Identification of Mission Sensitivities with Mission Modeling from the One System Organization at Hanford – 13292

Jeremy D Belsher*, Kayla L Pierson* and Rod F Gimpel**
* Washington River Protection Solutions, LLC, Richland, WA 99352
** One System – Waste Treatment Project, Richland, WA 99352

ABSTRACT

The Hanford site in southeast Washington contains approximately 207 million liters of radioactive and hazardous waste stored in 177 underground tanks. The U.S. Department of Energy's Office of River Protection is currently managing the Hanford waste treatment mission, which includes the storage, retrieval, treatment and disposal of the tank waste. Two recent studies, employing the modeling tools managed by the One System organization, have highlighted waste cleanup mission sensitivities.

The Hanford Tank Waste Operations Simulator Sensitivity Study evaluated the impact that varying 21 different parameters had on the Hanford Tank Waste Operations Simulator model. It concluded that inaccuracies in the predicted phase partitioning of a few key components can result in significant changes in the waste treatment duration and in the amount of immobilized high-level waste that is produced. In addition, reducing the efficiency with which tank waste is retrieved and staged can increase mission duration.

The 2012 *WTP Tank Utilization Assessment* concluded that flowsheet models need to include the latest low-activity waste glass algorithms or the waste treatment mission duration and the amount of low-activity waste that is produced could be significantly underestimated.

INTRODUCTION

Approximately 207 million liters of radioactive and hazardous waste is stored in single-shell tanks (SST) and double-shell tanks (DST) at the Hanford site in southeast Washington. The U.S. Department of Energy's Office of River Protection (ORP) is responsible for overseeing the River Protection Project (RPP), which encompasses the safe storage, retrieval, treatment and disposal of the tank waste.

The current RPP work scope is split between two primary contractors. Washington River Protection Solutions, LLC (WRPS) manages the Tank Farm project, which covers the activities required to retrieve, stage and transfer tank waste; provides supplemental treatment for tank waste and provides Waste Treatment and Immobilization Plant (WTP) support to ORP. Bechtel National, Inc. (BNI) manages the design, construction and commissioning of the facilities that comprise the WTP: a pretreatment facility, a high-level waste (HLW) vitrification facility, a low-activity waste (LAW) vitrification facility, analytical laboratory and the balance of facilities.

The One System integrated project team is an organizational structure that was formed in 2012 and is comprised of employees from both the WTP and Tank Farm projects. The One System organization is intended to integrate complimentary functions between WTP and Tank Farms and to enhance mission-based decision making to ensure that the RPP mission is prepared for WTP commissioning and initial plant operations.

Within the One System integrated project team, the System Planning and Modeling group is responsible for process modeling, mission planning and flowsheet evaluation. The System Planning and Modeling group manages two different dynamic flowsheet simulators; each of which were developed using the G2[1] programming language.

The Hanford Tank Waste Operations Simulator (HTWOS) models the RPP mission from the retrieval of tank waste to its vitrification at the WTP. HTWOS is the core of the RPP system planning process [1], which provides the basis for the alignment of program costs, scope, and schedules from upper-tier contracts to individual facility operating plans. In addition, HTWOS is used for more detailed analysis of the current mission configuration and for evaluation of alternate treatment scenarios.

The WTP dynamic model is limited to the operation of WTP facilities, but models the WTP in greater detail than HTWOS does. The WTP dynamic model supports the analysis of WTP operations as required by the WTP *Statement of Work* (Contract DE-AC27-01RB14136 Section C). The most recent of these analyses are documented in the 2012 *WTP Tank Utilization Assessment* [2].

Two recent studies, employing the modeling tools managed by the System Planning and Modeling group have highlighted RPP mission sensitivities: (1) The HTWOS Sensitivity Study [3] and (2) The *2012 WTP Tank Utilization Assessment* (TUA).

The HTWOS Sensitivity Study reported that inaccuracies in the predicted phase partitioning of a few key waste components can result in significant changes in the RPP mission duration and in the amount of HLW glass that is produced. In addition, reducing the efficiency with which tank waste is delivered from the DSTs to the WTP can increase the mission duration.

The TUA concluded that "[r]unning flowsheet models without the latest LAW glass algorithms for sulfur (sulfate), chlorine, fluorine, chromium and phosphorous (phosphate) will result in a significant underestimation" [2] of the amount of LAW glass produced and in the estimated RPP mission duration. This conclusion is confirmed when the results of the TUA are compared with HTWOS outputs, which uses an older LAW glass formulation algorithm.

THE HANFORD TANK WASTE OPERATIONS SIMULATOR SENSITIVITY STUDY

The Hanford Tank Waste Operations Simulator models all SSTs and DSTs, tracks up to 139 dissolved and non-dissolved ions, models simple chemistry and dozens of pieces of equipment. HTWOS outputs large amounts of data, including high-profile mission metrics such as the date by which all tank waste is treated, the date by which all SSTs are retrieved and the amount of HLW glass produced. All model outputs are reported as point values. Uncertainty due to enabling assumptions, engineering judgment or incomplete data coverage is not quantified. Consequently, HTWOS predictions appear more precise than really they are. This can mask risks that increase costs or delay the completion of the RPP mission.

System Planning and Modeling staff performed a sensitivity analysis on HTWOS. The HTWOS Sensitivity Study evaluated the impact that varying 21different parameters had on selected mission metrics. The sensitivity study provides useful information on how uncertainty can affect mission metrics. The HTWOS Sensitivity Study is also the early stage of development of an organizational capacity for more accurate uncertainty analyses associated with a specific flowsheet configuration.

.

