The Hanford Waste Feed Delivery Operations Research Model - 11248

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ASTRACT

Washington River Protection Solutions (WRPS), the Hanford tank farm contractor, is tasked with the long term planning of the cleanup mission. Cleanup plans do not explicitly reflect the mission effects associated with tank farm operating equipment failures. EnergySolutions, a subcontractor to WRPS has developed, in conjunction with WRPS tank farms staff, an Operations Research (OR) model to assess and identify areas to improve the performance of the Waste Feed Delivery Systems. This paper provides an example of how OR modeling can be used to help identify and mitigate operational risks at the Hanford tank farms.

INTRODUCTION

The U.S. Department of Energy, Office of River Protection manages the River Protection Project. The River Protection Project mission is to retrieve and treat the Hanford Site's tank waste and close the tank farms to protect the Columbia River. The tank contents include waste from World War II and Cold War era nuclear weapons production, and account for 60 percent by volume of the nation's high level radioactive waste. These aging and leak prone single-shell tanks are just a few miles from the Columbia River and within a 50-mile radius of more than 200,000 residents.

Washington River Protection Solutions is the U.S. Department of Energy, Office of River Protection's prime contractor responsible for safely retrieving approximately 57 million gallons of highly radioactive and hazardous waste stored in 177 underground tanks. The waste is stored in 149 older single-shell tanks and 28 newer double-shell tanks that are grouped in 18 farms on the 560-square mile Hanford site. The Office of River Protection cleanup mission is to retrieve waste from single-shell tanks, stage the waste in the double-shell tanks, and transport the waste to the Waste Treatment and Immobilization Plant (WTP). At the WTP it will be vitrified for safe long term storage.

Waste transfers to the WTP will utilize a complex network of equipment that comprises the tank farms. Besides the 149 SSTs and 28 double-shell tanks, this network is composed of an evaporator, pumps, valves, leak detectors and other instruments, and thousands of feet of underground piping. This equipment is used infrequently, hard to access, and extremely difficult to maintain. Over the next several years the tank farms must be prepared to safely and reliably transfer waste to the WTP. The tank farms mission is expected to be complete within the next 40 years. Successful completion of the Office of River Protection cleanup mission is dependent on identifying key risk areas and the necessary equipment upgrades that are required to support WTP operations.

This paper discusses ways that WRPS and Energy*Solutions* are using OR modeling as a tool to predict the performance of this process before actual waste transfers commence. Modeling is providing an invaluable insight into predicted operations of the tank farms, taking into account the resources, equipment, complex interactions, constraints and random variability that will likely be experienced during actual operations. This paper also discusses ways that modeling can be used as a tool to accurately forecast key performance characteristics associated with the tank farms including Total Operating Efficiency (TOE); mission timescales; overall equipment utilization, identification of key bottlenecks and the necessary upgrades to successfully complete the mission.

OPERATIONS RESEARCH MODEL APPROACH

Strategic planning at the Hanford Site is a complex and iterative process. The Hanford Tank Waste Operations Simulator (HTWOS), a dynamic flowsheet simulation and mass balance computer model, is used to simulate the current planned River Protection Project mission, evaluate the impacts of changes to the mission, and assist in planning near term facility operations. Development of additional modeling tools, including a Waste Feed Delivery OR Model will help to mitigate operational risks and further improve long term planning confidence.

The Waste Feed Delivery OR Model is currently being developed using the WITNESS™[1] simulation software, a discrete event simulation tool that is used by thousands of organizations in virtually every industry to achieve process performance excellence. Discrete event simulation works through modeling individual events that occur at given time intervals, taking into account resources, equipment, constraints and interactions. Discrete event models also include the randomness and variability that occurs in real life, and behave like real life processes such as production lines, airport baggage handling systems, etc.

The Waste Feed Delivery OR Model interfaces with HTWOS output via an Excel spreadsheet. HTWOS incorporates a simplified assumption that the WTP will achieve 70% TOE. The Waste Feed Delivery OR model develops a more realistic prediction of operating efficiency by incorporating the reliability, availability, maintainability and inspectability of more than 525 individual tank farm components including mixer pumps, transfer pumps, valves, jumpers, leak detection instruments. The HTWOS system plan outputs results from the Reliability Availability Maintainability (RAM) analyses including Mean Time Between Failures, Mean Time To Repair, and other operational losses are inputs into the Waste Feed Delivery OR model. The resulting OR model, when fully developed, will simulate the impacts of the reliability and maintenance of each item of equipment on mission timescales. It will help identify reliability-related cost and schedule drivers and find ways to mitigate them. This unique approach will ensure improvements are focused, equipment and resources are managed early, operations and maintenance costs are reduced, throughput and performance are improved and mission length is assured.

