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DISTRIBUTION SHEET

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Distribution	Inventory Control and Modeling	Date 11/09/99
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System Design Description Salt Well Liquid Pumping Dynamic Simulation

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Abstract: The Salt Well Liquid (SWL) Pumping Dynamic Simulation used by the single-shell tank (SST) Interim Stabilization Project is described. A graphical dynamic simulation predicts SWL removal from 29 SSTs using an exponential function and unique time constant for each SST. Increasing quarterly efficiencies are applied to adjust the pumping rates during fiscal year 2000.

12/14/99

Release Approval Date

Approved For Public Release

CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TERMS

DCRT	Doubly-contained receiver tank
DST	Double-shell tank
FY	Fiscal Year
GPM	Gallons per Minute
LMHC	Lockheed Martin Hanford Corporation
SST	Single-shell tank
SWL	Salt Well Liquid
A	Tank Farm A in 200 East Area (with one SWL tank)
AX	Tank Farm AX in 200 East Area (with one SWL tank)
BY	Tank Farm BY in 200 East Area (with two SWL tanks)
C	Tank Farm C in 200 East Area (with one SWL tank)
S	Tank Farm S in 200 West Area (with eight SWL tanks)
SX	Tank Farm SX in 200 West Area (with six SWL tanks)
T	Tank Farm T in 200 West Area (with two SWL tanks)
U	Tank Farm U in 200 West Area (with eight SWL tanks)
Y-10*X*	Tank Designation for Tank (number) *X* in Farm *Y*
*Y*10*X*	Tank Designation for Tank (number) *X* in Farm *Y* in model

DEFINITIONS OF MODEL PARAMETERS & (units)

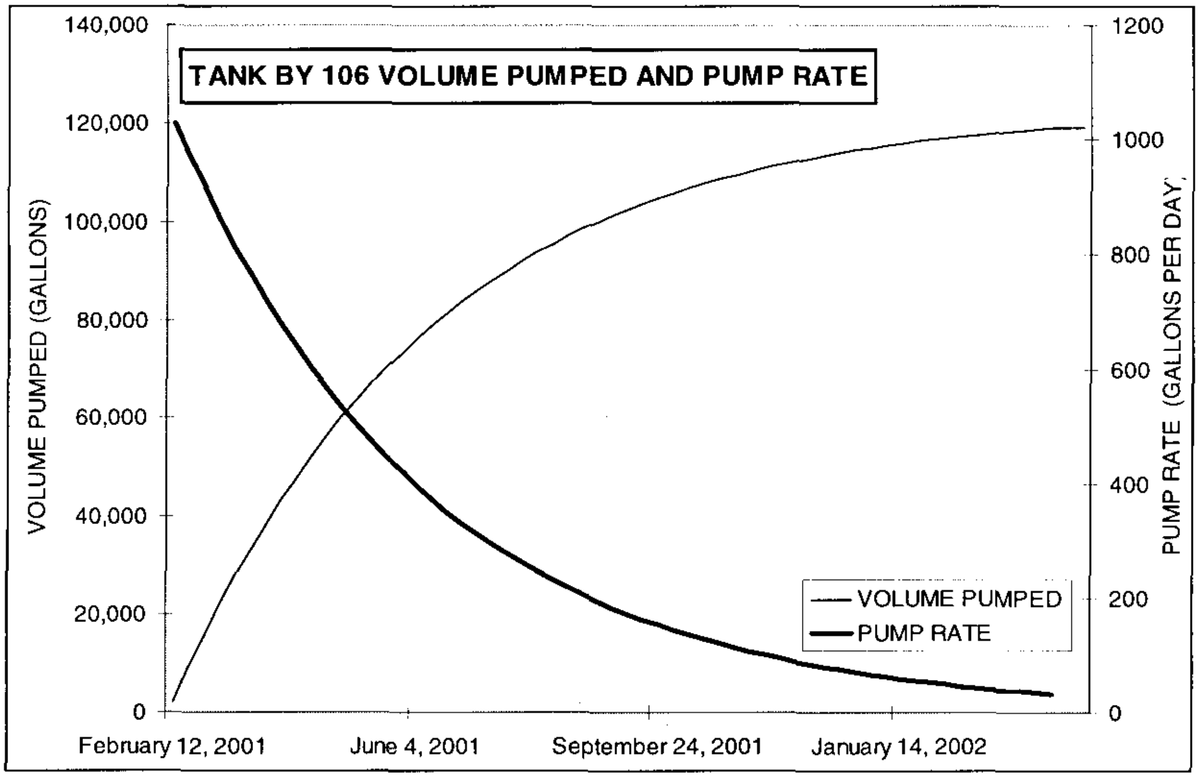
ACTUAL PUMP START	Day of actual SWL initial pumping.
ACTUAL VOL PUMPED	Historical cumulative SWL volume pumped from an SST through September 30, 1999 (gallons).
DATA DATE	Day that Prediction interval begins (October 1, 1999). Actual pumping data is used for interval up to this date.
FINAL RATE	Pump rate at end of pumping interval equal to FINAL RATE AT 100% times PUMP EFFICIENCY (gallons/day).
FINAL RATE AT 100%	Consent Decree definition of rate at pumping completion if PUMP EFFICIENCY were 100%. Value is 72 (gallons/day).
INITIAL INFLOW RATE	Average rate of liquid inflow into the pump sump measured during a period of stable hydraulic head and continuous pumping.
INITIAL VOLUME	Estimate of total pumpable SWL in an SST.
LAMBDA	SST's pumping time constant (1/day). The fraction of remaining volume removed each day.
LAMBDA THEORY	LAMBDA calculated from estimated SWL volume and estimated pumping duration (1/day).
LAMBDA MEASURED	LAMBDA calculated from measured SWL inflow rate and REMAINING VOL (1/day).
PUMP EFFICIENCY	Ratio of pumping time to total time during a tank's pumping interval. This ratio increases quarterly during FY 2000.
PUMP RATE	Rate at which SWL is pumped from an SST (gallons/day).
PUMP START	Scheduled (future) day of initial pumping.
REMAINING VOL	SWL volume remaining when prediction interval begins (gallons).
SWL PUMPED	SWL volume removed from the SST (gallons).
SWL REMAINING	SWL volume remaining to be pumped from the SST (gallons).

SYSTEM DESIGN DESCRIPTION SALT WELL PUMPING DYNAMIC SIMULATION

1.0 INTRODUCTION

The purpose this document is to describe the Salt Well Pumping Dynamic Simulation which supports Lockheed Martin Hanford Corporation's (LMHC) Interim Stabilization Project. The project is responsible for removing liquid waste from twenty-nine single-shell tanks (SSTs) at Hanford's 200 East and 200 West Areas. The salt well liquid pumping model is based on an exponentially decaying pump rate characteristic which causes the same fraction of the remaining volume to be removed each day. The pump rate characteristic is designed to complete liquid waste removal just as the limiting pump rated is reached. This characteristic is seen in Figure 1. Here, 0.85 percent of the remaining volume is removed each day.

Figure 1 Exponential Pumping Characteristic



The simulation uses this pumping model and input data from "Updated Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks" (Field 1999) to predict the waste volume removal profiles. The input data includes estimates of salt well liquid volume and minimum pumping duration for each tank to be stabilized. For tanks currently being pumped, additional input data provides pump operating characteristics and historical pumped waste volumes. The projection uses historical data, system dynamics and pumping characteristics to predict salt well liquid removal through completion of interim stabilization in 2003.

Simulation Overview

For salt well pumping purposes, a single-shell tank is viewed as a column of supernate, saltcake and sludge, each region becoming more difficult to pump and each having a lower effective hydraulic head. Accordingly, pumping rate declines with time and pumping is considered complete when the daily pumped volume, adjusted for 0.5 (or 50 %) total operating efficiency (TOE), falls to 36 gallons. This represents a 0.05 gallon per minute pumping rate.

The simulation has two key intervals which are (1) Data Collection (up to the DATA DATE) and (2) Prediction. For the Data Collection interval, the simulation calculates the average pumping rates from the actual cumulative volumes pumped and actual total pumping durations. At the DATA DATE, the Data Collection interval is over; the volumes have been reduced by the actual cumulative volumes pumped; and the Prediction interval begins. For the current simulation, the Prediction interval began on October 1, 1999 (DATA DATE) and data was collected through September 30, 1999.

During the Prediction interval, an exponential function approximates the pumping behavior. A fixed fraction of the remaining SWL volume is removed each day. The pumping rate declines until the predefined final rate is reached. By definition, no SWL volume remains at this point. The pump rate for a tank may be expressed as:

$$R_P = TOE * (\lambda * V_R + R_F) \qquad (1)$$

where R_P is the predicted pumping rate in gallons per day, TOE is the ratio of pumping time to total time, λ is the theoretical time constant for tanks with a future start date or with an indeterminate inflow rate and λ is the measured time constant for tanks with a measured SWL inflow rate (to pump sump), V_R is the remaining SWL volume, and R_F. is the final pumping rate. λ and R_F are calculated with TOE equal to 1 (or 100 %). The TOE increases quarterly during FY 2000 reflecting expected improvements in operating efficiencies.

The λ based on a measured SWL inflow rate is calculated as follows:

$$\lambda = (R_{Ii} - R_F) / V_{Rd} \qquad (2)$$

where λ is the time constant (1/day), R_{Ii} is measured initial inflow rate, and V_{Rd} is the remaining volume at the DATA DATE.

The ithink[1] graphical, dynamic simulation language is used for this application.. Graphical elements represent components in the system and the elements may be animated to show material movement through the system. Integrator elements represent SSTs (source tanks) with estimated SWL contents loaded as initial conditions. Additional integrator elements represent receiver tanks. Flow elements between the

[1] ithink is a trade mark of High Performance Systems, Hanover, NH.

source tanks and receiver tanks represent SWL pumps. A feedback arrow from a source tank to its associated flow element provides a natural first order lag or a pumping rate proportional to the remaining volume, i.e. the exponential function needed to approximate the SWL pumping behavior.

The products of the simulation are the predicted profiles of total pumped SWL volume and total pumped organic SWL volume. The products include predicted profiles for individual tanks and pumping rate profiles. Products also include pumping durations and the results of sensitivity studies. All product profiles extend through pumping completion.

Duration results are specified to be mathematically accurate to within a day. This is accomplished using a 0.5 day simulation time step. Tests demonstrate that no significant change in simulation results occurs using a smaller time step.

2.0 DECOMPOSITION DESCRIPTION

Module, Concurrent Process and Data Entity decompositions are provided. The module decomposition is provided through the use of sectors and arrays. Sectors spatially group closely related, interconnected elements. Arrays spatially group repetitive model structures. The Concurrent Process decomposition relates to pumping, accounting and operator interface. The Data Entity decomposition relates data inputs and data outputs (products). This description pertains to the official model version which is revision four of the model with actual pumping data to October 1, 1999 and contained in file **SWL_10_1_99R4.itm**.

2.1 Module Decomposition

The modules are organized as SWL Pumping Sub-models, Accounting Modules and User Interface Modules. Sectors are used to implement these three modules. Sectors graphically group related elements and provide a means to bundle interfaces to other groups of related elements. A sector is similar to a software module but more flexible in that a sector may implement portions of multiple modules. Six sectors are used to present four SWL Pumping Sub-models to provide a separation by tank farm. Three sectors provide (aggregate volume) accounting and four sectors provide user interface including a control panel. Automatic mapping features are provided to group element interfaces among sectors and provide convenient listings of source and destination elements within each group. The graphical presentation of the module decomposition is provided in Appendix A. The modules are described in detail below with references to corresponding Appendix A pages shown in parentheses (A-).

2.1.1 SWL Pumping Sub-models

The four SWL Pumping Sub-modules are as follows:

Future Pump Start (An Array Structure for 21 Tanks)
Limiting Inflow Rate (Tank T-104, Interim Stabilized in 1999)
Quarterly Pumping Efficiencies (Tanks S-102, SX-106 and U-103)
Limiting Inflow Rate/Quarterly Pumping Efficiencies (Tanks S-103, S-106, SX-104 and T-110)

To graphically aid the user, tanks have been assigned to six sectors as listed below. The appropriate SWL Pumping Sub-modules has been applied to each tank:

S-Farm	S-102, S-103 and S-106
SX-Farm	SX-104 and SX-106 (two sectors)
T-Farm	T-104 and T-110
U-Farm	U-103
Arrayed Tanks	21 remaining tanks with pump start after October 1, 1999

Future Pump Start

This is the fundamental SWL pumping sub-model (page A-8) and all other sub-models are variations of this fundamental structure. An array feature is used to replicate the same structure for 21 tanks. Vectors (converters with array feature selected) are used for parameter values assigned to individual tanks. The SWL REMAINING integrator is initialized with INITIAL VOLUME and then drained by the PUMP RATE flow element into the SWL PUMPED integrator. The PUMP RATE is computed as follows:

PUMP RATE[*tank*] = IF (TIME >=PUMP START[*tank*]) THEN LAMBDA[*tank*] * SWL REMAINING[*tank*] + FINAL RATE[*tank*] ELSE 0

where TIME is the simulation day, {*tank]* is the tank identifier (index), PUMP START[*tank*] is the simulation day when pumping begins, LAMBDA[*tank*] is the time constant, and FINAL RATE[*tank*] is the rate reached on the final day of pumping.