---

[1] G2 is a registered trademark of Gensym Corporation, Austin, Texas.

Hanford Flowsheet Description

In the current waste treatment flowsheet, most of the waste from the SSTs is retrieved to the DSTs which, after several preparatory transfers, deliver tank waste to the WTP. A simplified process diagram is shown in Figure 1.

At the WTP, tank waste is first processed through a pretreatment facility where it is separated into a largely liquid LAW portion and a HLW fraction that contains nearly all the solid waste. The LAW is then delivered to a LAW vitrification facility and, as necessary, to a supplemental LAW treatment facility. In the current flowsheet the supplemental LAW treatment facility is assumed to be an additional vitrification plant. The HLW portion is sent to a HLW vitrification facility. The molten LAW glass is poured into stainless steel containers, each of which contains approximately 5.51 MT of cooled glass. The molten HLW glass is poured into stainless steel canisters. Each HLW canister holds approximately 3.02 MT of immobilized HLW. The LAW containers are stored onsite at the Integrated Disposal Facility, while it is assumed that the HLW canisters are shipped offsite and stored in a geological repository.

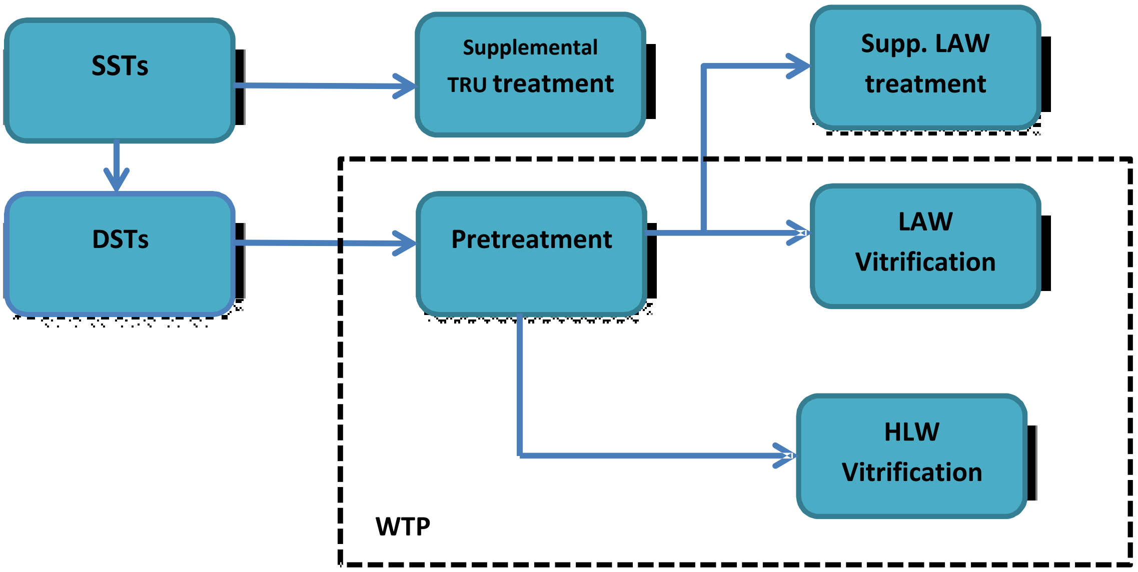

Fig. 1. Simplified RPP Mission Process Diagram

Parameters and Mission Metrics

The HTWOS Sensitivity Study included 21 different parameters and five mission metrics. Parameters were selected that were known to have an impact on one or more mission metrics. The 21 parameters fell into one of four categories: tank waste inventory parameters, waste solubility parameters, Tank Farm parameters and WTP parameters. The mission metrics were HLW canister count, LAW container count, waste treatment duration, SST retrieval duration and total sodium addition. The selected mission metrics are discussed below. Due to space limitations, not all of the 21 different parameters will be discussed but each of the four parameter categories will be, as well as any individual parameters of note.

Mission Metrics

The waste treatment duration[2] is the length of time starting from the beginning of fiscal year 2011 required to retrieve and mobilize all tank waste. Milestone M-062-00 of the *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement* [5] (henceforth, "Tri-Party Agreement") requires that "pretreatment processing and vitrification of Hanford High Level (HLW) and Low activity (LAW) Tank wastes" be completed by 12/31/2047.

The SST retrieval duration is the length of time starting from the beginning of fiscal year 2011 that is required to complete the retrieval of all SSTs. Tri-Party Agreement milestone M-045-70 requires that "waste retrieval from all remaining single-shell tanks" be completed by 12/31/2040.

The HLW canister count is the total number of HLW canisters produced during the RPP mission. HTWOS predicts that the production of HLW canisters will be the mission driver for much of the RPP mission; as a result the total HLW canisters produced is correlated with both the waste treatment mission duration and the total mission cost.

The LAW container count is the total number of LAW containers produced during the RPP Mission. On a volumetric basis most of the tank waste is disposed of as LAW. The production of LAW waste is a mission driver until the Supplemental LAW facility reaches its full capacity. The LAW container count includes containers produced by the WTP LAW Facility and the Supplemental LAW Facility.

The total sodium addition is the sum of the sodium added to the tank waste during the mission, including sodium hydroxide added in pretreatment for aluminum solubility and in tank farms during SST retrieval. Increased sodium addition results in larger LAW container counts.

Parameters

The tank waste inventory group contains four different parameters. The amount of mixed waste stored in Hanford's 177 underground tanks has an obvious connection with both the duration of waste treatment and the amount of immobilized-waste produced. Larger than expected quantities of waste could increase both SST retrieval durations and the expected quantities of HLW and LAW glass; both outcomes could result in increased treatment duration. Lower quantities could result in treatment facilities that are oversized. The initial inventory of aluminum is the highest profile tank waste inventory parameter.

