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Verification and Validation of the Decision Analysis Model for Assessment of Tank Waste Remediation System Waste Treatment Strategies

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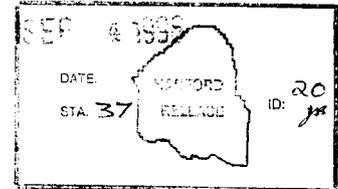
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Abstract: This document is the verification and validation final report for the Decision Analysis Model for Assessment of Tank Waste Remediation System Waste Treatment Strategies. This model is also known as the INSIGHT Model.

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1.0 INTRODUCTION AND OBJECTIVES

Westech International, Inc., following the work order documented in WHC-SD-WM-SWD-035, has completed a verification and validation (V&V) of a Microsoft Excel™ spreadsheet known as the INSIGHT Model (INSIGHT or the Model). This Model has been quite extensively described in WHC-EP-0874, *Decision Analysis Model for Assessment of Tank Waste Remediation System Waste Treatment Strategies* (the Report)(McConville 1995).

The V&V effort was comprised of six major activities.

- Determining and documenting the objectives of INSIGHT.
- Determining and devising a number of paths through the Model that would be the minimum necessary to ensure that all the data in the Model were used to support calculations on one or more paths.
- Exhaustive testing to ensure that, for all combinations of path choices and Model switch settings, the correct data are chosen from internal data tables for use in calculations.
- An expert review of the 41 formulae in the Report which fundamentally describe the calculations that the Model performs.
- A thorough investigation of how INSIGHT carries out the concept of the simplified calculations represented by the 41 formulae in the Report.
- Support activities such as programming which were necessary to carry out the tasks described above.

Three activities were described in the V&V plan which were not carried out in the project. These activities, and the justification for not carrying them out, is provided below. The first two such activities are described in the V&V Plan, Section 3.1.2, which states that:

"The INSIGHT developers have already performed reviews of some of the built-in data contained in the model. For the activity described by this document, selected audits will be performed of some of these previously conducted reviews. Also, a limited selection of the data not yet reviewed will be reviewed for correctness, including review of referenced document sources, or review by experts, as deemed necessary."

One of the advantages of INSIGHT is that the data are easy to locate and change as necessary. Much of the data embedded in INSIGHT has changed, and will continue to change as a comprehensive understanding of the waste characterization and technical disposal

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options continues to evolve. It was determined that it would not be cost effective to review data within INSIGHT since a significant portion of the embedded data are not current and the currency of any data is not immediately apparent. Some documentation does exist to support previous data audits during development of INSIGHT. However, a significant portion of the data have undergone revision in the Model since the documented audits. This renders an attempt to compare the current data to old audit documentation non-productive. This V&V report does offer suggestions for dealing with INSIGHT data validation in the recommendations section.

The third activity not carried out in the project is described in the V&V Plan, Section 4.2, which states that "[t]he purpose of the test cases is to verify that a selection of the calculational algorithms produce the expected numerical results." Six test cases were required and were created to ensure that all retrieval, pretreatment, high, and low level waste processes and forms were used in at least one case. However, the "expected numerical results" for the six test cases are not known. The input data and calculation methods used by other models are sufficiently different from those used in the six test cases that similarities between results cannot be used to gain confidence in INSIGHT's internal methods.¹ It was therefore decided that confidence in the calculation methods in the Model had to be gained by a detailed review of the spreadsheet formulae. Such an activity is targeted at the same end goal (i.e., assurance that the calculational methods in INSIGHT produce the intended results) and was the predominant activity in the V&V project.

2.0 REVIEW BOUNDARIES

The subject under review was the contents of some cells in the INSIGHT spreadsheet. Although the Report was used extensively in the review and two errors were found in the Report, it was not the intention of the V&V effort to consider the Report as part of the subject under review. Numerous other documents were used in the review of the Model, but none of these were part of the subject under review. The SuperTree™ decision analysis software is fundamental to the Model accomplishing its objectives. This software was specifically excluded from review by the V&V Project Plan and was not used in the review of INSIGHT at all. The following paragraphs address the delineation of which cells were reviewed in the INSIGHT spreadsheet.

2.1 FORMULAE IN DATA TABLES

Although data review was not the focus of any of the subtasks which were carried out, during evaluation of the Model, much of the data was inspected for reasonableness.

¹The *TWRS Process Flowsheet* (Orme 1995) was used to gain confidence in the Model's internal methods for input parameter sets other than those employed in the six test cases.

There were a number of cases where similar data items had vastly different values or identical values belonged to parameters that might be expected to have different values. When such anomalies surfaced, an effort was made to check the data. It is also important to note that the dichotomy between formulae and data in the Model is not as one would expect. Many data tables contain formulae. Such formulae, within the bounds of a data table, were treated as data. The most common type of formulae in data is to show the component parts of a number subsequently treated as a constant. The molecular weight of a chemical, for instance, might be stored in a cell as a formula expressing the sum of the atomic weights of its atoms. A cost value might be stored as an equation which represents escalation from a 1993 dollar value. In many cases, where a parameter formula might choose a value from a low, baseline, or high alternative, the low and high values might be stored as equations representing a percent of the baseline value.

2.2 NUMERIC VALUES IN FORMULAE

On occasion, data appear in formulae in the calculation section of INSIGHT. For instance, training and start up costs were given to be 3 years times the annual operating cost. The constant 3 is data. Many, but not all of the constants appearing in formulae were questioned. Extra emphasis was placed on confirmation of data in formulae because, since the data did not reside in data tables, they might not have been subject to the same standard for data validation after entry. Generally, numeric values were individually considered to determine if they made sense. For example, the number of moles of Phosphorus might be divided by 2 in a formula which seeks to determine the quantity of P₂O₅ in the waste stream. The constant 3875, for instance, proved to be the number of cubic meters in a million gallons. As another example, volatility factors for Cl, Fl, and PO₄ (0.048, 0.349, and 0.096 respectively) were checked with Bruce Higley (TWRS Process Technology). Cari McConville (TWRS Process Design) and other experts provided affirmations or clarifications of data values when requested.

2.3 SIMILAR FORMULAE

Generally, formulae exist in groups of similar formulae. Commonly, INSIGHT formulae were more similar, or more often similar, down columns than across rows. Extensive programming work was done to produce a report of the spreadsheet formulae to reveal these similarities. When a group of similar formulae was encountered, the method of the first formulae was examined for validity and the subsequent formulae were examined to determine how they were dissimilar. Dissimilarities were examined to ensure that they were appropriate. Two kinds of dissimilarities were common. Two formulae might be identical except for name substitutions. The most common substitution was the tank farm names. The other common dissimilarity was for two formulae to be identical except that references to certain other spreadsheet cells might be offset from the formula's location by exactly the same distance in the subsequent formula. This results in the second formula referring to cells one cell down from similar references in the formula above, to which it is being

compared. A formula that has only this type of difference can be said to be a perfect relative reference when compared to another formula.

2.4 VARIABLE NAMES

There are over 1,300 variables defined in INSIGHT. When evaluating formulae, variable names were closely scrutinized to determine that they were spelled correctly, and context was used to determine if the use of that variable name made sense in that location. It is possible that a correctly spelled variable name was used in the wrong location and escaped detection. Extensive efforts were made, however, to minimize this possibility. Variable names often appeared in a sequence from one formula to another. If such sequences were violated, the reason for a change in the sequence was examined. Variables also had strong relationships in formulae. No clear "strong relationship" exists between the mass of Potassium and the HLW separation efficiency for Sodium. In this particular case, such a mismatch turned out to be acceptable. Since the projected separation efficiencies for Sodium and Potassium are the same, a separate variable for expected separation efficiency for Potassium does not exist in the spreadsheet.

2.5 OPERATORS AND PARENTHESES

Operators and parentheses were closely examined to judge whether they were appropriate. In particular, where a formulae contained a complex divisor and/or dividend, it was necessary to examine whether parentheses were used properly to accurately place the factors in the divisor or dividend, as appropriate. Unit analysis was often used to confirm that the proper operands were used and parentheses were properly placed. Occasionally, there were unneeded set of parentheses. Such superfluous elements were ignored.

3.0 TASK DESCRIPTION AND RESULTS SUMMARY

3.1 REVIEW OF INSIGHT OBJECTIVES

The first task in the V&V Plan was to determine the objectives of the Model. Numerous documents including WHC-EP-0617, *Tank Waste Decision Analysis Report* (Johnson 1993), WHC-EP-0821, *Status Report on the Development of a Decision Analysis Model for Evaluating Pretreatment Alternatives* (Sutherland 1994), WHC-EP-0833, *Tank Waste Remediation System High-Level Waste Volume Decision Analysis Model* (Johnson 1995), and WHC-EP-0617, *Decision Analysis Model for Assessment of Tank Waste Remediation System Waste Treatment Strategies* (Johnson 1993), were reviewed to identify the objectives for INSIGHT development. A report was generated, "Objectives of the

INSIGHT Model," to document this review. This document is included as Appendix A. The text in this section includes a few excerpts from this document.

Although the Model integrates the technical options in the *Tank Waste Technical Options Report* (Boomer 1993) into alternative technical strategies, it does not appear to have been developed to a rigorously defined and documented set of objectives created for the purpose of developing the Model. Although some statements regarding objectives for the Model exist in various documents, it is not clear from document review, to what extent the Model was developed to meet some of these previously documented objectives, and to what extent the connections between INSIGHT and TWRS objectives were established after Model development.

From the Report, Section 1.0, Introduction, we find that:

"Initially, the TWRS attempted an analysis of uncertainty in modeling the Hanford Waste Vitrification Plant (HWVP). ... Decision makers requested a more flexible model capable of encompassing additional stakeholder values and evaluating alternative treatment strategies. The INSIGHT model was developed to meet this request in early 1992."

From the Report, Section 1.1, Development of the Model, we find that:

"The INSIGHT model was developed to assess alternative strategies as discussed in the *TWRS Systems Engineering Work Plan* (WHC 1995). The model is structured to provide a flexible evaluation tool for several different waste treatment alternatives with respect to varying stakeholder values."

Appendix F of the Report relates the performance measures of the INSIGHT model to TWRS high level stakeholder values and to TWRS Justification of Mission Need (DOE 1993) Objectives.