After the PUMP START date is reached, the PUMP RATE is approximately proportional to the SWL REMAINING volume but adjusted by FINAL RATE. The time constant is a theoretical (input parameter) lambda adjusted for pumping efficiency. LAMBDA*[tank*] and FINAL RATE[*tank*} are computed as follows:

LAMBDA*[tank*] = EFFICIENCY[*tank*} * LAMBDA THEORY*[tank*]

FINAL RATE[*tank*] = EFFICIENCY[*tank*} * FINAL RATE AT 100%

where LAMBDA THEORY*[tank*] is an externally calculated time constant that causes the liquid inventory to be removed by a calculated end date based on 100 percent pumping efficiency, FINAL RATE AT 100% is 72 gallons/per day (0.05*24*60 where 0.05 gallons per minute is the peak end rate with no pump down time, 24 hours per day and 60 minutes per hour are conversion factors) and EFFICIENCY[*tank*] is the pumping efficiency profile for *tank* defined below in Quarterly Pumping Efficiencies.

Limiting Inflow Rate

This SWL pumping sub-model (A-9) has two differences from the Future Pump Start sub-model; actual pumping data is used and lambda (time constant) is computed internally. Observed tank interstitial liquid draining dynamics limit the pump's ability to remove liquid. Operation of the integrators is the same in the Future Pump Start sub-model except the PUMP RATE is computed as follows:

tank PUMP RATE = IF (TIME >= *tank* DATA DATE) THEN *tank* LAMBDA * *tank* SWL REMAINING + *tank* FINAL RATE ELSE IF (TIME >= *tank* ACTUAL PUMP START) THEN *tank* AVG ACTUAL RATE ELSE 0

where *tank* is the tank identifier (e.g. T104 prefix), *tank* ACTUAL PUMP START is the first day of actual pumping, DATA DATE is the day extrapolation begins (the day after the last day of pumping data), *tank* AVG ACTUAL RATE is the average actual pumping rate achieved, and *tank* LAMBDA is the internally calculated time constant.

After the ACTUAL PUMP START date is reached, the PUMP RATE is AVG ACTUAL RATE until the DATA DATE is reached. Then the PUMP RATE is approximately proportional to the SWL REMAINING volume but adjusted by the FINAL RATE. The *tank* LAMBDA or time constant is computed from measured inflow rate as follows:

tank LAMBDA = *tank* EFFICIENCY * *tank* LAMBDA MEASURED

tank LAMBDA MEASURED= (*tank* INITIAL INFLOW RATE –
FINAL RATE AT 100%) / *tank* SWL REMAINING VOL

where SWL REMAINING VOL is the estimated remaining volume at the end of the actual pumping interval and INITIAL INFLOW RATE is the average rate of liquid inflow into the pump sump measured during a period of stable hydraulic head and continuous pumping.

The *tank* AVG ACTUAL RATE is computed as follows:

tank AVG ACTUAL RATE = *tank* ACTUAL VOL PUMPED / (DATA DATE -
tank ACTUAL PUMP START)

where *tank* ACTUAL VOL PUMPED is cumulative volume pumped at the DATA DATE when simulation prediction interval begins.

<u>Quarterly Pumping Efficiencies</u>

This SWL pumping sub-model (A-5, 6 and 10)has two differences from the Future Pump Start sub-model; actual pumping data is used and predicted pumping rate is adjusted for quarterly pumping efficiencies. A quarterly profile of average pumping efficiencies reduces the PUMP RATE during FY 2000 only. Operation of the integrators is the same in the Future Pump Start sub-model except the PUMP RATE is computed as follows:

tank PUMP RATE = IF (TIME >= DATA DATE) THEN *tank* LAMBDA *
tank SWL REMAINING + *tank* FINAL RATE ELSE IF (TIME >=
tank ACTUAL PUMP START) THEN *tank* AVG ACTUAL RATE ELSE 0

After the ACTUAL PUMP START date is reached, the PUMP RATE is AVG ACTUAL RATE until the DATA DATE is reached. Then the PUMP RATE is approximately proportional to the SWL REMAINING volume but adjusted by the FINAL RATE. The *tank* LAMBDA or time constant is computed is a theoretical (input parameter) lambda adjusted for pumping efficiency. The *tank* LAMBDA and *tank* FINAL RATE are computed as follows:

tank LAMBDA = *tank* PUMP_EFFICIENCY * *tank* LAMBDA THEORY *tank* FINAL RATE = *tank* PUMP EFFICIENCY * FINAL RATE AT 100%

where *tank* LAMBDA THEORY is an externally calculated time constant that causes the remaining liquid inventory (at DATA DATE) to be removed by a calculated end date based on 100 percent pumping efficiency.

Limiting Inflow Rate/Quarterly Pumping Efficiencies

This SWL pumping sub-model (A-7, 9 and 10) has three differences from the Future Pump Start sub-model; actual pumping data is used, predicted pumping rate is adjusted for quarterly pumping efficiencies and lambda (time constant) is computed internally. Observed tank interstitial liquid draining dynamics limit the pump's ability to remove liquid and these dynamics are used to compute lambda . Operation of the integrators is the same in the Future Pump Start sub-model except the PUMP RATE is as shown for the Quarterly Pumping Efficiency sub-model with *tank* LAMBDA THEORY replaced by *tank* LAMBDA MEASURED which is computed as follows:

tank LAMBDA MEASURED = (*tank* INITIAL INFLOW RATE -
FINAL RATE AT 100%) / *tank* REMAINING VOL

2.1.2 Accounting Modules

The accounting modules are sectors Total Volume Accounting (A-3), Organic SWL Volume Accounting (A-3) and Aggregate SWL Pumping Rate Accounting (A-4).

Total Volume Accounting

TOTAL SWL PUMPED is the sum of TOTAL 21 TKS PUMPED and the cumulative pumped volumes from the remaining eight tanks for which actual pumping data is available. TOTAL 21 TKS PUMPED is the sum of the 21 arrayed tank transferred volumes from the Future Pump Start sub-module.

TOTAL INITIAL SWL is the sum of INITIAL VOL TOTAL 21 TANKS and *tank* INITIAL VOLUME from the remaining eight tanks for which actual pumping data is available. INITIAL VOL TOTAL 21 TANKS is the sum of the 21 arrayed tank initial volumes from the Future Pump Start sub-module. This is a static calculation summing 29 input values.

TOTAL SWL REMAINING is the sum of TOTAL REMAIN 21 TANKS and *tank* SWL REMAINING from the remaining eight tanks for which actual pumping data is available. TOTAL REMAIN 21 TANKS is the sum of the 21 arrayed tank remaining volumes from the Future Pump Start sub-module. By definition, *tank* SWL REMAINING becomes zero on the date a tank is classified as Interim Stabilized.

PERCENT REMOVED is 100 times TOTAL SWL PUMPED divided by TOTAL INITIAL SWL.

Organic SWL Accounting

TOTAL ORGANIC SWL PUMPED is the sum of SWL TRANSFERRED for Tanks U-102, U-105, U-106, and U-109 (from the Future Pump Start sub-module 21 array) and U103 SWL PUMPED.

Aggregate SWL Pumping Rate Accounting

AGGREGATE SWL PUMPING RATE is the sum of RATE 21 TANKS and the pumping rates from the remaining eight tanks for which actual pumping data is available. RATE 21 TANKS is the sum of the 21 arrayed tank rates from the Future Pump Start sub-module.

2.1.3 User Interface Modules

The user interface modules are Model Navigation-Sectors Graphs and Tables (A-1), Control Panel (A-5), SWL Pumping Performance Measures and Calendar Logic (A-2 and A-4).

Control Panel

The Control Panel sector displays the calculated pumping duration (in days) for each tank. Each duration is calculated by accumulating the time during which the pumping rate is greater than zero. Therefore, while the model is running, each duration *(tank* PUMP TIME or PUMP TIME *tank* for 21 tank array) is the elapsed pumping time from the start of pumping to the simulation time. When the run completes, each duration is the total pumping time for that tank. Each duration is accumulated in an integrator located in the respective SWL Pumping sub-model.

The ALL TANK DURATION TABLE provides the duration results in tabular form. The Report Interval for the table should be set to 1800 (days) to simplify copying the duration results to another application.

Also, the Control Panel is provided as the location for future operator adjustable parameters used for sensitivity studies.

Model Navigation-Sectors Graphs and Tables

This sector provides a miniature graphic of the overall model layout. Besides the sector layout, the locations of key graphs and tables are identified.

SWL Pumping Performance Measures

These are percent SWL removal milestones set by Consent Decree for September 1999, 2002 and 2003. The measures include percent organic SWL removal milestones for September 2000 and 2001. These values are used on percent removal graphs to compare pumping performance with milestones.

This sector also provides the revision history for the simulation. Each revision has a colored converter with revision status information in the "document" field. Changes in the simulation related to that revision are shown in the same color in the simulation graphical presentation.

Calendar Logic

The simulation time unit is DAY and DAY is equal to 1 on June 1, 1988. DAY advances continuously during run time and typically finishes with a value equal to 1801 (or May 6, 2003). As an operator aid and to time tag output values, a calendar is computed during run time. MONTH, DAY OF MONTH, CALENDAY YEAR and DAY OF YEAR parameters are provided. The user may add these parameters to any table generated by the simulation. The CALENDAR DATA Table is also provided to manually convert between simulation day and calendar date. For example, the table is used to convert September 30, 1999 (last day of actual pumping data used in the simulation) to DAY equal 487. Every date input value must be entered in the DAY format as defined above.

2.2 Concurrent Process Decomposition

The concurrent processes are SWL Pumping, Aggregate Volume Accounting and Operator Interface. Within the SWL Pumping process, each tank's processing begins at its actual pumping start date or (planned) pump start date. Processing continues until no pumpable liquid volume remains in the tank. The Aggregate Volume Accounting and Operator Interface processes operate over the entire SWL pumping interval and therefore concurrently with the SWL Pumping process. The Aggregate Volume Accounting process continuously produces Total SWL Pumped, Total Organic SWL Pumped and Aggregate SWL Pumping Rate. The Operator Interface process continuously displays simulation output values and is able to accept operator inputs during run time, e.g. START DATE SLIP. This process also continuously converts simulation day to calendar month, day and year.

2.3 Data Entity Decomposition

Separate decompositions are provided for data inputs and data outputs (products).

2.3.1 Data Input Decomposition

The same input data set does not apply to all 29 SWL tanks. The twenty-one tanks with a future pump start date do share the same data set. The designator *tank* is a tank identifier and the designator [*tank*] is a tank identifier index in array data structures. The input parameter definitions by group are provided below.

<u>Global Input Parameters</u>

Consent Decree SWL Removal Vector	(Date, Percent Removed) for three dates
Organic Removal Vector	(Date, Percent Organic SWL Removed) for two dates

<u>For All 29 Tanks</u>

INITIAL VOLUME[*tank*] or *tank* INITIAL VOLUME (gallons) set to estimated volume until interim stabilized, then set to actual pumped volume

FINAL RATE AT 100 % 72 gallons per day at 100 % TOE (0.05 gallons per minute)

<u>For Tanks with Pump Start After September 30, 1999 (for each of 21 tanks)</u>

PUMP START[*tank*]	scheduled day of initial pumping
LAMBDA THEORY[*tank*]	time constant to remove liquid inventory and reach the FINAL RATE at the scheduled completion date)
PUMP EFFICIENCY{*tank*}	quarterly pumping efficiency profile for five quarters beginning initial quarter of FY 2000)

<u>For All Tanks with Actual Pumping Data (S-102, S-103. S-106, SX-104, SX-106, T-104, T-106 and U-103)</u>

tank ACTUAL VOLUME PUMPED	through September 30, 1999
DATA DATE	projection start date which is October 1, 1999
tank ACTUAL PUMP START	day when actual pumping began

<u>For Tanks with Pump Start Before September 30, 1999 with Limited Inflow Rate (S-103, S-106, SX-104, T-104 and T-110)</u>

tank INITIAL INFLOW RATE	effective August 1, 1999 at TOE of 100 %. The values for these tanks are 300, 350, 500, 158 and 200, respectively.

<u>For Tanks with Pump Start Before September 30, 1999 without Limited Inflow Rate (S-102, SX-106 and U-103)</u>

tank LAMBDA THEORY	time constant to remove liquid inventory and reach the FINAL RATE at the scheduled completion date)

<u>For Tanks with Quarterly Pumping Efficiencies (S-102, S-103, S-106, SX-104, SX-106, T-110 and U-103)</u>

tank PUMP EFFICIENCY	quarterly pumping efficiency profile for five quarters beginning initial quarter of FY 2000)

The input data in array structures, e.g. INITIAL VOLUME[*tank*] and LAMBDA THEORY[tank], may be updated by copying the data (with appropriate delimiters) from a spread sheet and then pasting the data into the appropriate model element ,e.g. INITIAL VOLUME or LAMBDA THEORY converter. The "Array" and "Apply to All" selections are checked in these converters to allow this data transfer method.

The input values used for INITIAL VOLUME and for calculating LAMBDA THEORY are provided in Appendix B which is excerpted from "Updated Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks" (Field 1999). The INITIAL VOLUME is the Total Pumpable Liquid Volume. LAMBDA THEORY is computed from Total Pumpable Liquid Volume and Pumping Duration at 100 % Efficiency.