There are nine different parameters in the solubility parameter group. The fraction of a waste component that ends up as immobilized LAW or as immobilized HLW is largely determined by the solubility of that component. The more soluble a waste component is, the larger fraction of it that will end up incorporated in LAW glass. Any uncertainty in the predicted phase partitioning translates into uncertainties in the amount of HLW and LAW glass produced. Solubility parameters cover the solubility behavior of multiple components such as aluminum, sulfate and phosphate, in tank farms and in the WTP.

The tank farm group contains two parameters. The first parameter influences the length of time that is required to retrieve waste from an SST. The other parameter affects the amount of time that it takes to complete waste transfers within the DST system and from the DST system to the WTP. Unexpected equipment failures can slow or delay transfers of tank waste. Key failures could even halt the retrieval of waste from the SSTs or stop all waste transfers in the DST system.

---

[2] In this discussion, the terms "waste treatment duration" and "SST retrieval duration" are used interchangeably with "waste treatment end date" and "SST retrieval completion date", respectively.

The final group, the WTP parameters, includes six different parameters that cover a range of operations in the WTP, including waste filtration in the Pretreatment Facility, the extent sulfate decomposition in the melters and HLW glass formulation.

Methodology

The HTWOS Sensitivity Study used a Latin Hypercube design to generate a 63 run experimental matrix, with all 21 parameters simultaneously varied in each run. The resulting data was used to create a Gaussian Process meta-model with a non-zero nugget for each mission metric. The sensitivity of HTWOS to the 21 different parameters was calculated using the meta-model. The experimental design and subsequent analysis was performed using the statistical software package JMP®[3].

Results

Fifty-seven of the 63 HTWOS runs in the experimental design completed. Five of the runs that did not complete were runs that had extremely large numbers of HLW canisters (40,000+) and were still treating waste past FY 2100.

Figure 2 plots the Treatment End Date and the SST Retrieval Completion against the HLW canister count. Figure 2 also shows the linear regression line and the coefficient of determination for both mission metrics. For the runs that did complete, the waste treatment end date and the SST retrieval completion date are strongly correlated with the HLW canister count.

This is an incomplete picture. The waste treatment end date and the SST retrieval completion date are largely explained by the HLW canister count when there are more than 20,000 HLW canisters. However, when the HLW canister count is relatively small (less than 20,000), the correlation between the treatment end date and the SST retrieval completion date is much less significant, as seen by the cluster of points on the lower left corner of Figure 2. This difference suggests that there may be two distinct mission behaviors: one where the HLW canister count is large and the production of HLW glass dominates the mission, and a second behavior where the HLW canister count is relatively small and the mission metrics are influenced by multiple parameters.

---

[3] JMP is a registered trademark of SAS, Cary, NC.