3.2 SPREADSHEET PATH ANALYSIS

It was important to determine that the Model could generate useful results sets for any combination of acceptable input parameters. The rules for acceptable combination of retrieval technologies, pretreatment alternatives, low level waste processes, high and low level waste forms, and HLW container types were reviewed to determine the minimum number of paths through the model necessary to ensure that all valid data sets supporting each alternative for the above technologies, alternatives, processes, forms, and container types was included in at least one path through the Model. Initially, it was determined that ten paths through INSIGHT were necessary to include every option portrayed in the Model and described in the Report.

As a result of a meeting held March 25, 1996, a decision was made to remove processing options from the Model to reduce the number of necessary paths. The options which were to be removed were processing alternatives and waste forms no longer considered viable alternatives for implementation in the TWRS program. After a revised version of the Model was delivered for testing, the number of paths (and therefore test cases) necessary to invoke all the data was determined to be six. A document was created to establish how the base case and the six test case files were prepared from the tendered version of the Model. This document is included as Appendix B. The project plan calls for a test log during the testing activities, but testing of a spreadsheet is not conducted like testing of a software program. There is no execution to be followed, or human interaction while a program runs. The test case files are simply created and saved. Appendix B, which describes the development of the six test cases serves as the "test log."

3.3 INVESTIGATION OF SPREADSHEET FORMULAE

3.3.1 Switchable input values

The formulae that actually do the basic work in the Model and which are expressed in simplified form by the formulae in the Report, depend heavily on the proper functioning of about 400 intermediate source data cells. They are source data cells because they obtain, and make available about 450 numbers used in calculations in the spreadsheet. They are appropriately called "intermediate" because, in nearly every case, they obtain the source data from tables. The proper value is selected from the tables based on one or more other criteria. Typically, the row of the data table is selected based on the content of a switch cell which is allowed to contain a 1, 2, or 3, usually representing a low, baseline, or high value. Usually, the column of the data table is selected based on the value of another cell which contains the proper value for a condition of the model, such as which LLW form, or pretreatment process, or retrieval technology is being used in this model run. Sometimes a third condition may exist which selects the proper table to obtain the value from.

These intermediate source data cells have been tested exhaustively to determine that they function correctly. This testing is documented in the working files turned over at the completion of the V&V project. Each of these cells' formulae have been individually proofread to uncover errors. Fifteen cells were found to contain errors. Those in column B in the row range 414 to 466, and the cell at G1678. These errors were corrected before the spreadsheet base case and test cases were developed.

In general, the Model was considered to have two types of formulae. Those which carry out the processing necessary to compute the desired results and those which ensure that the right values are selected for computation. The switchable input value testing is the only testing which was directed at uncovering errors, if any, in those formulae which ensure that the right values are selected for computation.

3.3.2 Expert Review

The next step in the audit process was to ask subject matter experts to agree that the formulae in WHC-EP-0874 are a workable approach to determine the material quantities, process durations, and cost for retrieval, pretreatment, HLW, and LLW processing. A "talking paper" was prepared which reiterated the 41 formulae in the Report² each followed by thought provoking questions to cause the experts to "think outside of the box" before routinely confirming that each formulae was correct as stated. This "talking paper" is included as Appendix C. Subsequently, meetings were held with Al Boldt (TWRS Process Engineering) to discuss HLW formulae, Kayle Boomer (TWRS Process Engineering) to discuss retrieval formulae and all cost formulae, Bruce Higley (TWRS Process Technology) to discuss LLW formulae, and Eric Slaathaug (TWRS Process Engineering) to discuss pretreatment formulae. All the experts generally agreed that the formulae in the Report presented a workable conceptual means to model the anticipated alternatives and expected functioning of the processes intended for deployment during the TWRS project.

The expert review uncovered two errors in the Report formulae, neither of which was found to exist in the Model. Formula 20 provides the method for determining the anticipated pretreatment facility D&D cost. In the formula, the annual pretreatment operating cost is multiplied by 2. The accepted multiplier is 3. The second error resulted from absence of brackets. Formula 21 provides the method for determining the number of containers of HLW produced. The formulae has two parts. In each part, there should be one factor in the numerator, and two factors in the denominator. In each part, the two factors which should be in the denominator are multiplied together, and should be surrounded by brackets. Formula 30 is a similar formula for the number of containers of LLW. Unlike formula 21, it is correctly printed in the Report.

Although the experts found only two errors in the Report formulae, they could only give a qualified affirmation that the remaining Report formulae were correct as printed. The basic reason for having to qualify the affirmation was that the terms in the Report formulae are ambiguous and could represent proper or improper means of determining a value for quantity, schedule, or cost; depending on the actual concepts or values the term represented in the spreadsheet.

²In this document, the 41 formulae are sequentially numbered. These numbers do not appear in the Report. They represent, however, the order of appearance of the formulae in the Report. If the reader intends to review the Report while reading this document, it is helpful to number the formulae in the Report accordingly. The retrieval formulae are numbered 1 to 11; pretreatment formulae, 12 to 20; HLW formulae, 21 to 29; and LLW formulae 30 to 41.

3.3.3 Detailed Investigation of Spreadsheet Formulae

The next step, and the most vital piece of the effort, was to determine if and how the formulae in the Report were actually carried out in the Model. A nine page "road map," with cell references, Appendix D, has been developed to show how each of the 41 formulae in the Report are addressed in INSIGHT. Each of the cells referenced, including all of the cells in rectangular cell ranges documented in the road map have been proofread to look for errors. A special printout of the spreadsheet formulae was generated to highlight the differences between similar formulae to help in this proof reading process.

4.0 SUMMARY OF ANOMALIES AND RESOLUTIONS

Cell references in this section are to the location of the relevant cells in the base case, or test cases 1 through 6, of the Model. Three types of comments may exist under each formula.

- A note may document an important characteristic or limiting criteria associated with a formula. Notes were also used for soft recommendations. In some cases the formulae are correct, but improvements are possible.
- A cautionary note was used when an important limitation exists. It may be possible to create a set of circumstances under which the formulae will not calculate the intended result.
- Findings are preceded by a capital letter. These are audit findings requiring further attention. In most cases, the findings will probably result in spreadsheet formulae modifications.

4.1 FORMULAE IN THE REPORT NOT FOUND IN THE MODEL

All but three formulae in the Report were traceable to a specific cell [or group of cells] in the Model. The following three formulae had no such corresponding location in the Model. The absence of counterparts for these three formulae in INSIGHT does not appear to have any negative impact on the Model functioning as it should.

1. Waste volume retrieved = (Existing Tank Waste Volume) * (1 - Heel)
7. Volume of waste retrieved = (Existing Tank Waste Volume) * (1 - Heel)

Because sluicing water is added to mobilize waste, volume is an ambiguous term. Once retrieved, the waste may have additional water added or evaporated to permit storage in DSTs within acceptable Sodium concentration limits. The volume of waste retrieved is not as relevant as the mass, moles, or curies of waste retrieved. Although formulae 1 and 7 do not have a close correlation with formulae in the INSIGHT model, the concept of volume is used in a more complex way as a part of formula 5 to predict the retrieval duration from data which state the sludge and saltcake volume of the farms.

3. Activity of waste retrieved = (Curies in existing tank waste inventory) * (1 - Heel)

No formula like this was found in the Model. Formula 4 however, is used to individually calculate the curies retrieved of Cs, Sr, Tc, and TRU.

4.2 FINDINGS RELATED TO RETRIEVAL FORMULAE

Formula 1 - Waste volume retrieved - Missing, as noted above

Formula 2 - Moles of component i retrieved

Note: The table at k263:q282 is perhaps the most complex data table in the spreadsheet. The value for kgs of Al+3 in the CC farm, for instance is 4.42E+05. The cell formula actually contains: =27/95*(194000+73300+19100+652000+498000)+2900+1100+17400+5060+7450 which resolves to 4.42E+05. Other oddities include the value for PO4-3 in the NCAW farm, which is 6226.67583684302 kgs. Where did this precision come from? These examples are not uncommon in this table cell range.

Note: The HLW Separations Efficiency is used to compute the number of moles of Al, Cr, and PO4 retrieved from DSTs. It is used to compute the number of moles of Al, Na, Ca, Fe, and Ni for SSTs. Similarly, specific solubility and insolubility factors are used for Al, Cr, and PO4 in DSTs, but in SSTs, the insolubility uncertainty factor is never used, and the solubility uncertainty is only used for Al. Why is the method used for the same chemical different for different farms?

- A) There is a specific characterization uncertainty for PO4 [b466]. It's value is used in the equation for Ni [b1934:b1945]. The general characterization uncertainty is used for PO4 [b1915:b1926] instead of the uncertainty defined for PO4.
- B) Computation of moles of SO4 from kgs of SO4 appears wrong in the TWRS data set because the formulae in f359:p359 use the grams per mole value from Potassium (K) instead of SO4 for all farms except farm A.

Formula 3 - Activity of waste retrieved - Missing, as noted above

Formula 4 - No comments**Formula 5 - Retrieval Duration**

Note: The basic formula for remaining heel after SST retrieval is primary heel x secondary heel (e.g., $0.001 \times 0.01 = 0.00001$). The spreadsheet data give heel values for each allowable retrieval technology without consideration of whether the technology is used as a primary or secondary retrieval process. Can the heel value for a process be the same if it was used as a secondary process instead of a primary process? In other words, if mechanical arm technology can remove 99% of all waste from the tanks, is it reasonable to expect it to remove 99% of the heel remaining if sluicing precedes it. The amount of radioactive material remaining in the tanks, although small, may be important in terms of tank disposal categorization criteria.

Note: See graph of retrieval durations, Appendix E. A tremendous portion of the time spent retrieving SSTs is waiting for the primary process to get the remaining 5% of what it is capable of. In reality, wouldn't a decision be made to switch to the secondary process early and avoid all this time spent with little progress?

A) The Model assumes that the primary SST heel fraction applies equally to saltcake and sludge. It may be more accurate to assume that the heel consists of 100% sludge and 0% saltcake. This would involve changes to the model so that there is no secondary retrieval process saltcake retrieval duration.

Formula 6 - Retrieval Equipment Setup and Removal Time

Note: Because the secondary retrieval process is expected to be operated concurrently with the primary process (except for the last few tanks), the time to set up and remove the secondary retrieval process is appropriately ignored.