2.3.2 Data Output (Product) Decomposition

All outputs are projections (equally time spaced, series of values) over the entire interval of SWL pumping except as otherwise noted.

Aggregate Performance Measures
Total SWL Pumped (presented in Figure 1)
Percent Removed (including graph comparing results with FY 2000 milestones)
Total Organic SWL Pumped (presented in Figure 2)
Percent Organic SWL Removed (including graph comparing results with FY 2000 milestones)
Aggregate SWL Pumping Rate (presented in Figure 3)

Constituent Performance Measures
tank SWL Pumped or SWL Pumped[*tank*]
tank Pump Rate or Pump Rate[*tank*]
tank Pump Time or Pump Time[*tank*] (pumping duration for each tank in days)

Figure 2 Total SWL Pumped

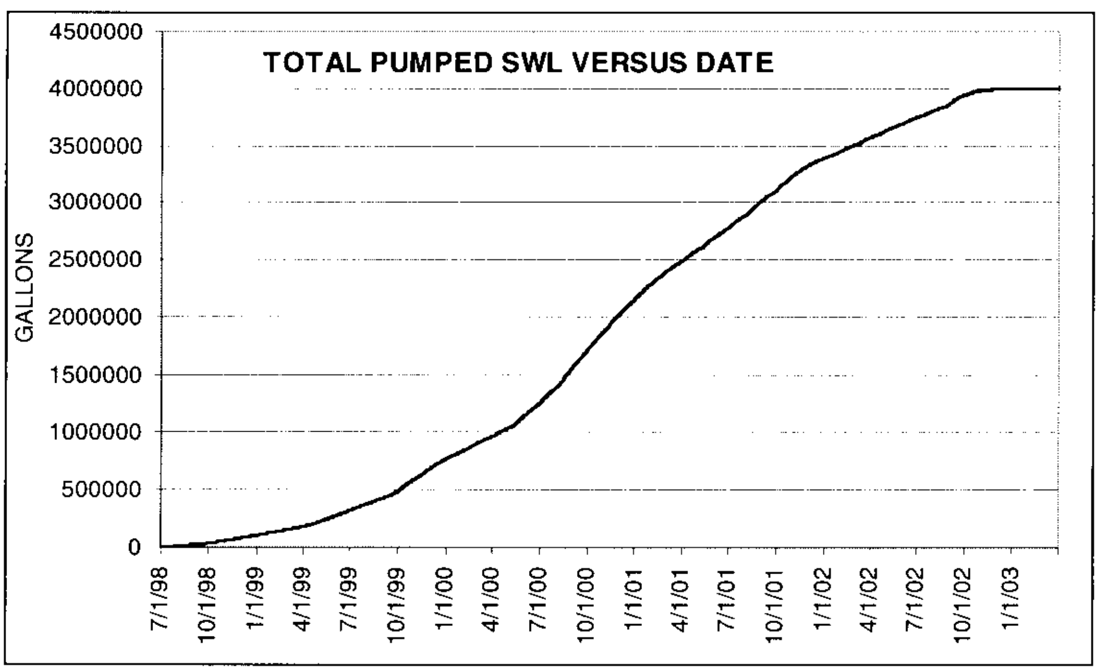


Figure 3 Total Organic SWL Pumped

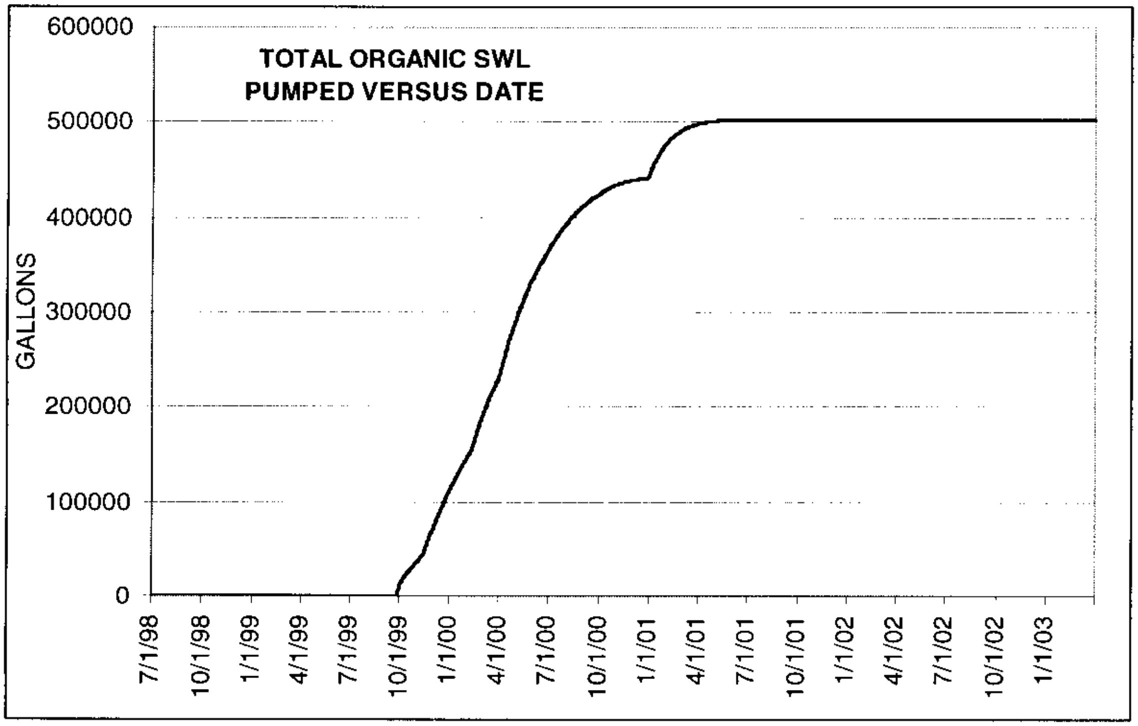
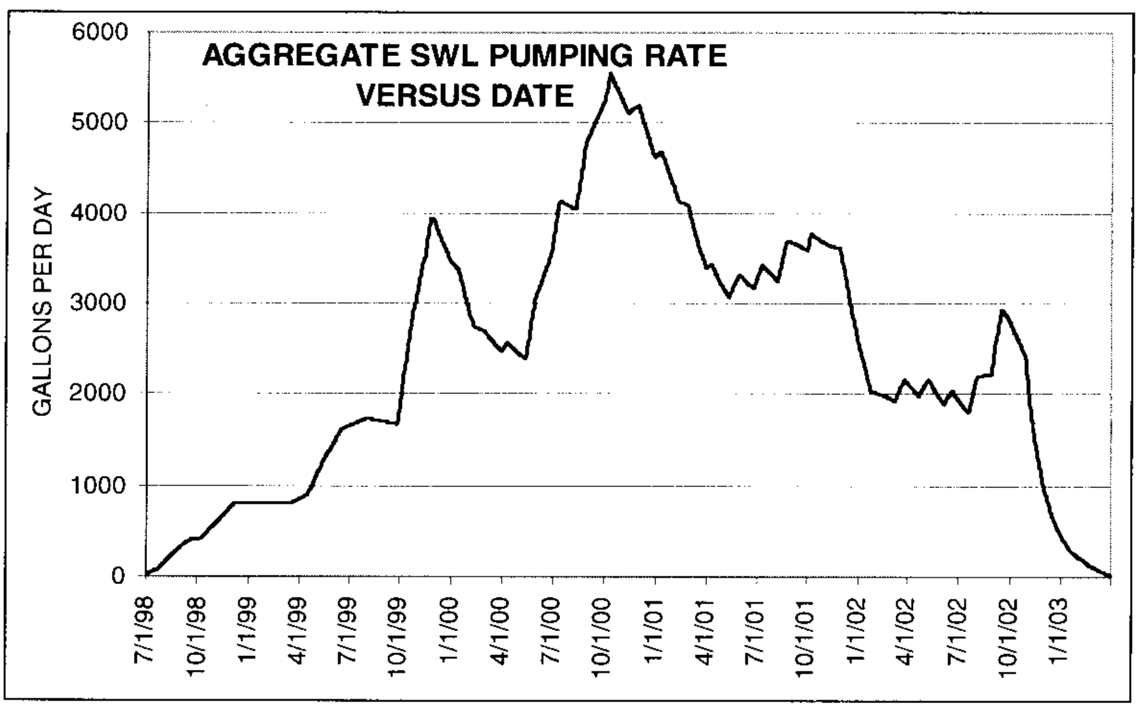


Figure 4 Aggregate SWL Pumping Rate



3.0 DEPENDENCY DESCRIPTION

The intermodule dependencies, interprocess dependencies, data dependencies and conversion dependencies are discussed. The automatic (interdependence) mapping tools available to the user are also described.

3.1 Intermodule Dependencies

Total Volume Accounting and User Interface modules access SWL Pumped, Pump Rate and Pump Time from each tank sub-model. Appendix C , generated by the *ithink* software, shows the intermodule dependencies. Arrows denote the direction of information flow. Not that there are no interdependencies among tank sub-models and all provide their output data to the Accounting modules. Control data may be provided to the tank sub-models from the Control Panel for sensitivity studies; but this data is set to nominal values for this report.

3.2 Interprocess Dependencies

The concurrent processes are SWL Pumping, Aggregate Volume Accounting and Operator Interface. For each tank, its processing begins at its actual pumping start date or (planned) pump start date. Processing continues until no pumpable liquid volume remains in the tank. The Aggregate Volume Accounting processes operate over the entire SWL pumping interval and therefore concurrently with the SWL Pumping process. The Aggregate Volume Accounting process continuously produces Total SWL Pumped, Total Organic SWL Pumped and Aggregate SWL Pumping Rate.

The Operator Interface process provides the user interface to the SWL Pumping and Aggregate Volume Accounting processes. The Operator Interface process uses graph, table, control knob and meter elements which are built into the *ithink* simulation language. These elements are viewed as icons on the graphical view and are distributed throughout the sectors. Each element has one or more parameters assigned. The graph and table contents are viewed by selection (double clicking the icon) and the contents are automatically updated by *ithink* during run time.

3.3 Data Dependencies

Time constants in the Future Pump Start sub-module are calculated externally by solving the following transcendental equation by iteration:

$$\text{LAMBDA THEORY} = \text{FINAL RATE AT 100\%} * [e^{\text{LAMBDA THEORY} * \text{duration}} - 1] / \text{INITIAL VOLUME}$$

where duration is the expected tank pumping duration in days (Field 1999), FINAL RATE AT 100% is the pumping rate at tank pumping completion (gallons per minute at

100% efficiency), INITIAL VOLUME is the expected total pumpable volume (Field 1999) in gallons.

FINAL RATE is related to PUMP EFFICIENCY as follows:

FINAL RATE = PUMP EFFICIENCY * FINAL RATE AT 100%

where PUMP EFFICIENCY is the expected fraction of time that pump is actually pumping, i.e. system, adequate SWL volume and pump are simultaneously available. Expected PUMP EFFICIENCY quarterly increases have been established by Interim Stabilization Project management. These expected values are implemented in the model as follows for most SSTs:

FY 2000 First Quarter (day 488)	0.370
FY 2000 Second Quarter (day 579)	0.410
FY 2000 Third Quarter (day 671)	0.420
FY 2000 Fourth Quarter (day 762)	0.470
FY 2001 First Quarter (day 854) and beyond	0.500

For tanks where SWL must be pumped through a DCRT, PUMP EFFICIENCY is 0.45. These are tanks BY-105 and BY-106 which are scheduled to start after FY 2000. Graphical converters are used to store PUMP EFFICIENCY input data and schedule the efficiency increases at the specified times.

The simulation start day (day 1) is June 1, 1998. All event dates including tank pump start dates and pump efficiency change dates are input as the number of days from the simulation start date.

3.4 Conversion Dependencies

Conversion dependencies are avoided by using common units. Simulation units are as follows:

Time	days
Volume	gallons
Volumetric rate	gallons/day
Time constant	1/day

4.0 INTERFACE DESCRIPTION

Module and process interfaces are discussed. The module interface consists of groups of element interconnections. These are automatically mapped into data flow arrows (interconnection groupings) which have the same source and destination sectors. The process interface consists of a higher level grouping of interconnections among the three top level processes. The process interface description also explains the path of the simulation's results to the end user.