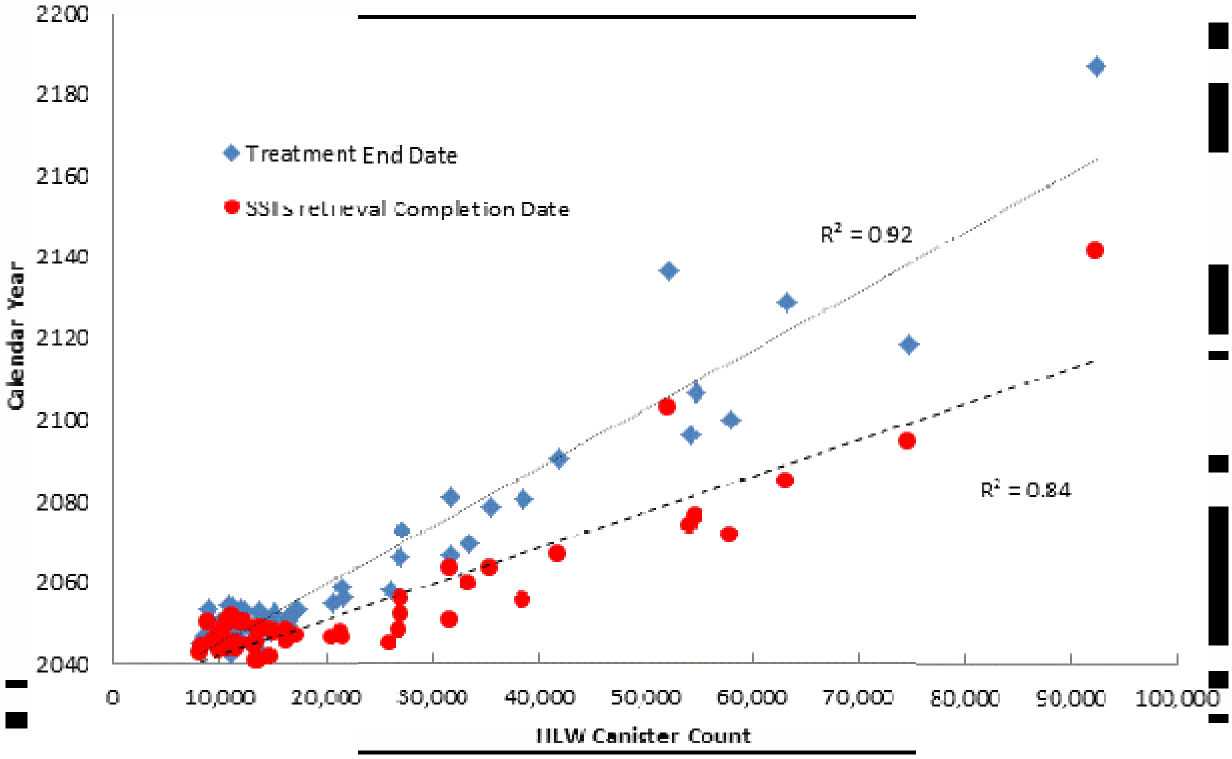

Fig. 2. HLW Canister Count and other Mission Metrics

Figure 3 plots the HLW canister count against the percent change (compared with the baseline value) in the fraction of solid sulfate reporting to the liquid phase upon the addition of retrieval water to an SST. The runs that produced more than 20,000 HLW canisters were also runs where sulfate was less soluble than is currently predicted in HTWOS . For this reason all of the results from the HTWOS Sensitivity Study were analyzed in two groups. The first group is the “full data set” and it includes all HTWOS Sensitivity Study runs in aggregate (a total of 57 runs). The second group only includes those runs where sulfate is as soluble as or more soluble than is currently predicted by HTWOS. This group is will be referred to as the “restricted data set” (a total of 32 runs). The two data sets are summarized in Table I.

Table I. Mission Metrics for Restricted and Full Data Sets

Mission Metric	Data Set	Low Value	High Value	Median Value
Treatment End Date	Full	Q1 2042	Q4 2188	Q2 2052
	Restricted	Q1 2042	Q1 2054	Q3 2048
HLW Canister Count	Full	8,500	92,500	14,000
	Restricted	8,500	17,500	11,500
LAW Container Count	Full	77,000	107,000	91,000
	Restricted	83,000	107,000	94,000
Total Sodium Addition (MT)	Full	14,000	31,000	21,500
	Restricted	14,000	31,000	22,500
SST Retrieval Completion Date	Full	Q2 2039	Q3 2142	Q1 2047
	Restricted	Q2 2039	Q2 2051	Q3 2045

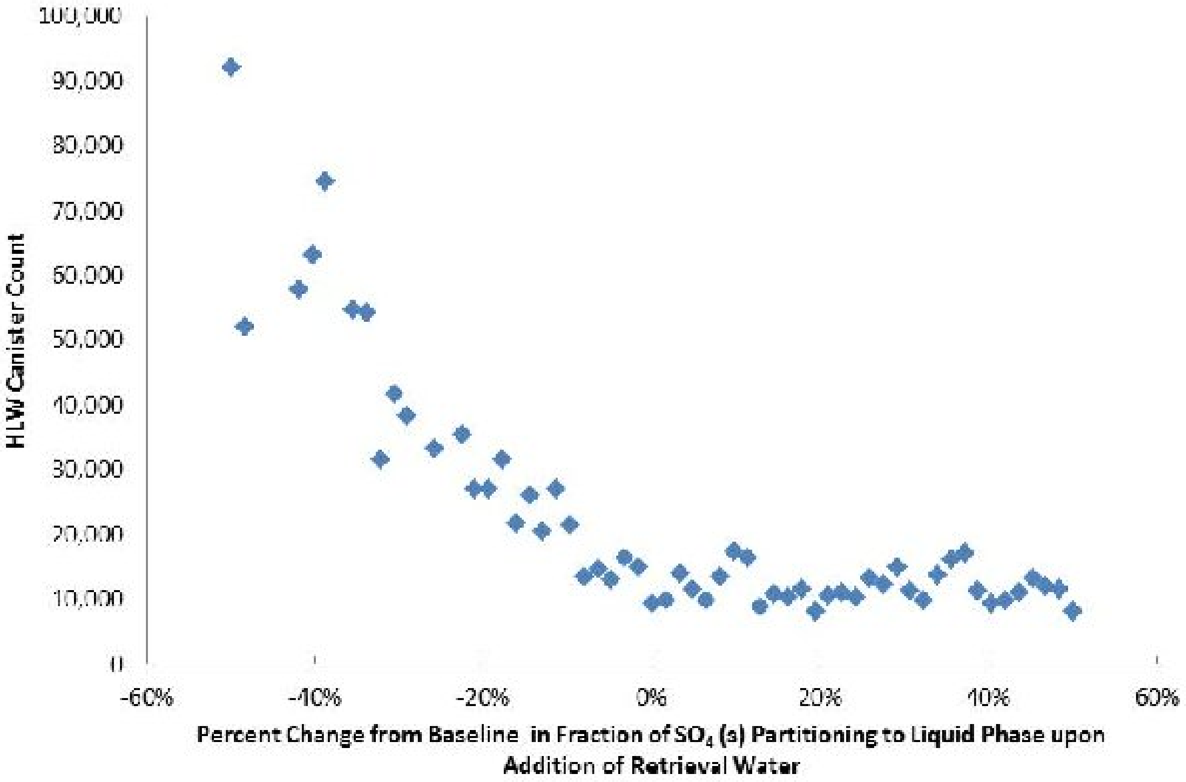

Fig. 3. Changes in Sulfate Partitioning and HLW Canister Count

The HLW canister count is extremely variable in both data sets. The volatility is most obvious in the full data set, where the highest HLW canister count is nearly 11 times larger than the low value. The LAW container count was the most stable mission metric ranging from 77,000 to 107,000 canisters in the full set data; the range is even tighter in the restricted data set. In both data sets the response surface of the Gaussian process meta-model for each of the mission metrics is well behaved and the impact of interactions between parameters is relatively small. Changes in model parameters generally result in gradual and easily predictable changes in mission metrics.