Formula 7 - Volume of waste retrieved - Missing, as noted above**Formula 8 - Retrieval Completion Date**

Note: Retrieval ends when the last SST is retrieved into a DSSF tank. Pretreatment will continue to draw waste from the DSSF tanks for some time after retrieval ends. The process flow from DSTs to pretreatment is not part of the retrieval duration.

Formula 9 - No comments**Formula 10 - Retrieval Operating Cost**

Note: The spreadsheet properly computes that DST retrieval operating costs continue long after the retrieval complete date, until the end of the latest date for LLW processing or HLW processing.

Formula 11 - Retrieval Capital Cost

Cautionary Note: For SSTs, the retrieval support systems capital cost is nominally \$519.5 million for mechanical arm technology and \$1,144.5 million for sluicing technology. Formula 11 computes the capital cost of both primary and secondary retrieval technologies, but adds the support cost for only the primary technology. This may be OK, but deserves explanation. If both sluicing and mechanical arm technology are used for SSTs, the spreadsheet assumes that the support cost of both will be the same as the support cost of sluicing. Also, sluicing must be the primary technology. Otherwise, the cost calculation would be off by a half billion dollars. [Mechanical arm technology isn't ever contemplated as an SST primary retrieval means.]

- A) DST retrieval capital cost is total DST capital cost divided by 28. When used, the capital cost is multiplied by 10 for the 10 non-DSSF DSTs. The total capital cost for DST retrieval is \$121 million. The spreadsheet only uses about \$46 million of the original \$121. If the formula is correct, perhaps the note associated with this formula could be used to explain why the other \$75 million is not considered here.

4.3 FINDINGS RELATED TO PRETREATMENT FORMULAE

Formula 12 - No comments

Formula 13 - Total Moles of Component i to LLW from Pretreatment

Note: The report formula has a factor called "fraction of component i chemical additions." The spreadsheet formulae have no such factor in the equations. However, a section of the spreadsheet does deal with Na chemical additions and the fraction of the Na which goes to HLW. This additional fraction of the added Na is added to the HLW Na separation efficiency fraction. Although less than 5% of the Na to be processed goes to LLW, 100% of the added Na goes to HLW. This effectively produces the same result as the report formula. The quantity of Na, NO₂, and NO₃ added from chemical additions which go to LLW are accounted for by hand calculations which were added to the LLW separation efficiencies for these components. These hand calculations were based on results of the TWRS Process Flowsheet, Rev.1. That is the reason why many of the LLW separation efficiencies are greater than 100% and why LLW separation efficiency for Na is not 1 - HLW separation efficiency for Na.

- A) A small error exists for PP2 separation efficiency data for Na for SST data in the TWRS data set. The cell reference which should add in the additional fraction of Na going to HLW points to the wrong cell. The reference is to cell E1133. It appears that it should be to cell E1067.

- B) For Ca and PO₄, in both DSTs and SSTs (rows 2042, 2050, 2056, & 2063) the quantity and separation efficiency of the component for the CC farm, or the A farm respectively, are used for all the farms.

Formula 14 - Total Curies of Component i to LLW from Pretreatment

Note: The data tables at A374:n387 have some lengthy formulae and an unlikely degree of precision.

Formula 15 - No comments

Formula 16 - Pretreatment duration [per farm]

Note: The report formula uses the volume of waste retrieved as a factor. The spreadsheet appropriately uses the volume of liquid from interim storage in DSTs to pretreatment. This volume could be quite different from the volume of waste retrieved.

Formula 17 - No comments

Formula 18 - Overall Pretreatment Cost

Cautionary Note: The overall cost has as a component, the pretreatment facility construction cost. The construction cost formula watches the pretreatment process used to process farm "A" waste as a trigger. If farm "A" waste is processed using "In tank" as the pretreatment option, then the cost of 10 more mixer pumps is added to the construction cost. The retrieval process is individually settable for each farm. If, for some reason, farm "A" was not processed using the "In Tank" option, but other farms were, this additional cost of 10 mixer pumps might be inadvertently ignored.

Formula 19 - Pretreatment Operating Cost

- A) The annual pretreatment operating cost (h1678:h1687) obtains its value from Column D of this row range, not column G. This results in the formula for pretreatment operating cost always obtaining the baseline cost regardless of the switch setting which controls whether the low, high, or baseline cost should be used.
- B) A part of the pretreatment operating cost is 3 years times the annual operating cost which accounts for startup and training. The formula calculates 3 * the sum of the operating costs for any combination of pretreatment process and facility used in the model. If the same pretreatment facility was used with more than one process (e.g., if the ESW pretreatment facility was used with both sludge wash [PP2] and enhanced sludge wash [PP5]), it seems that the operating cost of the ESW pretreatment facility would be added to itself before being multiplied by 3. This may be incorrect.

- C) Formula 19 [b2486] ignores the cost of PF6 (nominally \$180M), the new solvent extraction pretreatment facility, if used.

Formula 20 - Pretreatment Facility D&D Cost

Note: The report multiplies the annual pretreatment operating cost by 2 instead of three. The spreadsheet correctly multiplies by 3.

4.4 FINDINGS RELATED TO HIGH LEVEL WASTE FORMULAE

Formula 21 - Containers of HLW Produced

Note: The formula is conceptually more advanced in the spreadsheet than in the report. The report formula does not deal with several factors which appear in the spreadsheet formulae, most notably, the option of whether or not to blend the waste from the various farms.

Note: For Cl, Fl, and SO₄, the oxide mass is reduced multiplying the calculated mass by a volatility factor (0.5 for Cl and SO₄, 0.75 for Fl).

Note: Calculations for Sulfur are a little confusing. The tank waste form is SO₃, but the HLW form is SO₄. The calculations appear to be correct, but the formulae seem to apply a confusing mix of SO₃ and SO₄, particularly when doing table lookups.

Note: The "all waste oxides loading limit" is 1 - minimum concentration limit for SiO₂ - minimum concentration limit for B₂O₃ - 0.02. The 0.02 reduction represents the minimum concentration limit for LiO₂.

A) There appears to be an error in the formulae used to calculate the containers required for the component known as Al₂O₃+Na₂O. The formulae in row 2095 add the mass of Al₂O₃ to the mass of SO₃ instead of Na₂O.

B) In order to calculate the mass of CaO, the formulae for DSTs in row 2101 divides the moles of Ca by 2. The formulae for SSTs in row 2141 does not divide by 2. The moles should not be divided by 2. The formulae in row 2101 appear to be incorrect.

Minor Point: To be consistent with the other oxide labels, c2114 and c2148 could indicate that the oxide of interest for Uranium is U₃O₈. That would support the division of the number of moles of Uranium by 3.

Formula 22 - No comments

Formula 23 - No comments

Formula 24 - No comments

Formula 25 - No comments

Formula 26 - Overall HLW Facility Cost

Cautionary Note: The formulae for HLW operating, construction, and chemical cost watch the pretreatment process used to process farm "NCAW" waste as a trigger. If the CLEAN process is used for NCAW, and the HLW process is HWVP Joule Heated Melter, then a combined HLW and pretreatment facility is assumed. The HLW vitrification portion of the combined facility cost is \$672M. The HLW chemical and operating costs are set to zero. It is possible to set the pretreatment process for each farm separately. If the HWVP Joule Heated Melter and the CLEAN process are used, but not for the NCAW farm, this formula may not calculate properly.

Note: The report indicates that a factor of the overall HLW facility cost is HLW disposal cost. Actually, the factor used in the spreadsheet [b2518] is HLW melter replacement cost, not disposal cost.

Formula 27 - HLW Facility Operating Cost

Note: The report formula includes a factor for treatment equipment replacement cost. This factor is actually the melter replacement cost in formula 26 in the spreadsheet. No such cost is present in formula 27.

Formula 28 - Interim Storage Building Construction Cost

Note: As written, the formula in the spreadsheet would require an entire new interim storage building to be built if there was at least one container that would not fit in the last building. The formula could be made more sophisticated to model what we would actually do for a small number of extra containers. Perhaps special arrangements would be made for a 10 to 20 percent remainder. Beyond that, a new building would have to be built.

Formula 29 - No comments

4.5 FINDINGS RELATED TO LOW LEVEL WASTE FORMULAE

Formula 30 - Containers of LLW Produced

Note: The formula is conceptually much more advanced in the spreadsheet than in the report. The report formula does not deal with the option of whether or not to blend the waste from the various farms, nor does it deal with the complexity of how different methods are used to calculate the number of containers depending on various combinations of chemical of interest and waste form type.

Note: The volatility factor for Cl, Fl, and SO₄ is not used when the LLW form is Salt Grout.

Note: The mass of NO₂ and NO₃ are added together to compute the number of LLW containers required when the LLW form is Salt Grout.

A) When waste is not blended, the mass of Na and K are added together to compute the number of containers required for Na (rows 2193 & 2202). When waste is not blended, Potassium is ignored completely (d2217).

Formula 31 - Volume of LLW Produced

Note: If the LLW option chosen is Glass in Sulfur, the result is multiplied by 1 / glass ratio. The glass ratio (d1310) is a constant, currently 0.7.

Formula 32 - LLW Curie Content (total curies to onsite disposal)

Note: The report formula does not consider retrieval heel or general characterization uncertainty as the spreadsheet formulae do.

Formula 33 - No comments

Formula 34 - Concentration of TRU Elements

Note: The results for Cs, Sr, and Tc [formula 33] are in ci/m³. The results for TRU are in nCi/gm. The formula for TRU uses the LLW density to convert from m³ to gm.

Formula 35 - LLW Completion Date

Note: If pretreatment completion date governs LLW completion date, the spreadsheet formula allows no time for a last LLW campaign.

Formula 36 - LLW Startup Date

A) The report formula indicates that LLW processing cannot begin before pretreatment processing. The spreadsheet formula has no such restriction. LLW processing could start before pretreatment.

Formula 37 - LLW Duration

Note: The report formula includes a factor for total operating efficiency. The spreadsheet formula does not. It appears that the total operating efficiency has been included in the LLW processing unit throughput data (c1608). This is unlike the HLW duration formula which retains a HLW total operating efficiency (b2409).

Formula 38 - No comments

Formula 39 - LLW Facility Operating Cost

Note: A factor for determining the operating cost is the LLW processing duration. The LLW duration calculated in formula 37 is not used. The spreadsheet formula conservatively uses the TWRS completion date - LLW hot start date.