4.1 Module Interface

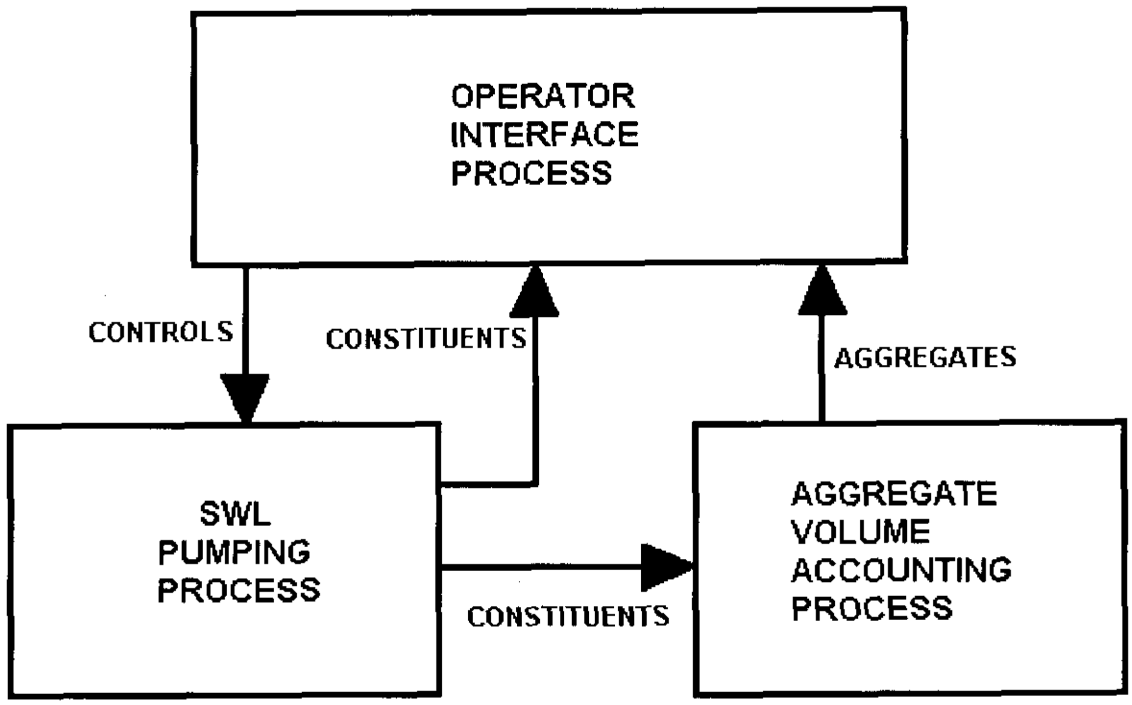
Arrows provide the interface between elements whether in one sector or between sectors. To avoid visual clutter, elements providing information to another sector are "ghosted." These are drawn with dashed or dotted lines on the model graphic view (Appendix A). The ghost image is then placed in the destination sector and connected to the destination element with an arrow. A map view is provided to show data flow between sectors. From the map view, the user may select a data flow and receive a table of sources and destinations for all data elements within the data flow. The map view for this simulation is shown in Appendix C.

4.2 Process Interface

The Operator Interface process generates sensitivity parameters which represent controls to the SWL Pumping process. The SWL Pumping process generates the individual tank output parameters which represent constituent data to the Aggregate Volume Accounting process and back to the Operator Interface process. The Aggregate Volume Accounting process provides aggregate results back to the Operator Interface process. Figure 4.2-1 shows these process interfaces. All parameters associated with the SWL Pumping process are available and may be user assigned to graphs, tables and meter displays. Several graphs are in place showing flow rate and remaining volume for specific tanks.

The simulation's Table 6 Percent Removed contains the constituent and aggregate volume removed parameters. To transport these results, the user simply copies the table's contents and then pastes into another Windows application.

Figure 5 Process Interfaces



5.0 REFERENCES

IRM Application Software System Life Cycle Standards, LMHC-PRO-2778, dated October 1, 1999 (formerly HNF-PRO-2778, February 2, 1999).

Software Practices – System Design Description, LMHC-PRO-515, October 1, 1999 (formerly HNF-PRO-515, dated September 18, 1997).

Field, J.G., Updated Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks, HNF-2978 Rev. 1, Dated September 1999

APPENDIX A SIMULATION GRAPHICAL PRESENTATION

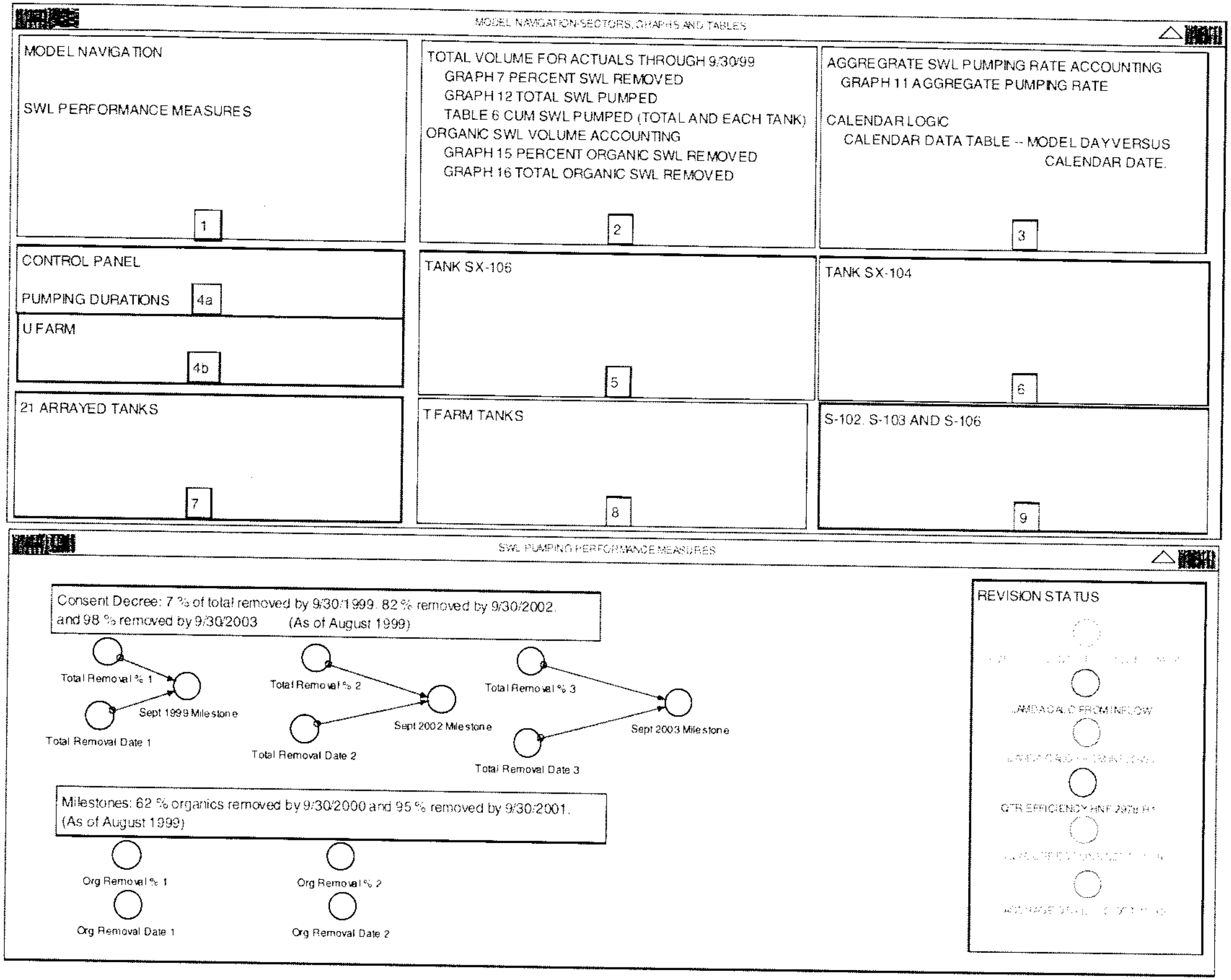
This dynamic simulation is built by placing graphical elements on the work space and then interconnecting the elements. The developer is then prompted for the numeric values needed to complete the model. Sectors are used to graphically group related elements and are treated as software modules. The modules are organized as SWL Pumping Sub-models, Accounting Modules and User Interface Modules. Five sectors are used to model SST SWL pumping behaviors; three sectors provide (aggregate volume) accounting; and four sectors provide the user interface including a control panel. To explain the fundamental operation of the simulation, a detailed discussion of the U FARM WITH ACTUAL PUMPING THROUGH 9/30/99 sector is provided. The other pumping sub-models are very similar.

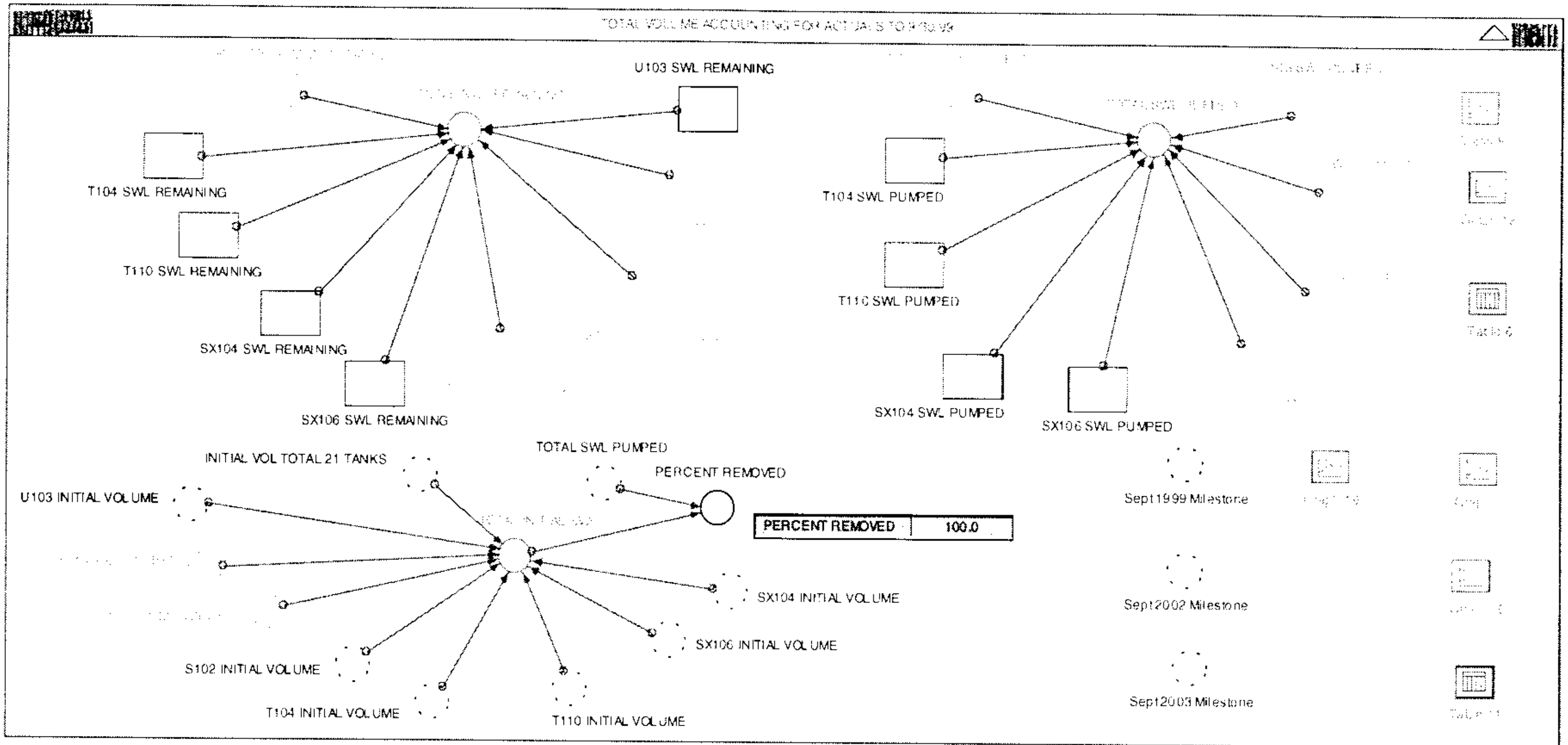
The U FARM WITH ACTUAL PUMPING THROUGH 9/30/99 sector (on A-5) shows the Tank U-103 sub-model. This tank had actual pumping data from September 26 through September 30, 1999 totaling 12,350 gallons. A theoretical lambda (time constant) was computed to remove the expected remaining volume in the remaining expected pumping duration with 100 % pumping efficiency (uninterrupted pump operation). This theoretical lambda is equal to 0.0215/day; the value is roughly the fraction of remaining volume pumped in one day.

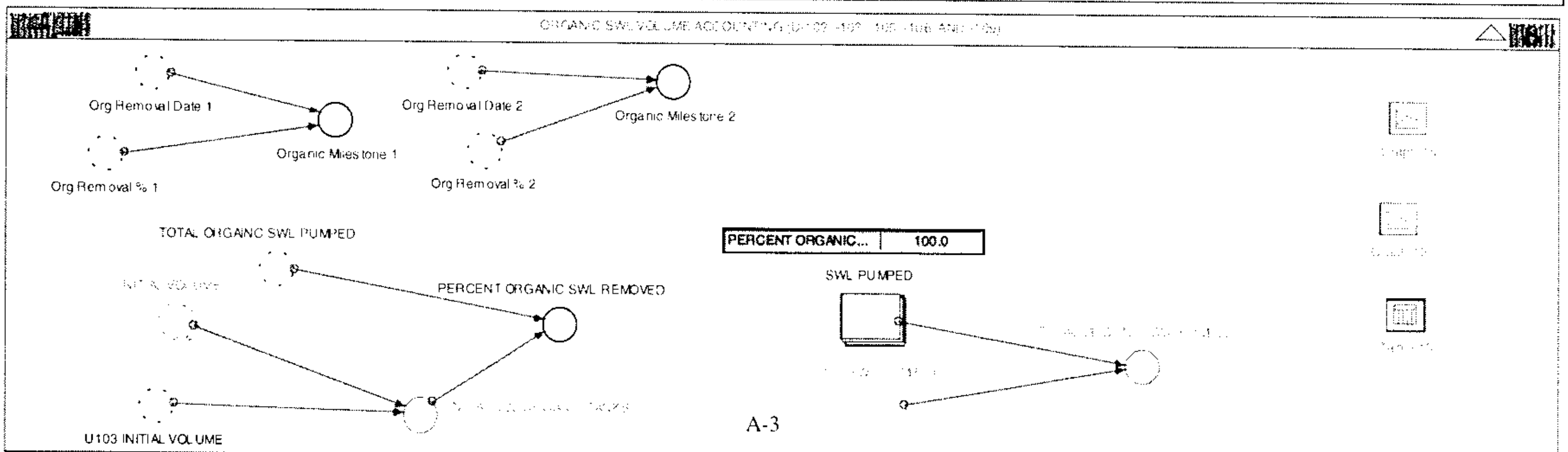
The pumping rate beginning October 1, 1999 (DATA DATE) is not purely proportional to the theoretical lambda because the rate equation includes a second term which is the final pumping rate. The selection of lambda results in zero remaining volume just as the final pumping rate is reached.