Table 2 provides a qualitative assessment of the impact that each parameter group has on the mission metrics. Overall, the solubility parameters have the most significant impact on mission metrics, followed by the inventory parameters which have moderate influence on the mission metrics and the WTP parameters which have a low impact to moderate impact on mission metrics. Depending on which data set is used, the Tank Farm parameters have either a low or high impact on mission metrics. These categories are discussed in more detail below.

Table II. Qualitative Impact of Parameter Groups

	Overall Impact	
Parameter Group	**Full Set**	**Restricted Set**
Solubility	Very High	High
Inventory	Moderate	Moderate
WTP	Moderate	Low
Tank Farm	Low	High

Solubility Parameters

The solubility parameters have a large impact on nearly all mission metrics in both the full and restricted data sets. In the full data set, the impact of sulfate solubility is so significant that it mutes the impact of nearly every other parameter. Over 90% of the variation in the HLW canister count, the treatment date and the SST retrieved by date is due to changes in the solubility of sulfate. Even though sulfate solubility dominants the model's behavior in the full data set, the phase partitioning of aluminum, bismuth and phosphate influence all five mission metrics, with variations in the HLW canister count being almost completely determined by variations in solubility of sulfate, phosphate, bismuth and aluminum.

In the restricted data set, sulfate solubility does not impact any of the mission metrics, but other solubility parameters still play a large role. Every mission metric except the SST retrieval duration is impacted by changes in the solubility of aluminum, bismuth, or phosphate. As with the full data set, the HLW canister count is very strongly influenced by the phase partitioning of aluminum, bismuth, and phosphate.

Inventory Parameters

The inventory parameters had a moderate impact in both the full and restricted data sets. Aluminum inventory influences the total sodium addition and the LAW container count in both data sets. Changes in the sulfate inventory results in changes in the LAW container count in both data sets. In the restricted data set phosphate inventory had an influence on the HLW canister count, the treatment end date and the SST retrieval duration.

WTP Parameters

In the full data set, changes to the WTP parameters resulted in moderate changes in the mission metrics. The impact on the mission metrics were primarily due to the interaction of sulfate solubility with WTP parameters such as the extent of sulfate decomposition in the melters and the amount of sulfur that can be incorporated in HLW glass. In the restricted data set, the sulfate solubility has, by design, no influence on mission metrics, so the impact of the WTP parameters on the mission metrics is significantly smaller.

Tank Farm Parameters

The Tank Farm parameters had two very different impacts on the mission metrics, depending on which data set is used. In the full data set, the production of HLW glass determines both the mission duration and the time required to retrieve waste from the SSTs. HLW glass production backs into the DST system, which slows down SST retrievals. In these scenarios, the rate of SST retrievals or the efficiency of waste movement through the DST system is largely irrelevant and changes in the tank farm parameters have little to no impact on the mission metrics.

The behavior of the waste treatment mission is more complicated in the restricted data set than it is in the full data set. In the restricted set, the production of HLW canisters is not the primary or only determinant of the overall treatment duration and the SST retrieval duration. Consequently, the tank farm parameters had a much larger influence on the mission metrics in the restricted data set than they do in the full data set. The efficiency with which tank waste is moved through the DST system has a large impact on the treatment end date and on the SST retrieval duration. The rate at which waste is retrieved from the SSTs has a smaller impact on SST retrieval duration and on the treatment end date.

2012 WTP TANK UTILIZATION ASSESSMENT SCENARIO 3

Like HTWOS, the WTP Dynamic Model was developed using the G2 object-oriented programming platform. The WTP Dynamic model only simulates the operation of the WTP. It includes most of the equipment that will be installed in the WTP, the piping between equipment, chemical reactions, chemical phase equilibrium and operating logic that mimics the anticipated plant operations. [4]. The WTP Dynamic Model produces large amounts of data that describe the projected daily operation of the WTP. The *2012 Tank Utilization Assessment* documents much of this data and the related analysis.

The 2012 TUA projects that the WTP LAW vitrification facility will immobilize approximately one third of the pretreated LAW waste. The remaining LAW will be immobilized by an additional facility. The current Hanford baseline assumes that this facility will be an additional LAW vitrification facility, but a final decision on which supplemental treatment facility to use will be made by April 30, 2015 [5].

The 2012 TUA baseline case models the supplemental treatment facility as a “black box” vitrification facility with an infinite capacity. The supplemental treatment facility is assumed to be available from the start of the mission to treat, if necessary, any quantity of LAW that exceeds the capacity of the WTP LAW facility. The amount of LAW glass produced is calculated by assuming that the ratio of glass produced per gallon of pretreated LAW feed in the supplemental treatment facility is the same ratio as in the WTP LAW Facility [2].

In Scenario 3 from the 2012 TUA, the Supplemental LAW Facility was not modeled as a “black box”, but as an additional LAW vitrification facility with 6 LAW melters (the WTP LAW Facility has 2 LAW melters). A single melter in the Supplemental LAW Facility was scheduled to begin operations approximately four years after the start of waste treatment. The Supplemental LAW Facility reached full capacity approximately seven years after the start of waste treatment.

Methodology

The Supplemental LAW Facility in Scenario 3 was modeled with the same technical assumptions, glass chemistry, melters and offgas system as the WTP LAW facility with the only difference being that the Supplemental LAW Facility internally recycles liquid effluents from the offgas system, while the WTP LAW Facility recycles liquid effluents back to the Pretreatment Facility. The internal recycle causes semi-volatiles to build up in the waste streams in the Supplemental LAW Facility which impacts LAW glass production.

The results from the TUA scenario 3 were compared with HTWOS results. HTWOS also models supplemental LAW treatment as an additional vitrification facility with 6 melters and internal recycle of semi-volatile components.