Formula 40 - LLW Facility Disposal Cost

Note: The formula is somewhat more advanced in the spreadsheet than in the report. It calculates differently for LLW forms of Glass, Glass in Sulfur, and all other forms.

Formula 41 - No comments

5.0 ASSESSMENT OF OVERALL SYSTEM QUALITY

5.1 GENERAL SUMMARY

INSIGHT was found to be in very good condition. The Model is well constructed and fairly well arranged for general use. Almost anyone could select from among the 27 preset strategies to review the Model intermediate and summary output values for the chosen strategy. With very little training, almost anyone could learn to create a new strategy from among the given set of process alternatives. Changing INSIGHT to deal with a new or modified process alternative, updated input data, or using the Model in conjunction with the SuperTree Decision Analysis Software requires an engineer who is familiar with the algorithms of the Model, as well as the process to be modified.

5.2 MODEL CORRECTNESS

More than 99% of the INSIGHT formulae were found to be correctly devised and entered. The formulae which contained typographic errors had very little, and in most cases absolutely no, impact on the final results.

It was quite common for errors to have absolutely no impact for the following reason. A number of the typographic errors impacted formulae used in the calculation of LLW quantities and HLW number of containers. These disposal quantities were calculated for many chemicals of interest. The number of containers actually required was the maximum number required by whichever chemical form was most limiting. Therefore, errors along the calculation path for a chemical form which was not limiting had no effect on the final result, unless the chemical form would be limiting if the errors were not present.

A number of the review findings were not typographic errors. Many are subject to debate about how the model should calculate and may not be errors at all, or are logic faults that would only produce erroneous results under unlikely, but still plausible, input combinations. These soft ambiguities tended to have the greatest potential impact. In some cases, a modification of a contentious formula could make a difference of fifty to one hundred million dollars in the total cost of a particular strategy. The findings mentioned above, and described in Section 4, must be considered by a post-V&V process to determine what changes are necessary to the Model.

The Model, enhanced by the SuperTree software, is intended to show the wide variations in anticipated cost and schedule which result from the lack of precision of our knowledge about input values such as waste characterization data. In one case, studied in the Report, we see that a particular strategy has a 40% chance of a life cycle cost of less than \$26 billion, and an 80% chance of a life cycle cost of less than \$34 billion. Since the uncertainty we are faced with results in an anticipated cost swing of greater than \$8 billion dollars, a potential calculating error in the Model that might vary the cost by \$50 to \$100 million dollars would represent less than 1% of the total uncertainty.

All tested paths through the model produced results suitable for pragmatic checking except one. The "all waste disposed offsite" option [test case 6], if blending of waste was not permitted, produced many "divide by zero" errors. INSIGHT cannot effectively model this strategy without revision of the spreadsheet formulae.

5.3 COMPARISON OF MODEL FUNCTIONALITY TO MODEL OBJECTIVES

INSIGHT appears to deliver results in accordance with its objectives such as they are defined in available documentation. See the section "Review of Objectives" above.

The mission for TWRS is defined in terms of abstract concepts embodied in stakeholder values and mission need objectives. The connection between these overarching needs and objectives and the functionality of INSIGHT is similarly intangible. However, the Model supports a few of these objectives directly and well, and many of them well, but indirectly. There are still, however, many objectives INSIGHT does not support at all, nor was it intended to do so.

From WHC-EP-0617, section A7.3, Decision Analysis Model; A7.3.1, "Purpose;" we find that the model creators recognized that:

"When evaluating potential technical strategies, traditional criteria -- such as environmental impacts, cost, and schedule -- as well as non-technical and political objectives, which reflect the needs of stakeholder groups, must be considered. ... The decision analysis model is only one of the sources of information by which the decision maker selects a technical strategy for accomplishing the TWRS Program mission."

Predominantly, the Model produces cost and duration information given a selection of options for waste disposal. It also produces estimates of LLW and HLW quantity, and the quantity of certain chemical forms of interest remaining onsite. Very importantly, it produces these estimates quickly and is capable of providing an opportunity for management to focus their attention on the impact the uncertainty range of input variables has on these important parameters to determine where efforts should be applied to reduce uncertainty and therefore improve the quality of the projections and probability of success. Furthermore, since the Model provides the opportunity to experiment with a large range of technical alternative combinations and input options, it reduces the risk that the best technical combination of options will be missed for lack of examination.

From WHC-EP-0617, section A7.3.2, "Model Results;" we find that:

- a) "The decision analysis model is a computer-based mathematical model developed to calculate and display some of the performance criteria that the decision maker will use in selecting a new technical strategy."
- b) "The decision analysis model integrates the technical options developed in the *Tank Waste Technical Options Report* into alternative technical strategies."
- c) "These alternative technical strategies were evaluated using the decision analysis model to identify which technical uncertainties have the greatest influence on the performance criteria. This process shows the important technical uncertainties and allows the decision makers to focus resources to resolve these uncertainties, thus providing a higher confidence in the decisions."

5.4 LIMITATIONS OF THE MODEL

INSIGHT provides only a few columns of data in a larger decision matrix. The Model is not intended, and does not provide decision data regarding the probability of successful implementation of technical alternatives, the potential for delays from regulatory review requirements or changing stakeholder values, or worker or public safety impacts of the various technical alternatives. Any of these or other factors could result in a management choice of an alternative that was far from the strategy favored by INSIGHT.

The spreadsheet does not model process flow. Waste to pretreatment always comes from DSTs. Waste from SSTs is stored in DSTs awaiting retrieval. The model will permit more waste to be retrieved into DSTs to await pretreatment than the available storage volume can accommodate and will allow pretreatment to draw more waste from DSTs than is currently available. The intermediate storage volume is sizable, but management attention, outside of the model, must ensure that no such natural boundaries are violated by poor process planning.

Many of the cost tables have data in 1993 dollars escalated to 1995 dollars. These data may have been originally given in 1993 dollars with forethought to the expected year of expenditure. The model does not, however, adjust the value of money to the year of expenditure. If the expenditures do not occur in the years originally projected, or the escalation rate changes, the cost data will be off.

The Model may or may not generate data, that appear trustworthy, from combinations of technical alternatives that have been ruled out as valid combinations for technical reasons. Although the model contains a table section which shows valid technical combinations, the Model does not enforce these restrictions. Strategies entered into the Model must be proofread to ensure that they obey the defined limitations.

6.0 RECOMMENDATIONS

6.1 RECOMMENDATIONS EXTENDING FROM THE V&V SCOPE

Evaluate the contractor findings presented in this report and make any necessary changes to the Model in a fashion that preserves or re-establishes the assurance of the V&V.

Consideration should be given to representing the cost escalation factor as a variable (presently 1.035). That way, the escalation factor could be changed in one place instead of many.

Efforts should be made to permit INSIGHT to withstand change to the embedded data without destroying the affirmation of the V&V. Within the confines of what the Decision Analysis Software, SuperTree allows, efforts should be made to separate the data sections from the working formulae.

At a minimum, the approved master version of INSIGHT should have cell protection applied to the ranges of formulae in the calculation section. In addition, the master file should be write protected. The file size, and the date and time last modified should be noted. Although there are ways to defeat any protection scheme, in the DOS/Windows and Macintosh environment [where INSIGHT can operate], it is not easily possible to make changes to a file and save it without changing the file size and date and time last modified.

Checking these three parameters can provide assurance that the copy in use is a legitimate copy of the master.

If or when SuperTree permits, the calculation and data segments of the model could reside on different spreadsheets in the same workbook. This would provide an additional visible separation of calculations and data.

When changes are made, it is not easy to confirm what cells were changed. The minimum security option when reviewing changes to the model is to trust the human editor to report to the verifier all the cells that were changed and, if cells were inserted or deleted, to trust that all of the formulae were devised in such a fashion to make them compatible with cell insertion and deletion. The issue of concern here deals with inter-cell references which may be named, absolute, relative, or mixed references. When cells are inserted or deleted, the location of cells below and/or to the right changes. This causes Excel to reconsider all of the spreadsheet formulae to see if changes are necessary to accommodate any of the changed cell locations. Following cell insertion or deletion, this causes the formulae in other cells to be changed by Excel, and not by the editor.

No effort was made during the review to determine that future insertion and deletion of cells would not cause cell references to become mismatched. However, INSIGHT has undergone a great deal of revision that involved the insertion and deletion of cells. It is obvious that the Model builders have paid a great deal of attention to the proper use of named, absolute, relative, and mixed references. It would appear reasonable to accept that, following future row insertion or deletion, the auditors who affirm that the Model changes are correct could accept that the changes Excel automatically made to other spreadsheet formulae were correct. It is less likely that, in the evolution of the Model, columns have been inserted or deleted. It is difficult to imagine that such a change would be made. If such a change is ever made, it would be appropriate to review the entire model to determine which cells were dependent upon columns to the right of the insertion or deletion to determine if such formulae properly used named, absolute, relative, or mixed references to accommodate the insertion or deletion.

If the minimum security option is insufficient to guarantee acceptable assurance of the Model's continued correct performance, it is possible to create a small program in Excel's Visual Basic for Applications that would compare edited and unedited versions of the model to determine every cell in which changes had been made. The output from this automated comparison process could be used by the auditor to accept the changes.

If or when SuperTree permits such an additional feature to be implemented, consideration should be given to linking the spreadsheet to external sources of data so that data changes don't have to be entered in multiple files.

6.2 OTHER RECOMMENDATIONS

Create a supervisor program that will methodically change the input parameters in INSIGHT and keep track of whether or not there has been improvement in the results. The supervisor could be intelligent enough to "goal seek" rather than randomly changing inputs to compare results. This is an extension of what SuperTree does. SuperTree can only modify the switches which can be set to the value 1, 2, or 3; which represent low, baseline, or high values for about 400 parameters. This idea can be carried further to permit a supervisor to change strategies in the model, or create new ones. The Model could be allowed to work night and day under these conditions, as long as there were unexplored options remaining of potential merit. For instance, one retrieval unit is too few, and one per tank would be too many [too expensive]. Let the spreadsheet vary the number of primary and secondary retrieval units until the best combination to minimize total project cost is found.

Use the Model to evaluate privatization bids, or let the proposers use the spreadsheet to develop bids. Obviously, the Model may not fit the privatization bids as currently constructed. Significant revision may be required. Implementation of this recommendation could permit the offerer's to gain a significantly better understanding of how adjustments in their offer influence the TWRS program total cost and schedule, and would permit the bid evaluators to investigate the sensitivity of the offer to uncertainty in waste characterization data, process interruptions, or other factors.