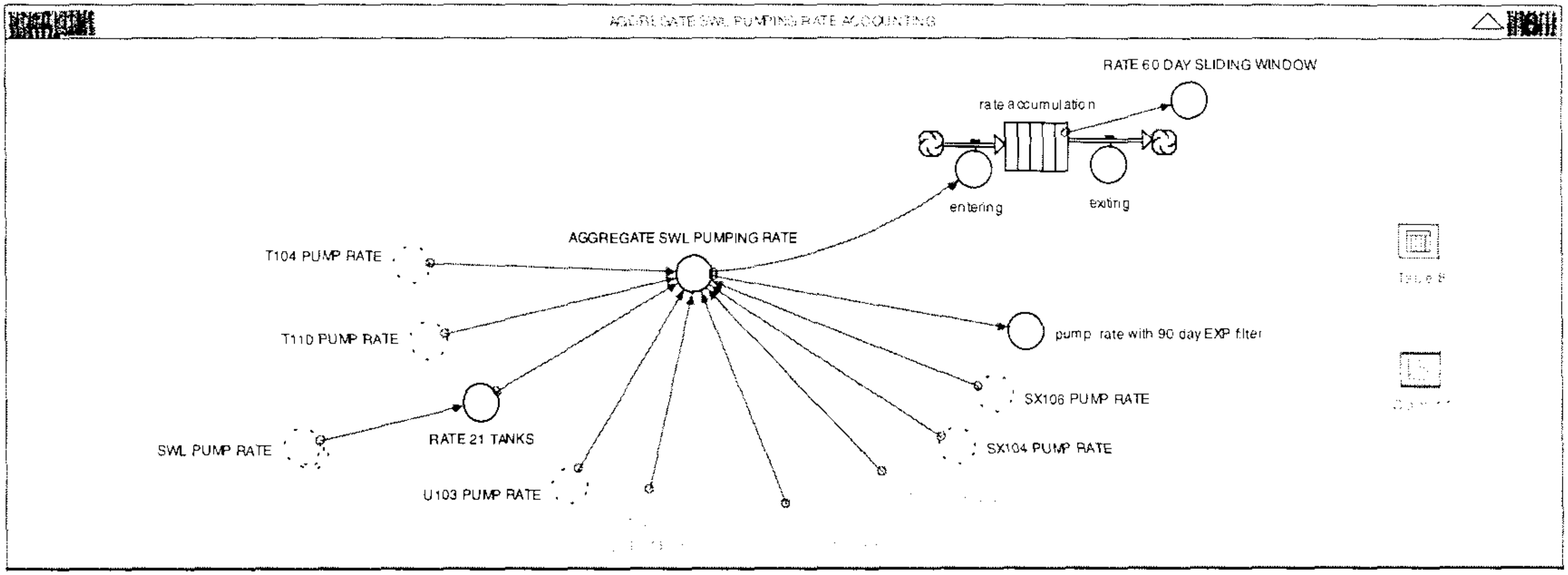
Pump efficiency is the final term used to adjust the pump rate. A FY 2000 quarterly pump efficiency profile was defined by Interim Stabilization Project management to capture the impact of expected pumping efficiency improvements. This term scales the pump rate which would otherwise be based on 100 % pumping efficiency.

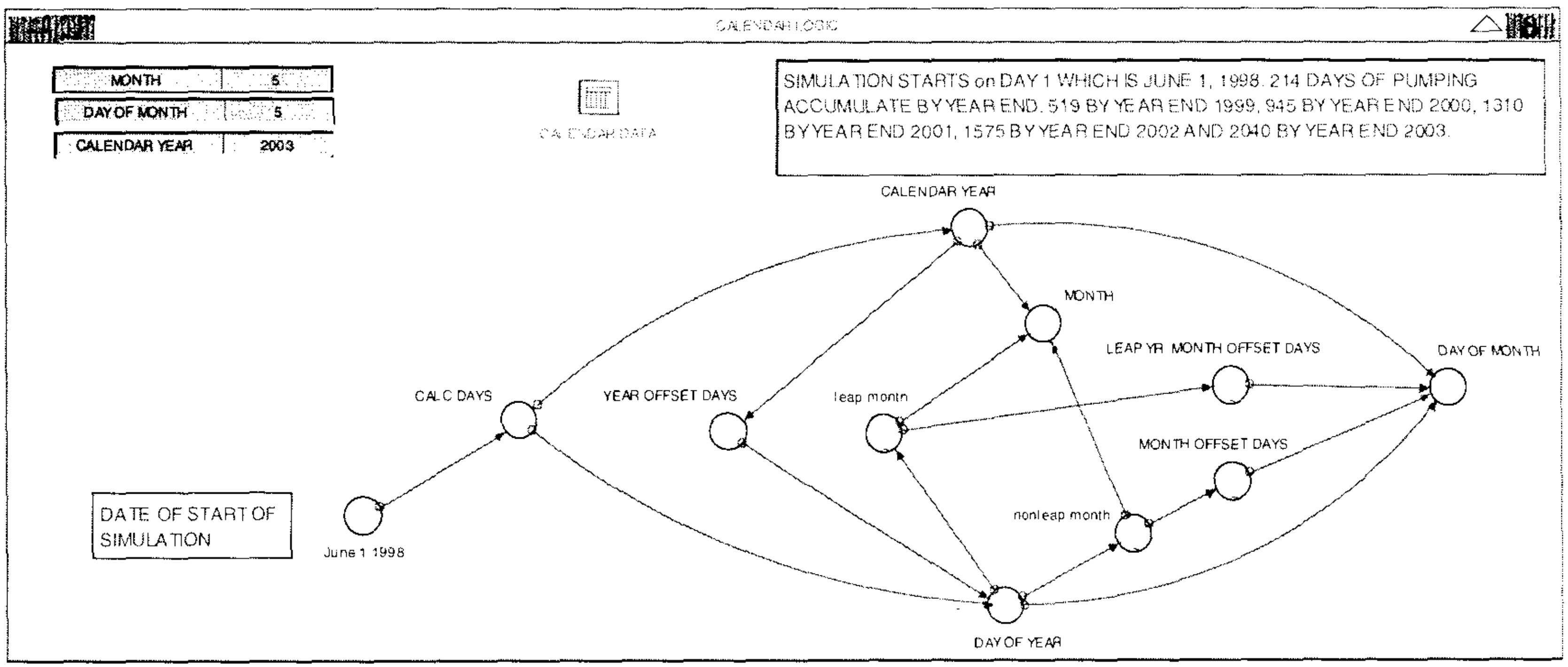
Using the names on the graphic, this sub-model operates as follows. The U103 SWL REMAINING integrator (reservoir) is initialized with U103 INITIAL VOLUME and then drained by the U103 PUMP RATE flow element into the SWL PUMPED integrator. The flow element contains the timing logic which selects theU103 AVG ACTUAL RATE until the DATA DATE and U103 LAMBDA*U103 SWL REMAINING + U103 FINAL RATE from the DATA DATE to completion. U103 SWL REMAINING drains until its volume is zero. The "non-negative" option is selected on all integrators to avoid negative volumes. This structure is used to assure conservation of volume.

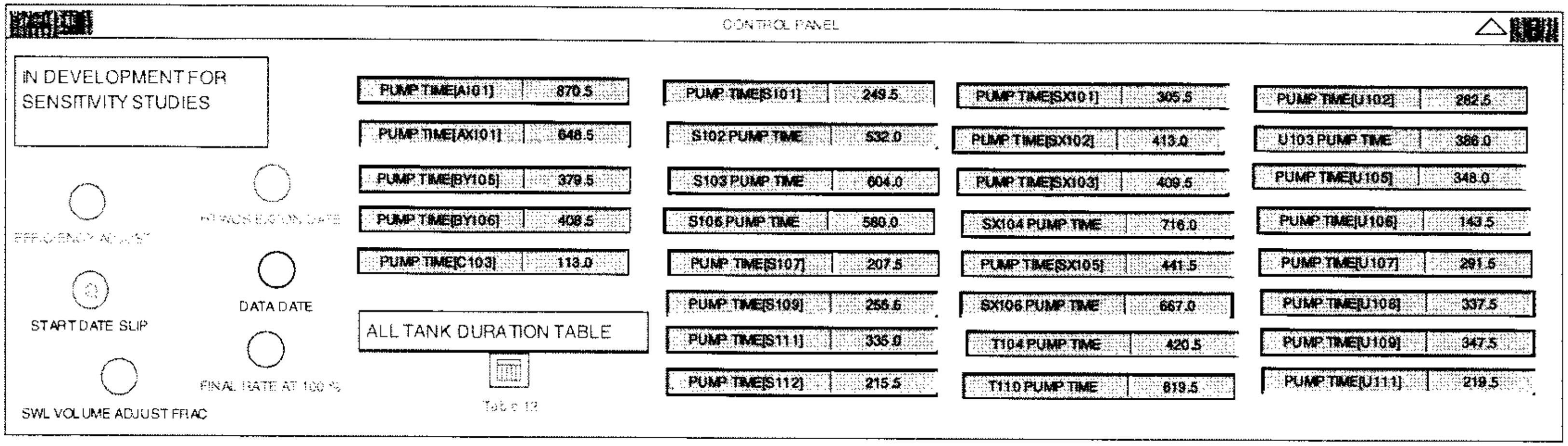

MODEL NAVIGATION-SECTORS, GRAPHS AND TABLES
MODEL NAVIGATION
SWL PERFORMANCE MEASURES
1
TOTAL VOLUME FOR ACTUALS THROUGH 9/30/99
GRAPH 7 PERCENT SWL REMOVED
GRAPH 12 TOTAL SWL PUMPED
TABLE 6 CUM SWL PUMPED (TOTAL AND EACH TANK)
ORGANIC SWL VOLUME ACCOUNTING
GRAPH 15 PERCENT ORGANIC SWL REMOVED
GRAPH 16 TOTAL ORGANIC SWL REMOVED
2
AGGREGRATE SWL PUMPING RATE ACCOUNTING
GRAPH 11 AGGREGATE PUMPING RATE
CALENDAR LOGIC
CALENDAR DATA TABLE -- MODEL DAY VERSUS CALENDAR DATE.
3
CONTROL PANEL
PUMPING DURATIONS
4a
U FARM
4b
TANK SX-106
5
TANK SX-104
6
21 ARRAYED TANKS
7
T FARM TANKS
8
S-102, S-103 AND S-106
9
SWL PUMPING PERFORMANCE MEASURES
Consent Decree: 7 % of total removed by 9/30/1999, 82 % removed by 9/30/2002, and 98 % removed by 9/30/2003 (As of August 1999)
Total Removal % 1
Total Removal Date 1
Sept 1999 Milestone
Total Removal % 2
Total Removal Date 2
Sept 2002 Milestone
Total Removal % 3
Total Removal Date 3
Sept 2003 Milestone
Milestones: 62 % organics removed by 9/30/2000 and 95 % removed by 9/30/2001. (As of August 1999)
Org Removal % 1
Org Removal Date 1
Org Removal % 2
Org Removal Date 2
REVISION STATUS