Glass Formulation Models

LAW and HLW glass must meet a variety of processing, acceptability and model validity constraints. A glass formulation model is a collection of these constraints and a series of mathematical correlations that predict glass composition based on waste composition. Any constraint that limits the amount of waste that can be incorporated into the glass is referred to as a "glass driver." The comparison of TUA Scenario 3 with HTWOS makes it clear (see "Results") that the choice of a LAW glass formulation model has a large impact on the RPP mission duration and also which mission functions act as mission drivers.

HTWOS uses a different LAW glass formulation model ("HTWOS LAW Glass Model") than the WTP Dynamic Model ("WTP LAW Glass Model"). The WTP LAW Glass Model incorporates more glass constraints that frequently predict larger glass masses than is predicted by the HTWOS LAW Glass Model. The HTWOS LAW glass model only includes mass fraction constraints for sulfur and sodium and it allows, for the most part, higher sulfur loading in the LAW glass than is allowed by the WTP dynamic model. In addition, the WTP LAW Glass Model contains limits on glass components that are not present in the HTWOS LAW Glass Model.[4] Figure 4 shows the sulfur and sodium limits for the HTWOS LAW glass model and the WTP LAW Glass model.

HTWOS formulates LAW glass using the sulfur and sodium limits documented in [6], which concluded that there is enough evidence to assume that, with further glass formulation data, the weight percent of Na_2O in the final glass (not including any volatilization that occurs in the melter) should be less than or equal to 20% and the weight percent of SO_3 should be less than or equal to 0.8%.

The HTWOS LAW Glass formulation model was adopted in 2004 as an enabling assumption that additional glass formulation work would validate the increased sodium and sulfur loading. At present not enough experimental evidence has been gathered to conclusively confirm that the HTWOS LAW Glass model will consistently produce acceptable LAW glass. In fact, more recent experimental data as documented in [7 -8] suggests that reduced sulfur loading (in Figure 4, this is the slanted segment on the WTP LAW Glass plot) and loading limits on chromium, phosphate, chloride and fluoride may be necessary to prevent the accumulation of salt in the LAW melters.

---

[4] The WTP LAW Glass Model includes mass fraction constraints in the glass for SO_3, Na_2O, K_2O, P_2O_5, Cl^-, F- and Cr_2O_3. For a detailed discussion on LAW glass formulation in the WTP dynamic model see [6].

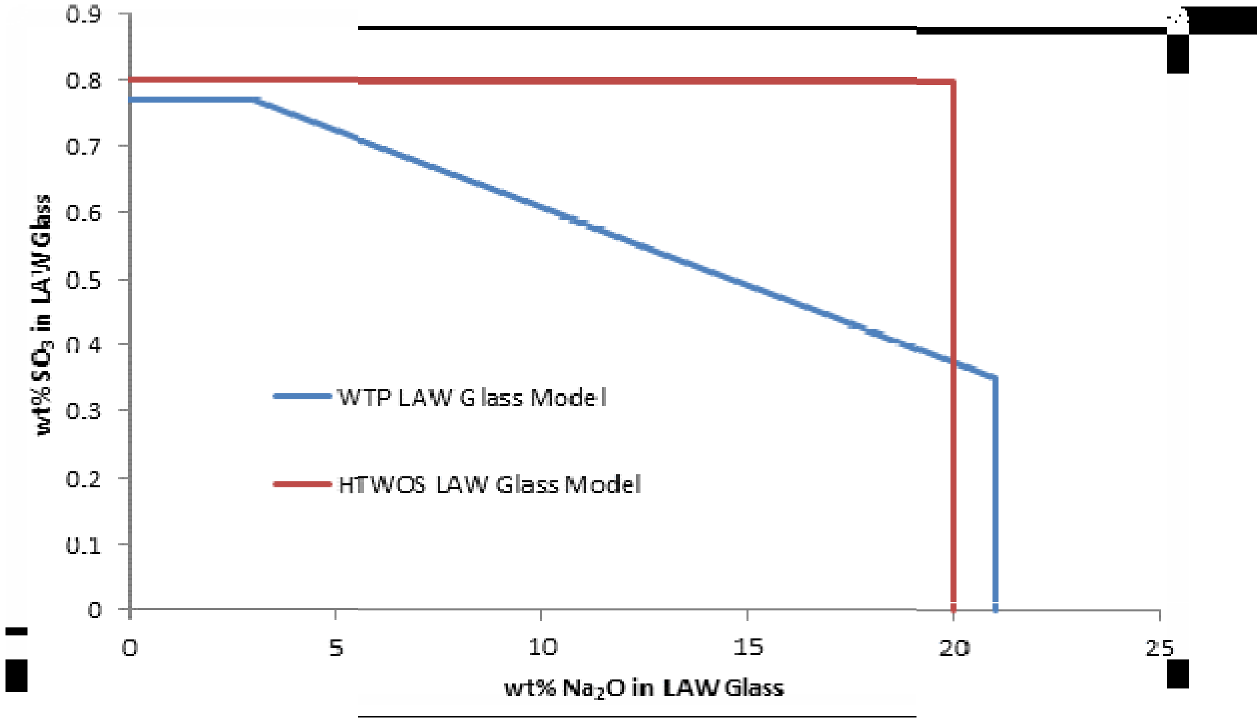

Fig. 4. LAW Glass Model Comparison

Results

Compared with the 2012 TUA baseline case, explicitly modeling the operation of the Supplemental LAW Facility in TUA Scenario 3 increased the projected mission duration by 8 years[5] and increased the total LAW container count from 114,000 to 162,000 containers. The increased mission duration is the result of the delayed start-up of the Supplemental LAW Facility, the finite capacity of the Supplemental LAW Facility and the 42% increase in the amount of LAW glass produced. The combination of these three factors results in insufficient vitrification capacity in the eight LAW melters (two in WTP LAW and six in Supplemental LAW) for approximately 50% of the mission. When LAW is delivered to the LAW melters faster than it can be vitrified, LAW becomes the mission driver as untreated LAW backs into the pretreatment facility which can slow down or stop the production of glass at the HLW melters and extend the mission duration. For most of Scenario 3, the production of LAW is the mission driver. In the 2012 TUA baseline case, the processing of waste through pretreatment was often the mission driver.