Make INSIGHT accessible via the Hanford internal, and perhaps the external World Wide Web. The Model is an excellent resource to help staff gain and understanding of the relationship between input data and output parameters of interest. This improved understanding could have an important effect on technical planning to carry out the TWRS Program. The increased visibility of the Model could have an important feedback effect with more user's able to suggest improvements. If visibility is permitted beyond Hanford via controlled access from other sites, or uncontrolled access, feedback may come from other DOE sites, from other waste sites such as SuperFund sites, and from various University graduate students and faculty.

7.0 REFERENCES

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- Sutherland, D. G., 1994, *Status Report on the Development of a Decision Analysis Model for Evaluating Pretreatment Alternatives*, WHC-EP-0821, Westinghouse Hanford Company, Richland, Washington.
- Johnson, M. E., 1995, *Tank Waste Remediation System High-Level Waste Volume Decision Analysis Model*, WHC-EP-0833, Westinghouse Hanford Company, Richland, Washington.
- McConville, C. M., 1995, *Decision Analysis Model for Assessment of Tank Waste Remediation System Waste Treatment Strategies*, WHC-EP-0874, Westinghouse Hanford Company, Richland, Washington.
- Orme, R. M., 1995, *TWRS Process Flowsheet*, WHC-SD-WM-TI-613, Rev. 1, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1995, *Tank Waste Remediation Systems Engineering Work Plan*, WHC-SD-WM-WP-285, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A
OBJECTIVES OF THE INSIGHT MODEL

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A task plan has been established to verify and validate the computer spreadsheet model known as the INSIGHT model. This model has been used to analyze various options for tank waste retrieval, pretreatment, low and high level waste processing, and packaging for disposal. The model currently accepts thirteen input parameters and delivers estimates for processing duration, processing cost, low and high level waste volumes, and the amount of certain radioactive materials remaining in the low level waste volume.

The initial version of the INSIGHT Decision Analysis Model was developed between April and December, 1992. Data from spreadsheet model runs have appeared in several reports.³ Although no comprehensive section documenting the objectives or requirements of the INSIGHT model appears in the reports noted, reading of the reports yields several excerpts which related to the objectives for which the model was developed. In particular, Appendix F of WHC-EP-0874 relates the performance measures of the INSIGHT model to TWRS high level stakeholder values and to TWRS Justification of Mission Need Objectives. A significant and fundamental goal of this V&V task is to delineate and affirm the objectives that the INSIGHT model was and is intended to satisfy.

The scope of the model has encompassed a reasonably broad treatment of factors related to the tank waste remediation decision analysis process, from waste retrieval to packaging, since at least 1993. While the scope and objectives have remain fairly constant, the inner workings of the model have evolved over several years to meet new demands placed on it by parties interested in analyzing tank waste remediation alternatives.

The document you are reading serves to define historical objectives for the model drawn from other documents and reports and is intended to serve as a basis for establishing current objectives.

The report, WHC-EP-0617, does not have a section clearly delineating the INSIGHT model objectives, however, several objectives can be inferred from statements therein. From the report, we gather the following information.

From A7.3, Decision Analysis Model; A7.3.1, Purpose; we find that the model creators recognized that:

"When evaluating potential technical strategies, traditional criteria -- such as environmental impacts, cost, and schedule -- as well as nontechnical and political objectives, which reflect the needs of stakeholder groups, must be considered. ... The decision analysis model is only one of the sources of

³ Most notable among the reports documenting use of the INSIGHT model are "Tank Waste Decision Analysis Report," WHC-EP-0617, Draft Published 3/31/93; "Tank Waste Remediation System High Level Waste Volume Decision Analysis Model," WHC-EP-0833, Release 1/9/95; and "Decision Analysis Model for Assessment of Tank Waste Remediation System Waste Treatment Strategies," WHC-EP-0874, Release 12/21/95.

information by which the decision maker selects a technical strategy for accomplishing the TWRS Program mission."

This suggests that the model intentionally deals with some criteria and not others, and may relate to both traditional criteria such as cost and schedule as well as non-traditional criteria such as land use and political objectives.

From A7.3.2, Model Results, we find that:

- a) "The decision analysis model is a computer-based mathematical model developed to calculate and display some of the performance criteria that the decision maker will use in selecting a new technical strategy."
- b) "The decision analysis model integrates the technical options developed in the *Tank Waste Technical Options Report* (Boomer, et al. 1993) into alternative technical strategies."
- c) "These alternative technical strategies were evaluated using the decision analysis model to identify which technical uncertainties have the greatest influence on the performance criteria. This process shows the important technical uncertainties and allows the decision makers to focus resources to resolve these uncertainties, thus providing a higher confidence in the decisions."

These quotes suggest that the model was developed to consider certain performance criteria given a set of alternative technical strategies with a focus on highlighting important technical uncertainties that have the greatest potential impact on the strategy performance criteria values. Such an approach should allow decision makers to focus resources on narrowing the technical uncertainty range.

Table A-5 in this section of the appendix identifies 18 performance criteria in the following categories. Four each in the categories Public and Worker Health and Safety, Environmental Impact, Technology Assurance, and Schedule. Two performance criteria are identified in the Cost category. Of these 18 criteria, 5 can currently be evaluated using the INSIGHT model. These are:

- Minimizing offsite HLW volume,
- Maximizing unrestricted land availability by minimizing onsite LLW volume,
- Minimizing the time duration for resolving safety issues,
- Minimizing campaign duration, and
- Minimizing total life-cycle cost.

Four more are amenable to mathematical modelling using the decision analysis model, but not currently evaluated using the model. These are:

- Minimize long term environmental contamination,
- Minimize the time duration for resolving environmental concerns,
- Minimize public transportation hazards, and
- Maximize early immobilization for disposal progress.

The report, WHC-EP-0874, provides more information about the objectives the INSIGHT model was developed to satisfy. From the report, we gather the following information.

From 1.0, Introduction, we find that:

"Initially, the TWRS attempted an analysis of uncertainty in modeling the Hanford Waste Vitrification Plant (HWVP). ... Decision makers requested a more flexible model capable of encompassing additional stakeholder values and evaluating alternative treatment strategies. The INSIGHT model was developed to meet this request in early 1992 (Johnson et al. 1993)."

This provides evidence that development of the INSIGHT model was requested by "decision makers."

From 1.1, Development of the Model, we find that:

"The INSIGHT model was developed to assess alternative strategies as discussed in the *TWRS Systems Engineering Work Plan* (WHC 1994a). The model is structured to provide a flexible evaluation tool for several different waste treatment alternatives with respect to varying stakeholder values."

This provides evidence that the model was intended to be a "flexible" tool which provides output that is respectful of "varying stakeholder values."

Appendix F, Table F.1, lists the 23 high level stakeholder values and for each one, indicates which INSIGHT model performance measure [if any] provides some contribution supporting the interest of that particular stakeholder value. Table F.2 does the same for Mission Need Objectives. On the following two pages, we have extracted the applicable performance parameters from Tables F.1 and F.2 to create new matrices which contrast the stakeholder values, and then the mission need objectives with relevant INSIGHT model performance parameters.

APPENDIX B
PREPARING THE TEST CASES

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**INSIGHT Model
Verification & Validation**

Preparing the Test Cases

This document records how the INSIGHT model test cases were prepared.

After the group meeting on March 25, 1996, a revision of the baseline INSIGHT model was prepared by Mike Johnson and Cari McConville and sent to Sid Eaton by cc:Mail. After downloading the model, it was given the file name MODEL331.XLS and immediately write protected. The date of downloading is the file date for this write protected version (i.e., 4/11/96).

The new model was created to remove options that existed in the previous version that would not be tested during the V&V. The rationale was that, since the execution path in an Excel spreadsheet is not readily available to the auditor, it was not reasonably possible to prove that formulae in the model that were not to be tested were, in fact, never involved in the calculations of the pathways that were tested. The best solution was to remove extraneous formulae and data. The test plan flowchart called Option B was the stated goal of the spreadsheet model revisions. In fact, the revised model did not remove all the formulae and data not portrayed in Option B. After discussion, it was determined that the flowchart needed to be revised to reflect the new state of the spreadsheet model. The current test plan requires six test cases and is depicted in a new flowchart called Option C. The current flowchart revision is dated 4/25/96.

Next, the test cases were prepared and recalculated. The first step was to establish a new spreadsheet model that included the test case strategies. A copy of the file MODEL331.XLS was made which was called BASECASE.XLS, and the following changes were carefully made to this new file.

B77:K82	Strategy Definition	The retrieval options, LLW form and HLW process and form for each of the test cases were defined. The number of HLW process units is always set to 1 for every strategy defined in the model. The calciner HLW process required 66 units. This option is no longer defined in the model. The number of SST primary and secondary retrieval units was varied reasonably in each case to detect impacts these changes may have on the model. [Because these values were selected arbitrarily, they may be changed in the future and test cases recalculated to match results that have been generated by other models such as Aspen].
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B107:S112	Pretreatment Process and Facility Definition	The test case pretreatment process and facility combinations were entered in this range. Five of the six combinations did not occur in any of the 19 strategies that were already defined in the model. The sixth combination, PP5.PF4, was used before in 14 of the 19 strategies which were already defined in the model. Note that when PP3 (TRUEX) is used, PP2 (ESW) is used for DSSF. There is no separation factor data for DSSF for TRUEX. It is generally possible for the model to work with different pretreatment processes and facilities associated with each farm. Except for the situation noted above, this option was not tested in the six test cases.
F49:M52	Test Case Instructions	A small table was created in this area of the spreadsheet. No cells directly use this table range. Four cells must have their value changed prior to recalculating each test case. The table specifies the appropriate values to be entered in each of these cells for each test case. Cell B2 is set to the strategy identifying letter of the test case (i.e., U through Z). Cell G48 must be set to 1 or 2, and determines whether the test case will use LANL or TWRS tank content data. Cell B1185 must be set to 1, 2, or 3, and determines which HLW container type will be used in disposal calculations. Cell B1419 must be set to yes or no, and determines whether all waste components are mixed to obtain a minimum quantity of HLW or whether waste calculations are performed on a "per farm" basis.