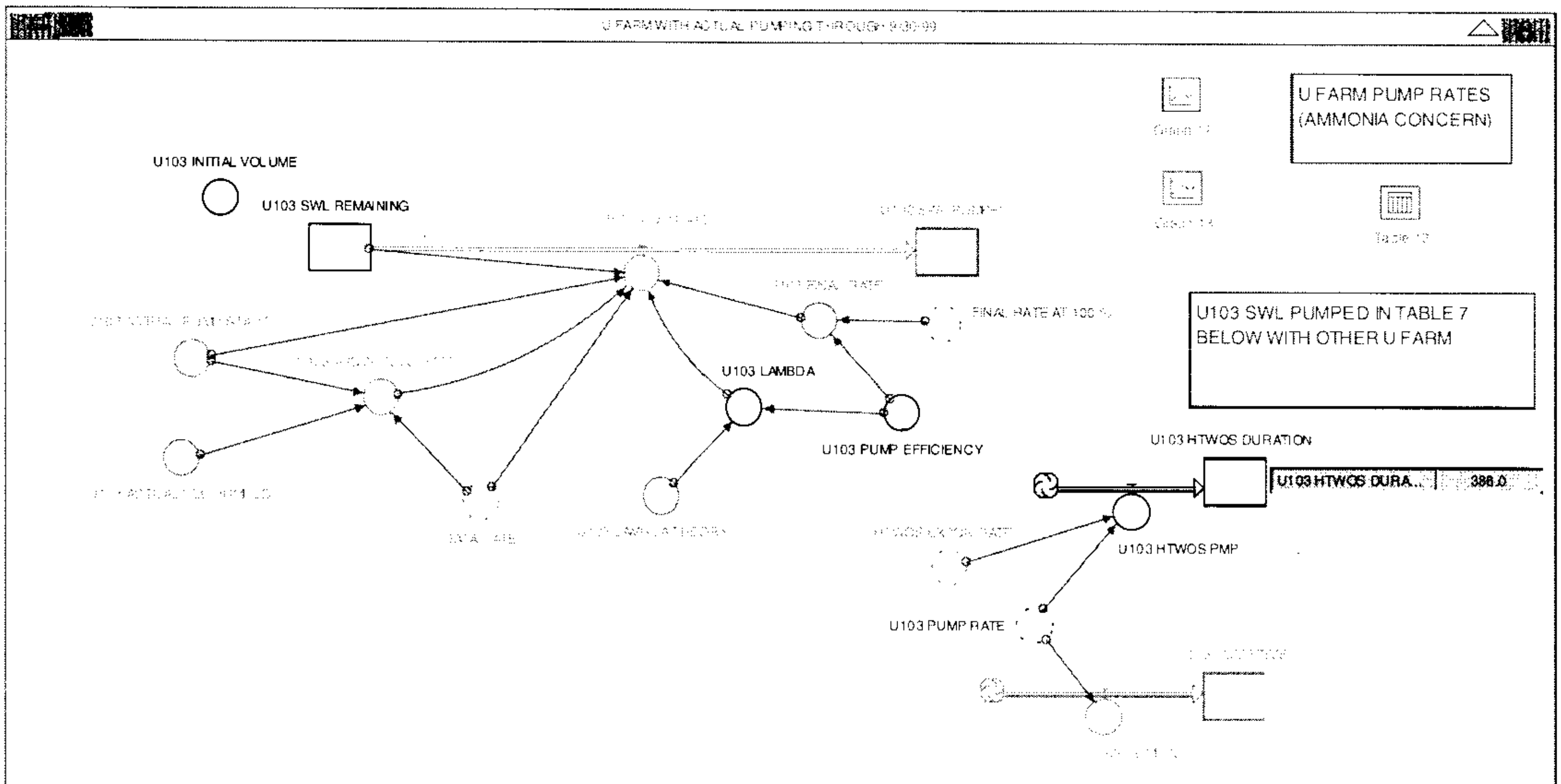

U103 SWL REMAINING
T104 SWL REMAINING
T110 SWL REMAINING
SX104 SWL REMAINING
SX106 SWL REMAINING
T104 SWL PUMPED
T110 SWL PUMPED
SX104 SWL PUMPED
SX106 SWL PUMPED
INITIAL VOL TOTAL 21 TANKS
TOTAL SWL PUMPED
PERCENT REMOVED
U103 INITIAL VOLUME
PERCENT REMOVED 100.0
SX104 INITIAL VOLUME
SX106 INITIAL VOLUME
S102 INITIAL VOLUME
T104 INITIAL VOLUME
T110 INITIAL VOLUME
Sept1999 Milestone
Sept2002 Milestone
Sept2003 Milestone

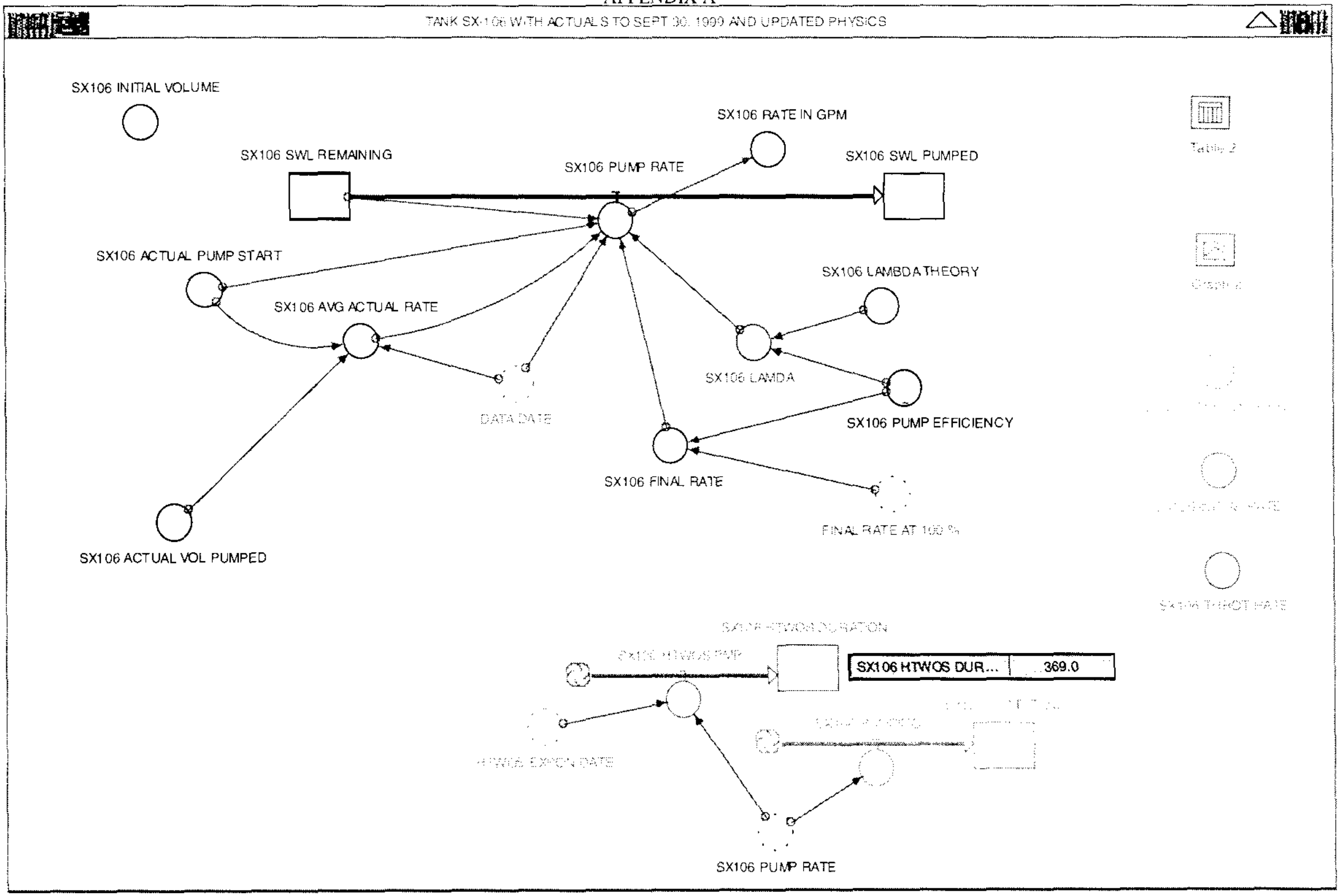

Org Removal Date 1
Organic Milestone 1
Org Removal % 1
Org Removal Date 2
Organic Milestone 2
Org Removal % 2
TOTAL ORGANIC SWL PUMPED
PERCENT ORGANIC SWL REMOVED
U103 INITIAL VOLUME
PERCENT ORGANIC... 100.0
SWL PUMPED

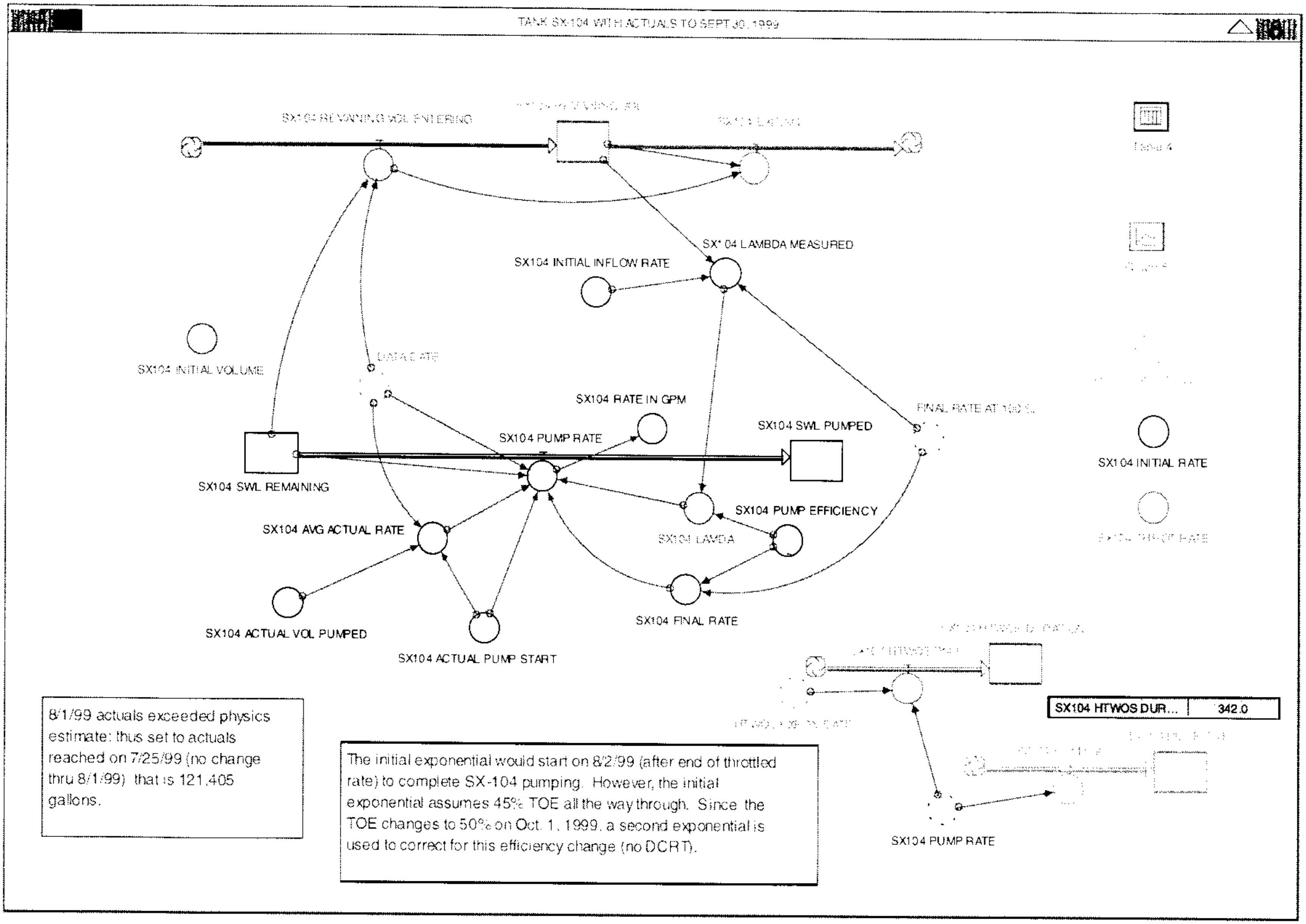

RATE 60 DAY SLIDING WINDOW
rate accumulation
entering
exiting
AGGREGATE SWL PUMPING RATE
T104 PUMP RATE
T110 PUMP RATE
pump rate with 90 day EXP filter
SX106 PUMP RATE
SX104 PUMP RATE
SWL PUMP RATE
RATE 21 TANKS
U103 PUMP RATE