In the 2012 TUA baseline case, the glass produced in the Supplemental LAW Facility is assumed to have the same composition as the LAW glass produced at the WTP. The large increase in LAW glass produced in TUA scenario 3 shows that this assumption is incorrect. The Supplemental LAW Facility produces more LAW glass per given amount of waste than the WTP LAW Facility does. Nearly all of this increase is due to the internal recycle of semi-volatile sulfur, chlorine and fluorine in the Supplemental LAW Facility. Figure 5 shows the halide[6] concentration in both Supplemental LAW glass and in the WTP LAW glass. The Supplemental LAW Facility generally produces glass with higher

---

[5] Assuming an operating efficiency of 100%.

[6] Halide concentration is defined as $X_{Cl} + 0.3\ X_F$ where X_{Cl} is the mass fraction of chlorine in the LAW glass and X_F is the mass fraction of fluorine in the LAW glass.

halide loading at any given time than the WTP LAW Facility and the LAW glass that it produces has, on average, higher halide loading than the WTP LAW glass.

Although both HTWOS and TUA Scenario 3 model the Supplemental LAW Facility in detail, they project significantly different mission durations. Table III shows the total length of time that the WTP is in operation, the LAW container count and the HLW canister count for the HTWOS System Plan 6 baseline case [1] (henceforth "HTWOS Version 6.6.1") and TUA Scenario 3. Scenario 3 of the TUA projects[7] the WTP to operate 14 years longer than is predicted by HTWOS Version 6.6.1. Much of the difference in the length of time that the WTP operates is because TUA Scenario 3 produces nearly 70% more LAW glass than HTWOS does.

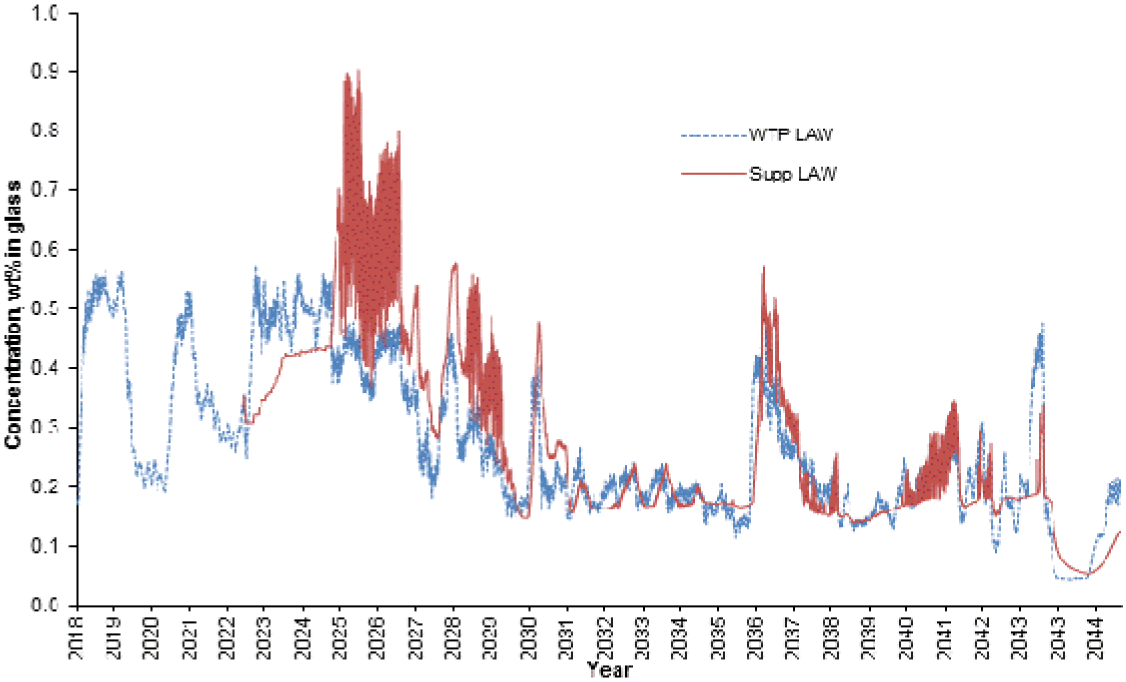

Fig. 5. Halide Concentration in WTP LAW and Supplemental LAW Glass

The difference in the amount of LAW glass produced between HTWOS Version 6.6.1 and TUA Scenario 3 is primarily due to the use of the different LAW glass formulation models. The HTWOS LAW Glass model allows higher sulfur loading does the WTP LAW Glass model and the HTWOS LAW Glass model does not include any halide constraints, so the internal recycle in the Supplemental LAW facility does not impact the LAW container count to the same extent that it does in the WTP dynamic model.

---

[7] In the TUA, the mission duration is reported at an assumed 100% operating efficiency. HTWOS assumes an operating efficiency of 70%. For the comparison between the two models, the TUA mission duration is divided by 0.70 to convert it to an operating efficiency of 70%.