The model contains 96 other switches, mostly used by SuperTree to vary parameters between low, base, and high values. These switches are to be tested for proper operation outside of the test case process. Their values were left "as found" for the six test cases. A list of all these switch locations is attached.

Several of the switches deserve special mention. The switch at B230 must remain set to 1. No other values are legal. The switches at B1493, B1496, B1499, B1592, and B1595 permit the spreadsheet model to select alternative LLW forms or pretreatment processes if a particular technology is judged not to work. These are binary switches. The permissible values for each these five switches are "No" [without quotes] or any other value.

Several corrections were made to the file BASECASE.XLS before saving the test cases. These changes are innocuous, since not having made them would not have changed the test results. This is true because all relevant data choices have the same value, or the

switch settings "as found" do not invoke a miscalculation. It is, however, easier to make the corrections than it is to prove that they have no effect on the test cases. The corrections are as follows:

References to cell $\$B\1654 , in cell G1678, were changed to $\$B\1675

G 1678: =IF($\$B\$1654=1$,C1678,IF($\$B\$1654=2$,D1678,IF($\$B\$1654=3$,E1678,0)))

change: =IF($\$B\$1675=1$,C1678,IF($\$B\$1675=2$,D1678,IF($\$B\$1675=3$,E1678,0)))

A lookup search range was changed to include 3 cells instead of 2 as follows:

B414 =LOOKUP(DSTNa_unc,D413:D414,E413:E415)

change: =LOOKUP(DSTNa_unc,D413:D415,E413:E415)

The same relative reference correction was made to cells:

B418, B422, B426, B430, B434, B438, B442, B446, B450, B454, B458,
B462, and B466

Data were removed from cells F392:F394, F400:F402, H392:H394, and H400:H402.⁴ These data were associated with retrieval/transfer systems RT2 and RT4. RT2 (i.e., Mechanical Arm) is not a valid transfer system for double shell tanks, and RT4 is a retrieval/transfer system no longer defined in the current model.

Following these changes, the file BASECASE.XLS was saved and write protected. Then the four cells B2, G48, B1185, and B1419 were set to the appropriate values for each test case as exhibited in the table described above located in the range F49:M52. After setting the three cells to proper values for each test case, and following recalculation, the resulting file was saved as CASEn.XLS where n represents the case number. Each of these files was subsequently write protected to prevent accidental modification.

Two assumptions are made that are worth noting for the record. The first is that Excel Version 5 properly opens and interprets Excel Version 4 files and calculates exactly the same result as Excel version 4 would have. The second assumption is that exactly the same result would be achieved on any computer which can run the Excel Version 5 program.

⁴ The values in the six cells F392:F394 and F400:F402, were restored by copying them from MODEL331.XLS on 5/6/96. Even though RT2 (Mechanical Arm) is not a valid retrieval process for DSTs, B406 (which calculates SST secondary retrieval system heel, takes its value from F400:F402 if the secondary retrieval system is RT2. Cells F392:F394 were restored because if RT2 was the primary SST retrieval process, cell B397 (vSSTretmult) would get its value from this range. As a result of this change, the six test cases had to be recreated and resaved.

APPENDIX C
ALGORITHMS FOR INSIGHT MODEL VERIFICATION

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This document contains the 41 formulae from the report "Decision Analysis Model for Assessment of Tank Waste Remediation System Waste Treatment Strategies," WHC-EP-0874. The formulae are "simplifications" of the actual calculations that are undertaken in the Excel spreadsheet known as the INSIGHT model. The INSIGHT model is undergoing Verification and Validation (V&V).

An element of the V&V project plan is to obtain expert consensus³ that the INSIGHT model formulae are acceptable means to obtain results in terms of TWRS remediation cost and schedule as well as quantities of high level waste and low level waste to be disposed of and a few miscellaneous parameters such as the curies of TRU elements sent to LLW disposal.

The 41 formulae are listed below. Interspersed among the formulae are questions from the INSIGHT model auditor. The auditor is an independent Excel expert with some knowledge of nuclear materials, but no prior experience with the TWRS program. Many of the questions may be easily answered. In fact, some questions may be totally irrelevant. The only purpose that the questions are intended to serve is to provoke thought among the experts to question the 41 formulae in this document. The existing questions need not be answered. However, they may provoke real questions from the experts which must be answered before consensus can be achieved that the formulae are correct as written. General comments "Costs are calculated in 1995 dollars ..." The translation of costs to 1995 dollars is "hardwired" in the model from specific years in which expenses are expected. Although the spreadsheet can calculate the start or finish of an activity, it does not use these estimated dates to do base year dollar value adjustments. Is that OK?

RETRIEVAL ALGORITHMS [Kayle Boomer]

Volume and Activity

General

Tank heel is more complex in the model than in the report. Especially for the SSTs where there is a quantity of heel after the primary process, some of which is removed after a secondary process.

Project plans call for the addition of waste from other Hanford operations during the period of waste retrieval and [pre]treatment. Are these additional wastes accounted for or insignificant?

³Some of the headings in this document are followed by names in brackets. These individuals are the experts who will be asked for assistance in confirming the validity of the approach evident in the formulae in each section.

How is the volume of new waste produced during the disposal process treated in the model? Could such wastes include pretreatment materials that require disposal such as ion exchange resins? How are LLW liquids generated in the HLW processing activities accounted for?

1. **Waste volume retrieved = (Existing Tank Waste Volume)*(1 - Heel)**

How is the amount of non-radioactive material added to tanks to accomplish retrieval (e.g., water for sluicing) treated in the model?

2. **Moles of component i retrieved = (Moles of component i in Existing Tank Waste Inventory)*(1 - Heel)**

How does the use of a "decayed to ... date" affect moles?

3. **Activity of waste retrieved = (Curies in Existing Tank Waste Inventory)*(1 - Heel)**

4. **Curies of radionuclide j retrieved = (Curies of radionuclide j in Existing Tank Waste Inventory)*(1-Heel)**

"Decayed to ... date" calculations don't include decay daughters. Is that OK?

Duration

5. **Retrieval duration = (Volume of Waste Retrieved)/ [(Retrieval Rate)*(Retrieval System Operating Efficiency)*(Quantity of Retrieval Units)]**

How steady will the retrieval rate be? Does an unsteady rate affect duration?

Will all tanks have the same rate?

For multi-unit or primary and secondary method retrievals, do all units have the same retrieval rate?

Is the retrieval rate affected by or inclusive of equipment setup and removal time?

Will the actual retrieval occur in campaigns with start/stop factors other than moving equipment from tank to tank?

Will the retrieval rate be influenced by input requirements of the chosen pretreatment process?

6. **Total equipment setup and removal time = (Number of tanks to be retrieved)*(Setup and Removal Time per Tank)/(Number of Retrieval Units)**

When a particular retrieval unit finishes at one farm, can it begin immediately at the next farm, or must the last retrieval unit finish at one farm before the first retrieval unit can begin at the next farm? This "tailing off" of retrieval, if it exists, can lengthen the total duration.

Consider the time between two tanks. Must removal from one tank completely finish before setup at the next tank can begin? Or, can setup at one tank begin as soon as teardown at the previous tank begins. If simultaneous teardown and setup of the same unit is possible, this would cut the total time in half.

7. **Volume of waste retrieved = (Existing Tank Waste Volume)*(1 - Heel)**

This formula is exactly the same as formula 1.

8. **Retrieval completion date = (Retrieval Start Date) + (Retrieval Duration) + (Total Equipment Setup and Removal Time)**

See comments for formula 6.

Retrieval cost

9. **Overall retrieval cost = (Retrieval Operating Cost) + (Retrieval Capital Cost)**

10. **Retrieval operating cost = (Annual Retrieval Operating Cost)*(Retrieval Duration)**

Do DST and SST retrieval processes operate at different times? Do they have different annual costs?

11. **Retrieval capital cost = (Capital Cost per Retrieval Unit)*(Number of Retrieval Units) + (Retrieval Support Systems Capital Cost)**

Is there a component of support system capital cost that varies with retrieval duration (e.g., the spare parts and material supplies the component requires per unit time like 2000 operating hours), or are such tangible item costs considered operating costs?

PRETREATMENT ALGORITHMS [Al Boldt and Eric Slaathaug]

Separations Algorithms

12. **Total Moles of Component i to HLW from Pretreatment = (HLW Separations Efficiency for Component i)*(Total Moles of Component i Retrieved)**
13. **Total Moles of Component i to LLW from Pretreatment = (1 - HLW Separations Efficiency for Component i + Fraction of Component i Chemical Additions) * (Total Moles of Component i Retrieved)**

Seems like the "fraction of component i chemical additions" should be a fraction of the total moles of component i retrieved. Is it?

Perhaps the fraction needs to be added before the separation fraction is taken from it (i.e., Total Moles of Component i to LLW from Pretreatment = (1 - HLW Separations Efficiency for Component i) * (Total Moles of Component i Retrieved + Fraction of Component i Chemical Additions))

14. **Total Curies of Component i to LLW from Pretreatment = (1 - HLW Separations Efficiency for Component i)*(Total Curies of Component i Retrieved)**
15. **Pretreated Waste Volume = (Moles of Na in Existing Waste Inventory)*(Waste Volume Retrieved)/(Allowable Na Concentration Limit in Storage Tanks)**

What units are the Na concentration limit in?

Duration Algorithms

16. **Pretreatment duration = (Volume of Waste Retrieved)/(Annual Pretreatment Facility Waste Volume Throughput)**

How closely matched are the pretreatment facility's throughput capability and the retrieval system's max or average feed rate?

Are process outages considered in pretreatment duration?

17. **Pretreatment completion date = Pretreatment Start Date + Pretreatment Duration for all Tank Waste**

At the end of work at each farm and at the end of the process, one might imagine that the remaining waste was all SST secondary process heel removal. If the feed rate tapers off significantly below the pretreatment process throughput capability, doesn't that extend the completion date?

COST ALGORITHMS [and Kayle Boomer]

18. **Overall pretreatment cost = (Pretreatment Facility Construction Cost) + (Pretreatment Operating Cost) + (Pretreatment Facility D&D Cost)**
19. **Pretreatment operating cost = (3 years)(Annual Pretreatment Operating Cost) + (Pretreatment Duration)(Annual Pretreatment Operating Cost)**
20. **Pretreatment Facility D&D Cost = (0.3)(Pretreatment Facility Construction Cost) + (2 years)(Annual Pretreatment Operating Cost)**

Presumably, this formula accounts for onsite and offsite disposal costs for solid and liquid materials resulting from D&D.