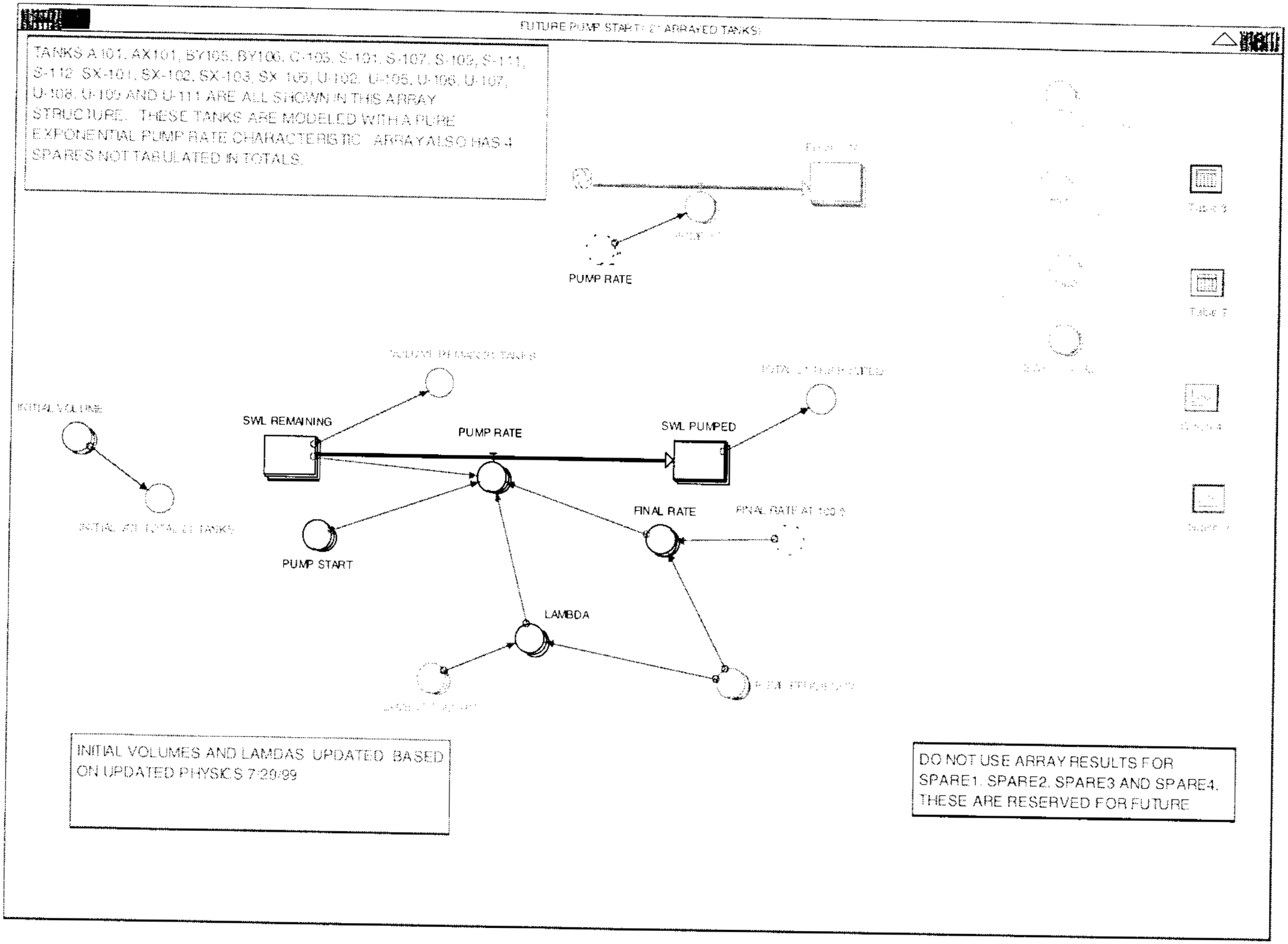

MONTH 5
DAY OF MONTH 5
CALENDAR YEAR 2003
SIMULATION STARTS on DAY 1 WHICH IS JUNE 1, 1998. 214 DAYS OF PUMPING ACCUMULATE BY YEAR END. 519 BY YEAR END 1999, 945 BY YEAR END 2000, 1310 BY YEAR END 2001, 1575 BY YEAR END 2002 AND 2040 BY YEAR END 2003.
CALENDAR YEAR
MONTH
LEAP YR MONTH OFFSET DAYS
DAY OF MONTH
CALC DAYS
YEAR OFFSET DAYS
leap month
MONTH OFFSET DAYS
nonleap month
DATE OF START OF SIMULATION
June 1 1998
DAY OF YEAR

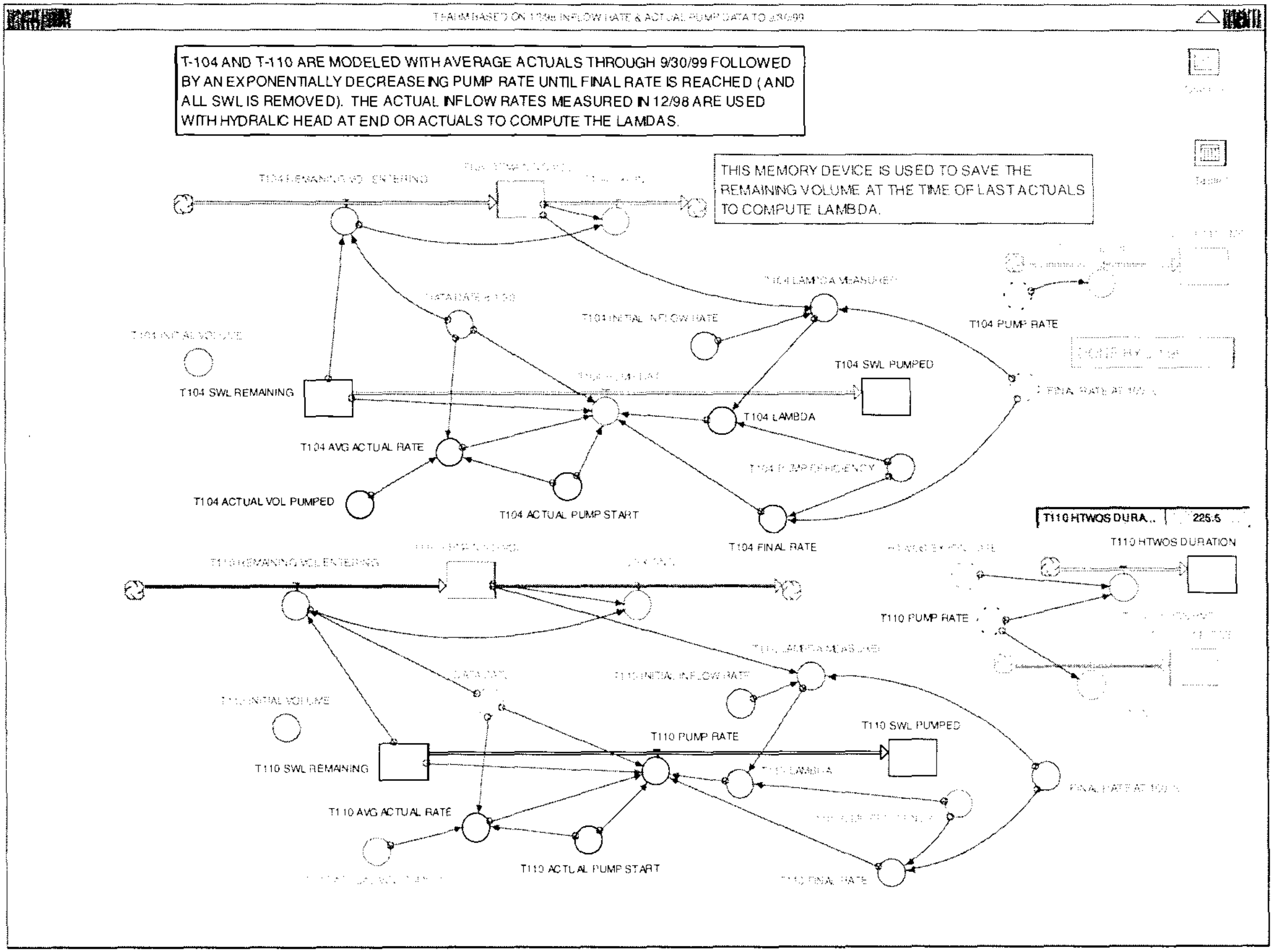

CONTROL PANEL
IN DEVELOPMENT FOR SENSITIVITY STUDIES
EFFICIENCY ADJUST
HTWOS EDTON DATE
START DATE SLIP
DATA DATE
FINAL RATE AT 100 %
SWL VOLUME ADJUST FRAC
PUMP TIME[A101] 870.5
PUMP TIME[AX101] 648.5
PUMP TIME[BY105] 379.5
PUMP TIME[BY106] 408.5
PUMP TIME[C103] 113.0
ALL TANK DURATION TABLE
Table 12
PUMP TIME[S101] 249.5
S102 PUMP TIME 532.0
S103 PUMP TIME 604.0
S106 PUMP TIME 580.0
PUMP TIME[S107] 207.5
PUMP TIME[S109] 255.5
PUMP TIME[S111] 335.0
PUMP TIME[S112] 215.5
PUMP TIME[SX101] 305.5
PUMP TIME[SX102] 413.0
PUMP TIME[SX103] 409.5
SX104 PUMP TIME 716.0
PUMP TIME[SX105] 441.5
SX106 PUMP TIME 667.0
T104 PUMP TIME 420.5
T110 PUMP TIME 619.5
PUMP TIME[U102] 282.5
U103 PUMP TIME 386.0
PUMP TIME[U105] 348.0
PUMP TIME[U106] 143.5
PUMP TIME[U107] 291.5
PUMP TIME[U108] 337.5
PUMP TIME[U109] 347.5
PUMP TIME[U111] 219.5

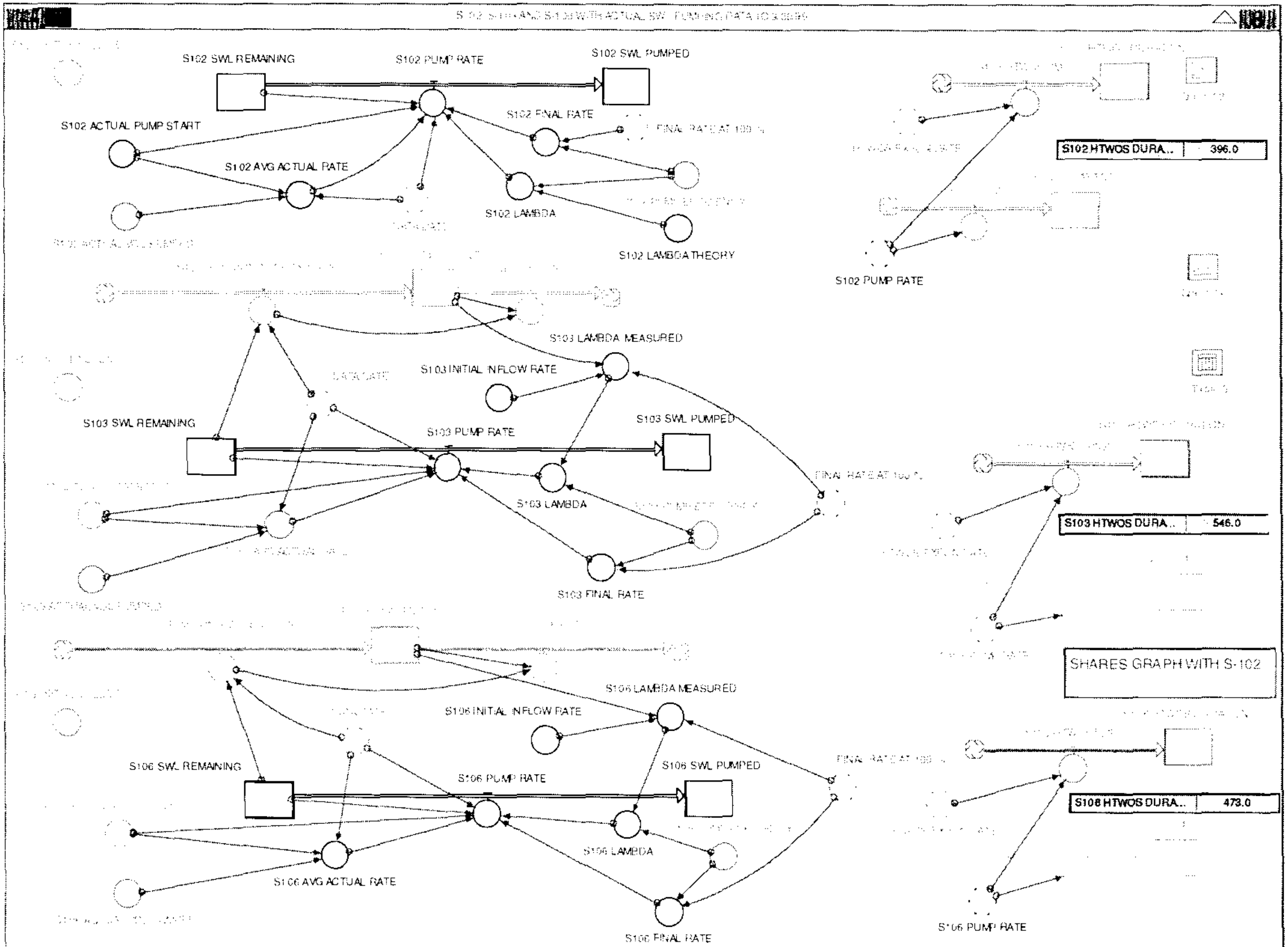

U FARM WITH ACTUAL PUMPING THROUGH 9-30-99
U FARM PUMP RATES (AMMONIA CONCERN)
Table 12
U103 INITIAL VOLUME
U103 SWL REMAINING
FINAL RATE AT 100 %
U103 LAMBDA
U103 PUMP EFFICIENCY
U103 SWL PUMPED IN TABLE 7 BELOW WITH OTHER U FARM
U103 HTWOS DURATION
U103 HTWOS DURA... 386.0
U103 HTWOS PMP
U103 PUMP RATE


TANK SX-106 WITH ACTUALS TO SEPT 30, 1999 AND UPDATED PHYSICS
SX106 INITIAL VOLUME
SX106 RATE IN GPM
SX106 SWL REMAINING
SX106 PUMP RATE
SX106 SWL PUMPED
Table 2
SX106 ACTUAL PUMP START
SX106 LAMBDA THEORY
SX106 AVG ACTUAL RATE
SX106 LAMDA
DATA DATE
SX106 PUMP EFFICIENCY
SX106 FINAL RATE
FINAL RATE AT 100 %
SX106 ACTUAL VOL PUMPED
SX106 HTWOS DUR...
369.0
SX106 PUMP RATE


TANK SX-104 WITH ACTUALS TO SEPT 30, 1999
SX104 INITIAL INFLOW RATE
SX' 04 LAMBDA MEASURED
SX104 INITIAL VOLUME
SX104 RATE IN GPM
FINAL RATE AT
SX104 SWL PUMPED
SX104 PUMP RATE
SX104 SWL REMAINING
SX104 INITIAL RATE
SX104 PUMP EFFICIENCY
SX104 AVG ACTUAL RATE
SX104 LAMDA
SX104 FINAL RATE
SX104 ACTUAL VOL PUMPED
SX104 ACTUAL PUMP START
SX104 HTWOS DUR... 342.0
SX104 PUMP RATE
8/1/99 actuals exceeded physics estimate: thus set to actuals reached on 7/25/99 (no change thru 8/1/99) that is 121,405 gallons.
The initial exponential would start on 8/2/99 (after end of throttled rate) to complete SX-104 pumping. However, the initial exponential assumes 45% TOE all the way through. Since the TOE changes to 50% on Oct. 1, 1999, a second exponential is used to correct for this efficiency change (no DCRT).


