rate to

minimize the need for interim storage. The remaining shipping capacity is assigned to Hanford.

B. Scenario 2: No Repository

This scenario uses the schedules and throughputs of the base case scenario, but storage capacity for all immobilized waste is provided by interim storage facilities. The maximum interim storage capacity that would be needed at each site was calculated, and throughput data that can be used to develop facility construction schedules were derived. Information from this scenario could also be used in cost studies to determine the optimum size of interim storage facilities.

C. Scenario 3: Reduced Throughput at Various Facilities

This scenario perturbs the base case scenario by reducing throughputs between HLW storage and the treatment facility by 30% at sites where facilities neither exist presently nor are under construction (i.e., Hanford and the INEL). New schedules are calculated based on the reduced throughput. This scenario simulates a reduction in funding as a reduction in throughput to reflect downsized facilities. It is assumed that SRS and West Valley will operate as currently planned, because construction funds for those sites are already committed. This scenario illustrates how reduced funding could impact existing agreements and court orders.

Scenario 3 facilitates closure of the West Valley site, limits the need for interim storage capacity at SRS, and minimizes interim storage capacities at Hanford and the INEL. Interim storage capacities at Hanford and the INEL are minimized by delaying startup of HLW immobilization facilities until the repository is ready to receive waste shipments (2015). Startup dates for SRS and West Valley remain unchanged.

D. Scenario 4: Repository Delayed 30 Years

This scenario recomputed the base case (Scenario 1), with the repository opening being delayed 30 years (to 2045). This scenario illustrates the impact of a delay in repository operations on interim storage needs, and would require additional construction. This case assumed that all current agreements and court orders are or will be met, other than those requiring deep geologic disposal.

Minimization of interim storage can be accomplished by delaying startup of treatment at Hanford and the INEL until the repository opens. Production rates for both sites were the same as in the base case scenario. SRS and WVDP proceeded according to current schedules for waste immobilization. WVDP will ship waste at a rate sufficient to allow the site's interim storage to be emptied in one year. SRS will be assigned the remainder of the transportation throughput, until Hanford and the INEL come on line. At that time, SRS's share of the transportation throughput will be set equal to the production rate (throughput to interim storage), and the remainder of the transportation throughput will be divided between Hanford and the INEL. This scenario illustrates the latitude for adjustment in DOE's HLW treatment schedule, while minimizing interim storage costs and meeting all milestones in existing orders and agreements.

E. Scenario 5: Repository Delayed 30 Years, Milestones Renegotiated

This scenario assumed a 30-year delay in repository operations, as in Scenario 4, and calculated new schedules for Hanford and the INEL to minimize interim storage at those sites. Minimization of interim storage was accomplished by delaying production until the repository began receiving waste.

The transportation throughput available to each site was determined from the total transportation throughput available to the two sites based on production rates at each site. Savannah River and West Valley proceeded according to current schedules for waste immobilization. West Valley shipped waste at a rate sufficient to allow the site's interim storage to be emptied in one year. Shipment schedules for SRS, Hanford, and the INEL were based on production rates at each site. Savannah River's share of the transportation throughput was set equal to the production rate (throughput to interim storage) that was used while the site was producing waste forms. This scenario illustrates the latitude for adjustment in DOE's HLW treatment schedule while minimizing interim storage costs and helps define issues for renegotiating orders and agreements.

IV. SELECTED RESULTS AND DISCUSSION

In the Base Case scenario, total interim storage required by the system reaches a maximum of 5742 m^3 in 2021, and then decreases to zero by 2038. System interim storage requirements as a function of time are shown graphically in Figure 1.

While shipments to the repository are shown in this figure to begin in 2015, system inventory continues to build until production ceases at SRS in 2020 because system production rate exceeds shipment/receipt rate during that time. When production ceases at Hanford, system inventory decreases until all interim storage is empty in 2038. However, shipments to the repository must continue until 2044, when production ceases at the last site (INEL). The amount of glass in interim storage at each site is shown as a function of time in Figure 2.

Graph for SYSTOR

SYSTOR - GLASS ———— m3
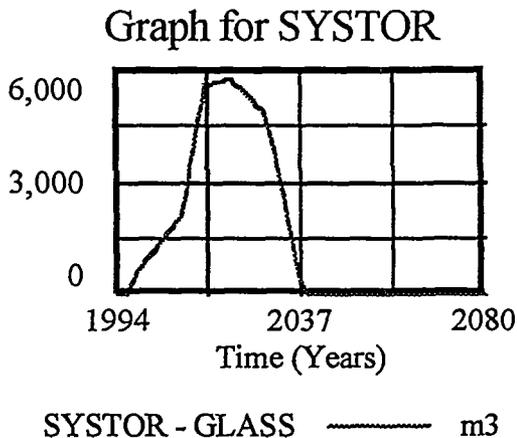
Figure 1. System Interim Storage Requirements as a function of time (year). The initial slope is attributable to production at SRS, with a brief contribution from WVDP in 1997 and 1998. The steep increase in slope is a result of the start of production at Hanford in 2009. Shipments to the repository begin in 2014. Production at SRS is complete in 2020, and at Hanford in 2028. These events are all marked by decreases in slope

Glass in Interim Storage

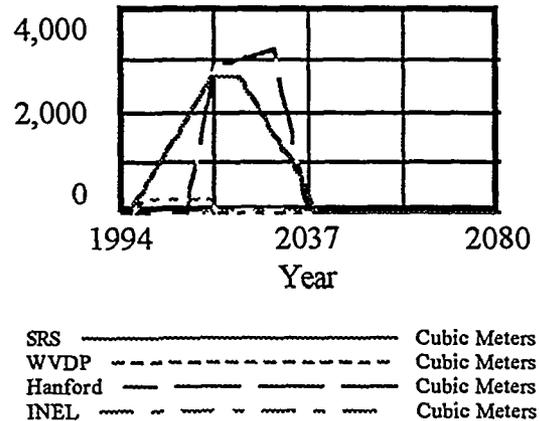|	
SRS ———————	Cubic Meters
WVDP – – – – – – –	Cubic Meters
Hanford — — — —	Cubic Meters
INEL — – — – — – —	Cubic Meters

Figure 2, shows the amount of glass in interim storage at each site as a function of time. Shipments to the repository start in 2015. Interim storage at West Valley is emptied the first year of repository operation.

References

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5. Idaho Department of Health and Welfare, 1994, *Consent Order for the United States Department of Energy, Idaho National Engineering Laboratory*, April 3, 1992, as amended.

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