HIGH-LEVEL WASTE ALGORITHMS [AI Boldt]**Volume Algorithms**

21. **Containers of HLW produced = Maximum of [sum of(Mass of Component i Oxide in Pretreated HLW)/(Component i Waste Oxide Loading Limit)*(HLW Mass per Container)] or [(Total Mass of Oxides in Pretreated HLW)/(Waste Oxide Loading Limit)*(HLW Mass per Container)]**

Can't envision the real world situation for this one to question it

22. **Volume of HLW produced = (Quantity of HLW containers produced)*(Volume of HLW per container)**

Note that volume of HLW contained < container volume.

Duration Algorithms

23. **HLW completion date = Maximum of (HLW Startup Date + HLW Duration) or (Pretreatment Completion Date)**

If Pretreatment date governs, then HLW completion date = PT completion date + time to run last HLW facility campaign.

24. **HLW startup date = Maximum of (HLW Availability Date) or (Pretreatment Startup Date)**

25. **HLW duration = (Total HLW Containers Produced)/[(Total Operating Efficiency)*(Annual HLW Facility Container Throughput)]**

COST ALGORITHMS [and Kayle Boomer]

26. **Overall HLW Facility cost = (HLW Facility Operating Cost) + (HLW Facility Construction Cost) + (HLW Interim Storage Building Construction Cost) + (HLW Disposal Cost) + (HLW Facility D&D Cost)**

Make sure HLW disposal cost isn't added to overall facility cost since disposal cost is included in facility cost.

27. **HLW Facility operating cost = (HLW Process Duration)*[(Annual HLW Facility Operating Cost) + (Annual HLW Facility Consumable Operating Cost)] + (Treatment Equipment Replacement Cost) + (Personnel Start-up Training Cost) + (HLW Container Materials Cost)**

Shouldn't formula show that HLW Container Cost is based on number of containers?

Isn't treatment equipment replacement cost also a variable based on the number of hours of operation or cubic meters of HLW processed or some such measurement?

Is training cost three times annual op cost as is used elsewhere?

28. **HLW Interim Storage Building construction cost = (Construction cost per Interim Storage Building)*(Quantity of HLW Containers Produced)/(Quantity of HLW Containers per Interim Storage Building)**

Rounding must be handled properly. Does one container too many require a whole new building at the unit construction cost per ISB? Is the construction cost divisible by the number of remaining containers that must be stored?

Do the ISBs have any operating or D&D costs?

29. **HLW Facility D&D cost = (0.3)(HLW Facility Construction Cost) + (3 years)(Annual HLW Facility Operating Cost)**

LOW-LEVEL WASTE ALGORITHMS [Bruce Higley]

Volume and Activity Algorithms

30. **Containers of LLW produced = sum of [Mass of component i oxide in pretreated LLW]/[(Component i waste oxide loading limit)*(LLW volume per container)*(LLW Density)]**

Can't envision the real world situation for this one to question it

31. **Volume of LLW produced = (Quantity of LLW Containers Produced)*(LLW Volume per Container)**

Does the concept of containers apply OK to 5,300 m³ grout vaults?

32. **LLW curie content (total curies to onsite disposal) = (1 - HLW separation efficiency for radionuclide i)*(total curies of radionuclide i in tank waste inventory)**

This formula, as stated, yields results for one radionuclide. For all radionuclides, formula would be = sum(...).

33. **Concentration of radionuclide i (Ci/m³) = (total curies of radionuclide i sent to LLW processing)/(total volume of immobilized LLW produced)**

How uniform will this sort of thing be across all the LLW volume?

34. **Concentration of TRU elements (nCi/g) = (total curies of TRU elements sent to LLW processing)/(total mass of immobilized LLW produced)**

Formula 33 (above) has volume as a divisor, this formula has mass. Why?

Duration Algorithms

35. **LLW completion date = Maximum of (LLW Startup Date + LLW Duration) or (Pretreatment Completion Date)**

If Pretreatment date governs, then LLW completion date = PT completion date + time to run last LLW facility campaign.

36. **LLW startup date = Maximum of (LLW Availability Date) or (Pretreatment Startup Date)**

37. **LLW duration = (Total LLW Containers Produced)/[(Total Operating Efficiency)*(Annual LLW Facility Container Throughput)]**

Does this formula work OK with 5,300 m³ grout vaults?

COST ALGORITHMS [and Kayle Boomer]

38. **Overall LLW Facility Cost = (LLW Facility Operating Cost) + (LLW Facility Construction Cost) + (LLW Disposal Cost) + (LLW Facility D&D Cost)**

Make sure LLW disposal cost isn't added to overall facility cost since disposal cost is included in facility cost.

39. **LLW Facility Operating Cost = (LLW Process Duration)*(Annual LLW Facility Operating Cost) + (Personnel Start-up Training Cost)**

Is training cost three times annual op cost as is used elsewhere?

40. **LLW Facility Disposal Cost = (Quantity of LLW Containers Produced)*(Disposal cost per LLW Disposal Unit)/(Quantity of Containers per Disposal Unit)**

Does this formula work OK with 5,300 m³ grout vaults?

41. **LLW Facility D D Cost = (0.3)(LLW Facility Construction Cost) + (3 years)(Annual LLW Facility Operating Cost)**

APPENDIX D
ROADMAP OF THE INSIGHT MODEL ALGORITHMS

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Algorithms for INSIGHT Model Verification
Retrieval Algorithms

	DST farm retrieval durations are not used in total retrieval duration calculation. However, they are calculated on the spreadsheet as: DST farm retrieval duration = [e196:e212]DST farm total volume / [b1486]DST retrieval rate [in mgal/yr]	+	[b405]Pri_heel_% * [e406]Sec_Retr_Frac * 3785 * [j2253:j2269]Saltcake_vol / (365 * [b1478]Sec_Salt_Retr_Rate * [h43]Quantity of Secondary Units)		
		+	[b405]Pri_heel_% * [e406]Sec_Retr_Frac * 3785 * [j2253:j2269]Sludge_vol / (365 * [b1479]Sec_Sludge_Retr_Rate * [h43]Quantity of Secondary Units)		
6	[f2253:f2269]Total equipment setup and removal time = Data is in months Only primary units are considered		[b196:b212]Number of tanks to be retrieved * ([b1432]Setup and Removal Time per Tank / 12) / [h41]Number of Retrieval Units		
7	Volume of waste retrieved = (Existing Tank Waste Volume)*(1 - Heel)		No such calculation in spreadsheet A more complex form is a part of retrieval duration formulae, see formula 5 above.		
8	[c2274]Retrieval completion date = Report Formula: Retrieval completion date = Retrieval Start Date + Retrieval Duration + Total Equipment Setup and Removal Time	for each farm	[b1424 or g2253:g2268]Retrieval Start Date + [e2253:e2269]Retrieval Duration + [f2253:f2269]Total Equipment Setup and Removal Time		
			Only SST farms count The first SST farm start date is a table lookup Each SST farm starts after the previous one finishes The final date is the last farm complete date rounded to whole years		
9	[b2456]Overall retrieval cost =		[b2448]DST Retrieval Capital Cost + [b2452]SST Retrieval Capital Cost + [b2449]DST Retrieval Operating Cost + [b2453]SST Retrieval Operating Cost		
10	[b2449 & b2453]Retrieval operating cost = Report Formula: Retrieval operating cost = Annual Retrieval Operating Cost * (Retrieval Duration)	DSTs SSTs	[b1628]Annual Retrieval Operating Cost * [b2439]Project Duration (not followed) ([b1648]Operating Cost for Primary Retrieval Units + [b1649]Operating Cost for Secondary Retrieval Units) * ([c2274]SST Retrieval Complete Date - [b1424]SST Retrieval Start Date)		
11	[b2448 & b2452]Retrieval capital cost = Total DST Cap cost is divided by 28 then multiplied by 10. Is that OK?? (doesn't include DSSFs) Retrieval Support Systems Capital Cost is: \$0 for mixers [included in cap costs], \$1144.5 M for slicers \$519.5 M for mech arm	DSTs SSTs	[b1622]Capital Cost per Retrieval Unit * [b196 & b198:b200]Number of Retrieval Units + [b1632]Retrieval Support Systems Capital Cost [b1638]Capital Cost per Primary Retrieval Unit * [h41]Number of Primary Retrieval Units + [b1639]Capital Cost per Secondary Retrieval Unit * [h43]Number of Secondary Retrieval Units + [b1642]Retrieval Support Systems Capital Cost		