FUTURE PUMP START (21 ARRAYED TANKS)
TANKS A-101, AX101, BY105, BY106, C-105, S-101, S-107, S-109, S-111, S-112, SX-101, SX-102, SX-103, SX-105, U-102, U-105, U-106, U-107, U-108, U-109 AND U-111 ARE ALL SHOWN IN THIS ARRAY STRUCTURE. THESE TANKS ARE MODELED WITH A PURE EXPONENTIAL PUMP RATE CHARACTERISTIC. ARRAY ALSO HAS 4 SPARES NOT TABULATED IN TOTALS.
PUMP RATE
INITIAL VOLUME
SWL REMAINING
PUMP RATE
SWL PUMPED
FINAL RATE
PUMP START
LAMBDA
INITIAL VOLUMES AND LAMDAS UPDATED BASED ON UPDATED PHYSICS 7/29/99
DO NOT USE ARRAY RESULTS FOR SPARE1, SPARE2, SPARE3 AND SPARE4. THESE ARE RESERVED FOR FUTURE


T-104 AND T-110 ARE MODELED WITH AVERAGE ACTUALS THROUGH 9/30/99 FOLLOWED BY AN EXPONENTIALLY DECREASEING PUMP RATE UNTIL FINAL RATE IS REACHED (AND ALL SWL IS REMOVED). THE ACTUAL INFLOW RATES MEASURED IN 12/98 ARE USED WITH HYDRALIC HEAD AT END OR ACTUALS TO COMPUTE THE LAMDAS.
THIS MEMORY DEVICE IS USED TO SAVE THE REMAINING VOLUME AT THE TIME OF LAST ACTUALS TO COMPUTE LAMBDA.
T104 SWL REMAINING
T104 AVG ACTUAL RATE
T104 ACTUAL VOL PUMPED
T104 ACTUAL PUMP START
T104 LAMBDA
T104 SWL PUMPED
T104 FINAL RATE
T104 PUMP RATE
T110 HTWOS DURA...
225.5
T110 HTWOS DURATION
T110 PUMP RATE
T110 SWL PUMPED
T110 PUMP RATE
T110 SWL REMAINING
T110 AVG ACTUAL RATE
T110 ACTUAL PUMP START


S102 SWL REMAINING
S102 PUMP RATE
S102 SWL PUMPED
S102 ACTUAL PUMP START
S102 FINAL RATE
S102 AVG ACTUAL RATE
S102 LAMBDA
S102 LAMBDA THEORY
S102 PUMP RATE
S102 HTWOS DURA... 396.0
S103 LAMBDA MEASURED
S103 INITIAL INFLOW RATE
S103 SWL REMAINING
S103 PUMP RATE
S103 SWL PUMPED
S103 LAMBDA
S103 FINAL RATE
S103 HTWOS DURA... 546.0
SHARES GRAPH WITH S-102
S106 LAMBDA MEASURED
S106 INITIAL INFLOW RATE
S106 SWL REMAINING
S106 PUMP RATE
S106 SWL PUMPED
S106 LAMBDA
S106 AVG ACTUAL RATE
S106 FINAL RATE
S106 HTWOS DURA... 473.0
S106 PUMP RATE

APPENDIX B

INPUT DATA--INITIAL VOLUME AND MINIMUM PUMPING DURATION

The paragraph below and Table B-1 following are excerpted from Updated Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks (Fields 1999). These Total Pumpable Liquid Volumes initialize the SWL REMAINING integrators in the Salt Well Liquid Pumping Dynamic Simulation. For each tank where SWL pumping starts after September 30, 1999, the Total Pumpable Liquid Volume and Pumping Duration at 100 % Efficiency are used to compute LAMBDA, the simulation's time constant.

Table B-1 lists the supernatant, saltcake and sludge volume estimates used to calculate pumping durations for each tank. If a LOW reading was used to calculate the height of the liquid level in the solids, this is also included in the table. Each tanks calculated pumpable liquid volume and jet pump durations for 100 percent efficiencies are also shown in Table B-1. As noted in the Introduction, the revised pumpable liquid estimates are based on better characterization and pumping information with less uncertainty and a lower average compared to previous estimates. The revised pumpable liquids also appear to correlate better with characterization and pumping data. However, with the data currently available, there is still a large amount of uncertainty in estimating the pumpable liquid volume in a tank. Actual pumping durations will vary depending on the permeability of saltcake and sludge, supernatant volumes, pumping rates and pumping efficiencies achieved.

Table B-1. Estimated Pumpable Liquid Volumes and Durations on June 1, 1998. (2 sheets)

Tank No.	Supernate volume (gal)[1]	Saltcake volume (gal)[1]	Sludge volume (gal)[1]	Liquid level height (LOW, in.)	Sludge liquid (gal)	Saltcake liquid (gal)	Supernate (gal)	Total pumpable liquid (gal)	Pumping duration at 100% efficiency (days)
241-A-101	508,000	380,000	3,000	-	-	79,000	508,000	587,000	429
241-AX-101	386,000	295,000	3,000	-	-	58,000	386,000	444,000	323
241-BY-105	0	455,000	48,000	-	-	111,000	-	111,000	171
241-BY-106	0	478,000	84,000	-	-	119,000	-	119,000	184
241-C-103	79,000	0	119,000	-	4,000	-	79,000	83,000	57
241-S-101	12,000	204,000	211,000	-	17,000	51,000	12,000	80,000	125
241-S-102	0	444,000	105,000	-	1,000	111,000	-	112,000	174
241-S-103	17,000	222,000	9,000	-	-	35,000	17,000	52,000	64
241-S-106	53,000	426,000	0	-	-	76,000	53,000	129,000	149
241-S-107	14,000	69,000	293,000	-	30,000	17,000	14,000	61,000	104
241-S-109	0	494,000	13,000	139.00	-	83,000	-	83,000	128
241-S-111	111,000	244,000	117,000	-	3,000	61,000	111,000	175,000	168
241-S-112	0	517,000	6,000	119.80	-	70,000	-	70,000	108
241-SX-101	0	448,000	0	-	-	99,000	-	99,000	153
241-SX-102	134,000	380,000	0	-	-	82,000	134,000	216,000	207
241-SX-103	0	519,000	115,000	-	2,000	130,000	-	132,000	205
241-SX-104	0	448,000	136,000	215.20	10,000	134,000	-	144,000	230
241-SX-105	0	572,000	65,000	-	-	141,000	-	141,000	218

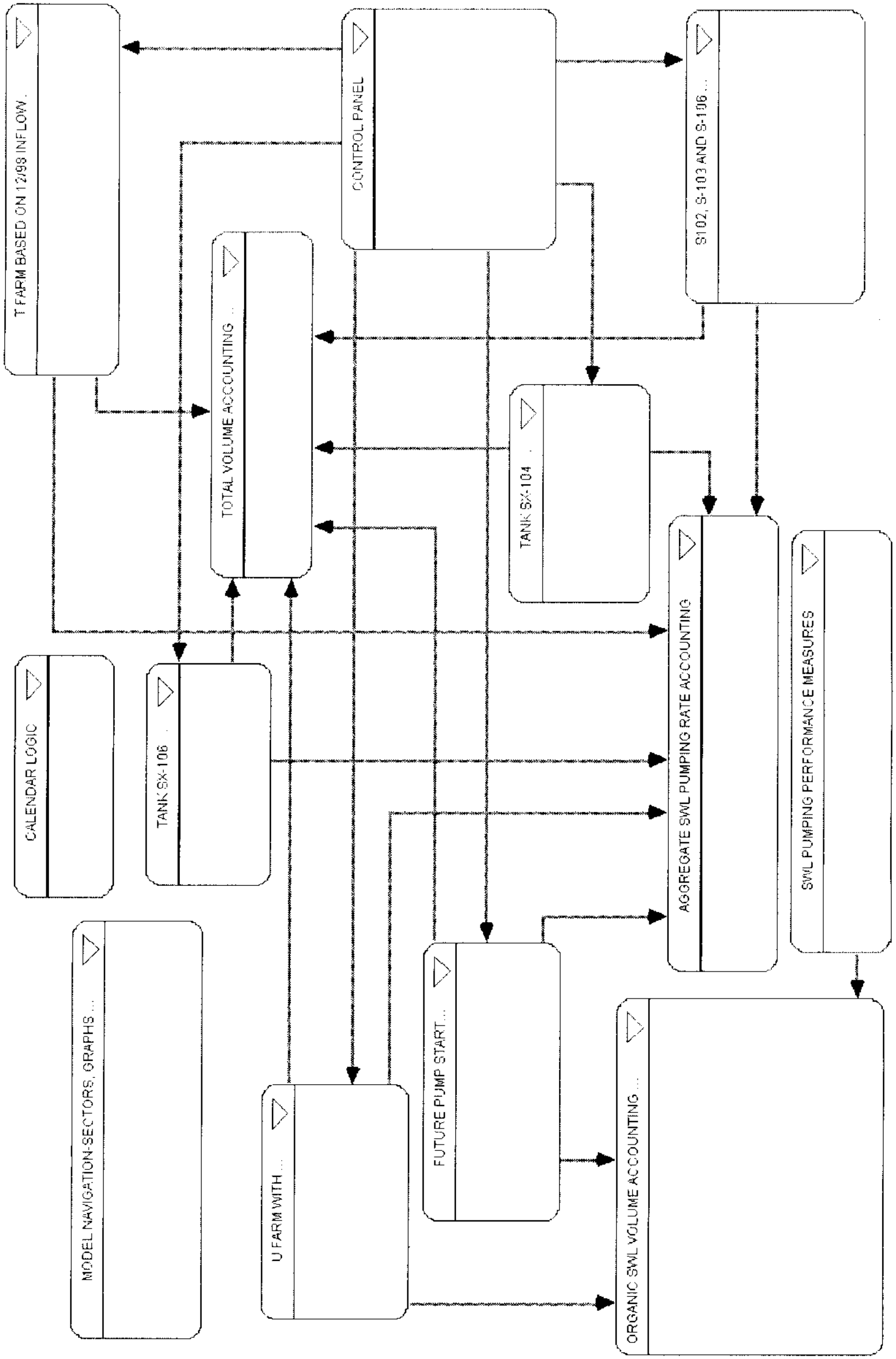
Table B-1. Estimated Pumpable Liquid Volumes and Durations on June 1, 1998. (2 sheets)

Tank No.	Supernate volume (gal)[1]	Saltcake volume (gal)[1]	Sludge volume (gal)[1]	Liquid level height (LOW, in.)	Sludge liquid (gal)	Saltcake liquid (gal)	Supernate (gal)	Total pumpable liquid (gal)	Pumping duration at 100% efficiency (days)
241-SX-106	215,000	323,000	0	-	-	68,000	215,000	283,000	235
241-T-104	0	0	343,000	-	37,000	-	-	37,000	86
241-T-110	0	0	369,000	-	41,000	-	-	41,000	95
241-U-102	18,000	314,000	43,000	-	-	75,000	18,000	93,000	127
241-U-103	13,000	443,000	12,000	-	-	102,000	13,000	115,000	165
241-U-105	37,000	349,000	32,000	-	-	83,000	37,000	120,000	150
241-U-106	15,000	211,000	0	-	-	41,000	15,000	56,000	72
241-U-107	33,000	360,000	15,000	-	-	82,000	33,000	115,000	146
241-U-108	24,000	415,000	29,000	-	-	100,000	24,000	124,000	169
241-U-109	19,000	411,000	35,000	-	-	99,000	19,000	118,000	164
241-U-111	0	303,000	26,000	-	-	71,000	-	71,000	110
TOTALS	1,688,000	9,724,000	2,231,000		145,000	2,178,000	1,688,000	4,011,000	4716

[1] Tank Waste Volumes as of June 1, 1999, see Appendix B.

Source:
Field, J.G., Updated Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks, HNF-2978 Rev. 1, Dated September 1999.

APPENDIX C MODULE INTERFACE MAP



MOD ULE INTERFACE MAP