Table III. HTWOS and TUA Scenario 3 Mission Metrics

	WTP Operations Duration* (years)	LAW Container Count	HLW Canister Count
HTWOS Version 6.6.1	25	96,000	10,700
TUA Scenario 3	39	162,000	11,200
% difference	56%	69%	5%

*** At an assumed 70% operating efficiency**

CONCLUSION

Mission modeling from the One System organization at Hanford has identified three sensitivities that could result in the RPP Mission durations that are significantly longer, and in missions that are more costly, than currently predicted by either HTWOS or by the WTP Dynamic Model.

1. In the HTWOS Sensitivity Study the amount of HLW glass produced was highly sensitive to the predicted solubility of a few components. In the sensitivity study these included aluminum, sulfate and phosphate. Chromium was not included in the HTWOS Sensitivity Study but it shares some key characteristics[8] with aluminum, sulfate and phosphate so it should be included in the group. Changes in the predicted phase partitioning of these component can lead to increases in the HLW canisters that extend the mission duration by years or even decades.

2. The RPP mission was also shown to be sensitive to the efficiency with which tank waste is transferred within the DST system in preparation for delivery to the WTP. Specific equipment failures are not modeled in HTWOS, but the duration of transfers are extended to account for a decreases in waste transfer efficiency. In the HTWOS Sensitivity Study, increases in the length of time that tank waste transfers are delayed due to equipment failures extended the mission duration by up to 7 years. It is worth noting that this is very similar to the mission duration increase due to DST transfer inefficiencies that is reported in [9].

3. Scenario 3 of the 2012 TUA showed that "[r]unning flowsheet models without the latest LAW glass algorithms for sulfur (sulfate), chlorine, fluorine, chromium and phosphorous (phosphate) will result in significant underestimation of the supplemental LAW glass quantities." [2] The comparison with HTWOS highlights that this underestimation of supplemental LAW glass quantities can also result in an underestimation of the RPP mission duration. Using an inaccurate LAW glass formulation model can over- or underestimate the required capacity of supplement LAW treatment.

Based on these conclusions, the following actions are recommended:

1. The System Planning and Modeling group has developed a Pitzer activity coefficient based thermodynamic model [10] that is anticipated to be an improvement over the current solubility modeling used for system modeling and system planning. It is recommended that this thermodynamic model be implemented in both HTWOS and the WTP Dynamic Model.

---

[8] These characteristics are: Most (~75% or more) of component is immobilized in LAW glass and the component is an HLW glass driver.

2. Gather more waste partitioning data that is specific to Hanford tank waste. There is a limited amount of high quality solubility data for Hanford tank waste. This complicates the evaluation of solubility models. The data requirements are not limited to current conditions in tank farms. Data about solubility during the mixing of waste from different tanks and data involving conditions that will occur in the WTP are also necessary.

3. The methodology used by HTWOS for modeling the efficiency of DST transfers needs to be revisited. Even if the current method of delaying each individual transfer is acceptable, the amount of time that each transfer is delayed may need to be adjusted. In addition, further analysis (as done in [9]) needs to be done to identify which types of equipment failures lead to the most significant delays in waste transfers in the DST system. Work then needs to be done, for key pieces of equipment, to determine how to reduce the number of failures, the length of failure or to mitigate in the impact of the equipment failures.

4. The HTWOS and the WTP LAW Glass Formulation models need to be revaluated based on the most recent LAW glass formulation work. Once this is complete, HTWOS and the WTP Dynamic Model should adopt the same LAW glass formulation model.

REFERENCES

1. Certa, P. J., et al, 2011, River Protection Project System Plan, Rev. 6, ORP-11242, Washington River Protection Solutions, LLC, Richland, Washington.

2. Jenkins, K. D., et al, 2012, 2012 WTP Tank Utilization Assessment, Rev. 0, 24590-WTP-RPT-PE-12-001, Bechtel National, Inc., Richland, Washington.

3. Belsher, J.D, et al, 2012, Hanford Tank Waste Operations Simulator (HTWOS) Sensitivity Study, RPP-RPT-51819, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

4. Deng, Yueying, 2011, Dynamic (G2) Model Design Document, 24590-WTP-MDD-PR-01-002, Rev. 12, Bechtel National, Inc., Richland, Washington.

5. Ecology, EPA and DOE, 1989, Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement, as amended, Washington State Department of Ecology, U. S. Environmental Protection Agency, and U. S. Department of Energy, Olympia, Washington.

6. Stone, I.Z. ed., 2011, Flowsheet Bases, Assumptions and Requirements, Rev. 6, DE-AC27-01RV14136, Bechtel National, Inc., Richland, Washington

7. Vienna, J.D., 2005, Preliminary ILAW Formulation Algorithm Description, Rev.0, 24590-LAW-RPT-RT-04-0003, River Protection Project, Waste Treatment Plant, Richland, Washington.

8. Vienna, J.D. and Kim, D, 2007, Halide, Chromate, and Phosphate Impacts on LAW Glass Salt limit, CCN 150795, River Protection Project, Waste Treatment Plant, Richland, Washington.

9. Gallaher, B. N., et al, 2011, Phase 3 Waste Feed Delivery Operations Research Model Initial Assessment Report, Rev. 0, RPP-RPT-50742, Washington River Protection Solutions, LLC, Richland, Washington.

10. Carter, R, 2011, Development of a Thermodynamic Model for the Hanford Tank Waste Operations Simulator (HTWOS), Rev. 0, RPP-RPT-50703, Washington River Protection Solutions, LLC, Richland, Washington.

ACKNOWLEDGEMENTS

The authors would like to thank Daniel Greer for statistical analysis on the HTWOS Sensitivity Study.