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Pretreatment			
12	[a2004:p2038] Total Moles of Component i to HLW from Pretreatment =	for each farm [a471:i584]HLW Separations Efficiency for Component i * [a1854:i1983]Total Moles of Component i Retrieved	[switched value] [formula 2]
13	[a2040:p2066] Total Moles of Component i to LLW from Pretreatment = Report Formula: Total Moles of Component i to LLW from Pretreatment = (1 - HLW Separations Efficiency for Component i + Fraction of Component i Chemical Additions) * Total Moles of Component i Retrieved	for Na, NO ₂ , NO ₃ [a1074:i1091]LLW separation efficiency * [a1854:i1983]total moles of chem retrieved from all tanks for other chems (1 - [a471:i584]HLW separation efficiency) * [a1854:i1983]total moles of chem retrieved from all tanks Fraction of Component i Chemical Additions is moles Na added / moles Na available for retrieval. The result is added to the Na HLW separation efficiency data in the data table.	[switched value] [formula 2] [switched value]
	Error?? -> Ca & PO ₄ are CC or A farm all the way across.		
14	[a2068:p2080] Total Curies of Component i to LLW from Pretreatment = [Data tables at a374:n387 are complex, possible errors]	(1 - [a471:i584]HLW Separations Efficiency for Component i) * [b2002:i2002]Total Curies of Component i Retrieved	[switched value] [formula 4]
15	[g2338:g2354] Pretreated Waste Volume [per farm] = Report Formula: Pretreated Waste Volume = Moles of Na in Existing Waste Inventory * Waste Volume Retrieved / Allowable Na Concentration Limit in Storage Tanks	for DSTs (1 - [b401]DST heel) * exc DSSF Max([b393]DST retrieval multiplier + 1) * [b224:b228]DST farm solids volume or [b217:b221]DST farm total volume for DSSF same as others exc no heel Max([b393]DST retrieval multiplier + 1) * [b224:b228]DST farm solids volume or [b217:b221]DST farm total volume for SSTs (([h1854:h1870]moles of Na retrieved from the farm / [b260]Na concentration limit) / 3,785,000	[switched value] [switched value] [switched value]
16	[e2338:e2354] Pretreatment duration [per farm] = Report Formula: Pretreatment duration = Volume of Waste Retrieved / Annual Pretreatment Facility Waste Volume Throughput	[g2338:g2354] Pretreated Waste Volume [per farm] / [b1529:b1545] Annual Pretreatment Facility Waste Volume Throughput	[formula 15] [switched value]
17	[b2386] Pretreatment completion date = Max Report Formula: Pretreatment completion date = Pretreatment Start Date + Pretreatment Duration for all Tank Waste	[d2382:h2382] Pretreatment Completion Date for the last farm or [c2274] SST Retrieval Completion Date + (21 Million Gallons / [e2355] Pretreatment Processing Rate for the last farm) After retrieval, at most, 21 million gallons may remain staged in DSTs awaiting pretreatment	[see below] [formula 6] [switched value]
	[d2366:h2382] Pretreatment Completion Date for each farm =	first farm [b2338:b2354] farm specific pretreatment ready date + [e2338:e2354] pretreatment duration [per farm] other farms Max([b2338:b2354] farm specific pretreatment ready date + [e2338:e2354] pretreatment duration [per farm] or [d2366:h2382] date previous farm completes pretreatment + [e2338:e2354] pretreatment duration [per farm])	[switched value] [formula 16]
18	[b2493] Overall pretreatment cost =	[b2473] Pretreatment Facility Construction Cost + [b2486] Pretreatment Operating Cost + [b2480] Pretreatment Facility D&D Cost	[see below] [formula 19] [formula 20]

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Algorithms for INSIGHT Model Verification
High Level Waste Algorithms

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23	(b2414)HLW completion date =	Max of ((b2397)HLW Startup Date + (b2392)HLW Duration or (b2386)Pretreatment Completion Date	(formula 24) (formula 25) (formula 17)
24	(b2397)HLW startup date =	Maximum of ((b1581)HLW Availability Date or Minimum((b2338-b2354)Pretreatment Startup Date (for each farm)	(switched value) (part of formula 17)
25	(b2392)HLW duration =	(b2176)Total HLW Containers Produced / (b2409)Total Operating Efficiency * (b2402)Annual HLW Facility Container Throughput)	(b1551)HLW Unit Life - (b1558)Outage Duration) / (b1551)HLW Unit Life	(formula 21) (see below) (see below) (switched value) (constant, currently 0.5)
	(b2409)Total Operating Efficiency =		(b45)Number of HLW Units * (b1572)HLW Facility Capacity Factor * (b1564)HLW Facility Throughput * 365 * 24 / (b1186)HLW Mass per Container	(Strategy Table Lookup) (switched value) (switched value * kg/hr) (switched value)
26	(b2541)Overall HLW Facility cost =	(b2533)HLW Facility Operating Cost + (b2499)HLW Facility Construction Cost + Error ??? doesn't include Disposal costs, but does include melter replacement cost ->	(b2505)HLW Interim Storage Building Construction Cost + (b2518)HLW Disposal Melter Replacement Cost + (b2538)HLW Facility D&D Cost	(formula 27) (refers to b1708; switched value) (formula 28) (formula 29)
	(b2518)HLW Melter Replacement Cost =	INT ((b2513)HLW Process Duration / Integer function truncates fraction. Is this OK??	(b1551)HLW Unit Life) * (b1731)Melter Replacement Cost * (H45)Number of HLW Process Units	(part of formula 27) (switched value) (constant, currently \$39M) (strategy table lookup)
27	(b2533)HLW Facility operating cost =	(b2513)HLW Process Duration * (b1716)Annual HLW Facility Operating Cost + Why is NCAW the trigger for recognizing PP4?	(b1724)Annual HLW Facility Consumable Operating Cost) + Treatment Equipment Replacement Cost + (b2526)Personnel Start-up Training Cost + (b2530)HLW Container Materials Cost	(switched value) (switched value) (3 * HLW Op Cost) (No. of containers * switched value)
	Error ??? Not in formula, but see formula 26		(Note: When CLEAN is used, HLW Annual Op cost is only HLW materials cost)	
	(b2513)HLW Process Duration =	(b2436)Completion Date for TWRS - (b2397)HLW startup date		(currently a part of formula 39) (formula 24)
28	(b2505)HLW Interim Storage Building construction cost =	Max of (0 Report Formula: HLW Interim Storage Building construction cost = Construction cost per Interim Storage Building * Quantity of HLW Containers Produced / Quantity of HLW Containers per Interim Storage Building)	or (Integer of ((b2176)Quantity of HLW Containers Produced / (b1700)Quantity of HLW Containers per Interim Storage Building) + 1) - 1) * (b1695)Construction cost per Interim Storage Building	???? Don't see how other possible value could ever be negative (formula 21) (switched value) (switched value)
	Error ??? This formula must decide what to do with one or more containers that exceed capacity of the last storage building. How many extra would require building a new building?			
29	(b2538)HLW Facility D&D cost =	0.3 * (b2499)HLW Facility Construction Cost + 3 [years] * (b1716)Annual HLW Facility Operating Cost		(refers to b1708; switched value) (switched value)

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34	[d1802]Concentration of TRU elements (nC/g) = Report Formula Concentration of TRU elements (nC/g) = total curies of TRU elements sent to LLW processing / total mass of immobilized LLW produced	[d1797]total curies of TRU elements sent to LLW processing / [b1277]LLW density * [b2234]total volume of immobilized LLW produced	[formula 32] [table lookup] [formula 31]
35	[b2430]LLW Completion Date = Maximum of ([b2425]LLW hot start date + [b2421]LLW duration) or [b2386]Pretreatment Complete Date	= vifyear is a switched value) [formula 37] [formula 17]
36	???]LLW startup date = Maximum of ([b1610]LLW Availability Date OR Pretreatment Startup Date (min[b1523,b1525]???)	[switched value] [spreadsheet will let LLW start before pretreatment]
37	[b2421]LLW duration = not in spreadsheet ---->	[b2322]Total LLW Containers Produced / Total Operating Efficiency * [b1600]Annual LLW Facility Container Throughput	[formula 30] [switched value] [efficiency now included in data ???]
38	[c2579]Overall LLW Facility Cost =	[c2565]LLW Facility Operating Cost + [c2549]LLW Facility Construction Cost + [c2573]LLW Disposal Cost + [c2569]LLW Facility D&D Cost	[formula 39] [= vifweiconcost is a switched value] [formula 40] [formula 41]
39	[c2565]LLW Facility Operating Cost =	[b2554]LLW Process Duration * [b1764]Annual LLW Facility Operating Cost + [b2559]Personnel Start-up Training Cost	[see below] [switched value] [= 3 * D1764]
not 37	[b2554]LLW Process Duration =	[b2436]TWRS completion date - [b2425]LLW hot start date [b2436]TWRS completion date = Maximum of ([see below] [= vifyear is a switched value] [formula 17] [formula 23] [formula 35]
		[b2386]Pretreatment Completion Date [b2414]HLW Completion Date [b2430]LLW Completion Date	
40	[c2573]LLW Facility Disposal Cost = Report Formula LLW Facility Disposal Cost = Quantity of LLW Containers Produced * Disposal cost per LLW Disposal Unit / Quantity of Containers per Disposal Unit	For Glass INT ([b2232]onsitecon / 600) + 1 * [b1772]wdispcost For Glass in Sulfur INT ([b2232]onsitecon / 197) + 1 * [b1772]wdispcost + [b2232]onsitecon * [b1777]L2concost Otherwise [b2232]onsitecon * [b1772]wdispcost	[onsitecon is formula 30] [wdispcost is a table lookup] [L2concost is a constant]
41	[c2569]LLW Facility D&D Cost =	0.3 * [c2549]LLW Facility Construction Cost + 3 years * [b1764]Annual LLW Facility Operating Cost	[table lookup] [table lookup]

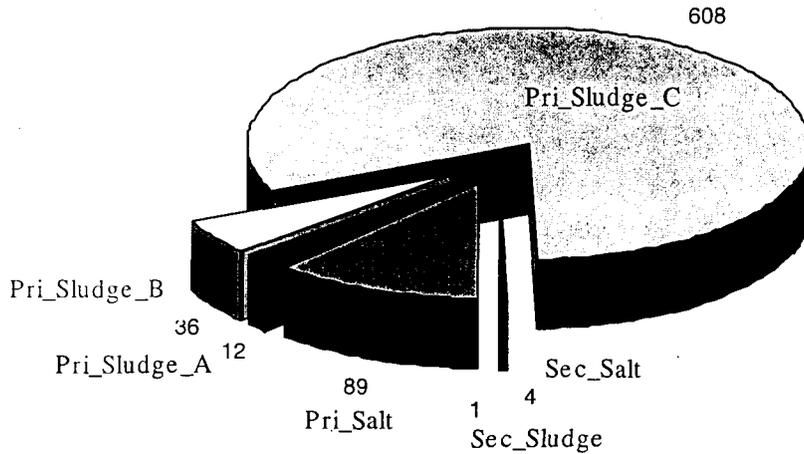
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APPENDIX E
GRAPH OF TWRS CUMULATIVE RETRIEVAL TIME

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Cumulative Retrieval Duration (in Weeks) of Each Activity



DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	SE Risk Management & Modeling	Date 8/28/966
Project Title/Work Order		EDT No. 618211
		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
N. G. Awadalla	H6-35	X			
S. C. F. Eaton	H6-35	X			
D. J. Francis (RL)	K6-51	X			
B. D. Frank	H6-35	X			
B. C. Gneiting	H6-35	X			
N. J. Graves	H6-35	X			
R. W. Harmsen	H6-35	X			
G. Jansen	H6-35	X			
B. J. Knutson	H6-35	X			
C. A. Mconville	H5-49	X			
D. A. Seaver (PNNL)	K8-07	X			
J. D. Thomson	H6-35	X			
R. S. Wittman	H6-35	X			
B. D. Zimmerman	H6-35	X			
Central Files	A3-88	X			