HANFORD TANK FARMS

The Hanford tank farms are comprised of a complex network of inter-dependent waste storage, retrieval, treatment and disposal facilities in varying stages of design, construction, operations

[1] WITNESS™ is a trademark of the Lanner Group Limited Corporation, Redditch, Worcestershire, UK

and future planning. The major processes include waste storage, retrieval, treatment and disposal.

Waste Storage

The Hanford tank farms include 177 underground tanks in two basic designs: single-shell tanks and double-shell tanks. There are 149 single-shell tanks, each having a storage capacity between 55,000 and one million gallons. There are 28 double-shell tanks, each having a storage capacity between one and 1.25 million gallons. The double-shell tanks play three critical roles in the tank farms: they receive and store the waste retrieved from the single-shell tanks; they stage waste for subsequent delivery to the WTP; and they support evaporator operations to minimize the total volume of waste that needs to be stored.

All 177 waste storage tanks were built underground and are clustered in 18 groups or "farms" with two to18 tanks per farm, spread across several square miles. Waste transfers between tanks and related facilities occur via installed double-encased underground transfer lines, or temporary high integrity hose-in-hose above ground transfer lines. The vast majority of tank waste resides in the single-shell and double-shell tanks. However, a small amount of waste is also stored in Inactive Miscellaneous Storage Tanks or other site facilities.

The total Hanford tank waste inventory is approximately 57 million gallons, containing an estimated 177 million curies of radionuclides.

Waste Retrieval

Retrieval of wastes from the single-shell tanks has already commenced. A variety of waste retrieval techniques have been employed. The method used for retrieval depends on the nature of the waste, tank integrity, tank design and various other factors. The modified sluicing method is performed with double-shell tank supernatant and used to retrieve large quantities of sludge from the single-shell tanks. The modified sluicing with water method is used to dissolve saltcake in the single-shell tanks. Vacuum retrieval relies on a multi degree-of-freedom mast and manipulator arm inserted through the tank’s central riser, capable deploying a vacuum wand throughout a large volume envelope within the tank. A mobile retrieval system combines a vacuum retrieval system with an in-tank, tracked, remotely operated vehicle to push or sluice waste toward the vacuum inlet.

Waste Treatment

The waste retrieved from the single-shell tanks is stored in the double-shell tanks where it is consolidated into feed batches for the WTP. The double-shell tanks will be used to transfer waste directly to the WTP Pretreatment Facility, where the waste is processed into two streams; high-level waste and low activity waste. The high-level waste contains most of the radionuclides and will be vitrified into a glass waste form and poured into stainless steel containers to be stored temporarily on-site, pending a final decision on disposal at an off-site repository. The low activity waste, which contains fewer radionuclides will also be vitrified into a glass waste form in a separate facility and subsequently disposed at a permitted facility on the Hanford Site. WTP is under construction and is expected to begin hot operations in 2019.

A supplemental low activity waste treatment facility is planned as part of the baseline to provide the additional low activity waste treatment capacity beyond that available at the WTP low activity waste facility.

The treatment of tank wastes will generate secondary liquid waste streams that will be collected and treated at the Liquid Effluent Retention Facility and the Effluent Treatment Facility. The Liquid Effluent Retention Facility is designed to store evaporator process condensate and other dilute liquid waste for subsequent treatment at the Effluent Treatment Facility. The Effluent Treatment Facility collects, treats and stores liquid low level mixed wastes and disposes treated wastes meeting applicable state and federal permit requirements.

WASTE FEED DELIVERY OPERATIONS RESEARCH MODEL

The Waste Feed Delivery OR Model is being developed for potential application as a strategic planning tool that simulates the integrated Office of River Protection tank closure systems. The model will provide insight into actual performance characteristics associated with the Tank Farm operations including TOE, overall equipment utilization and downtime, to enable key decision makers to identify and mitigate reliability related cost and schedule drivers.

The Waste Feed Delivery OR Model has been developed using a phased approach. Each phase incorporates additional scope and offers an opportunity to update and upgrade the model (Fig. 1). The Waste Feed Delivery OR Model simulates the movement of liquid and solid materials through the various tanks in the tank farms to the WTP via a complex network of transfer lines and equipment. The current model simulates waste transfers from the single-shell tanks to waste retrieval facilities and double-shell tanks, waste transfers from double-shell tank to double-shell tank, evaporator campaigns and transfers to the WTP. The current model is being modified to incorporate the WTP with the Waste Feed Delivery system in an integrated OR model. Future enhancements under consideration include Supplemental Treatment and immobilized low activity waste and immobilized high-level waste Canister Storage Facilities. A screen shot of the WITNESS™ simulation model showing an overview of the Waste Feed Delivery OR Model is provided in Fig. 2.

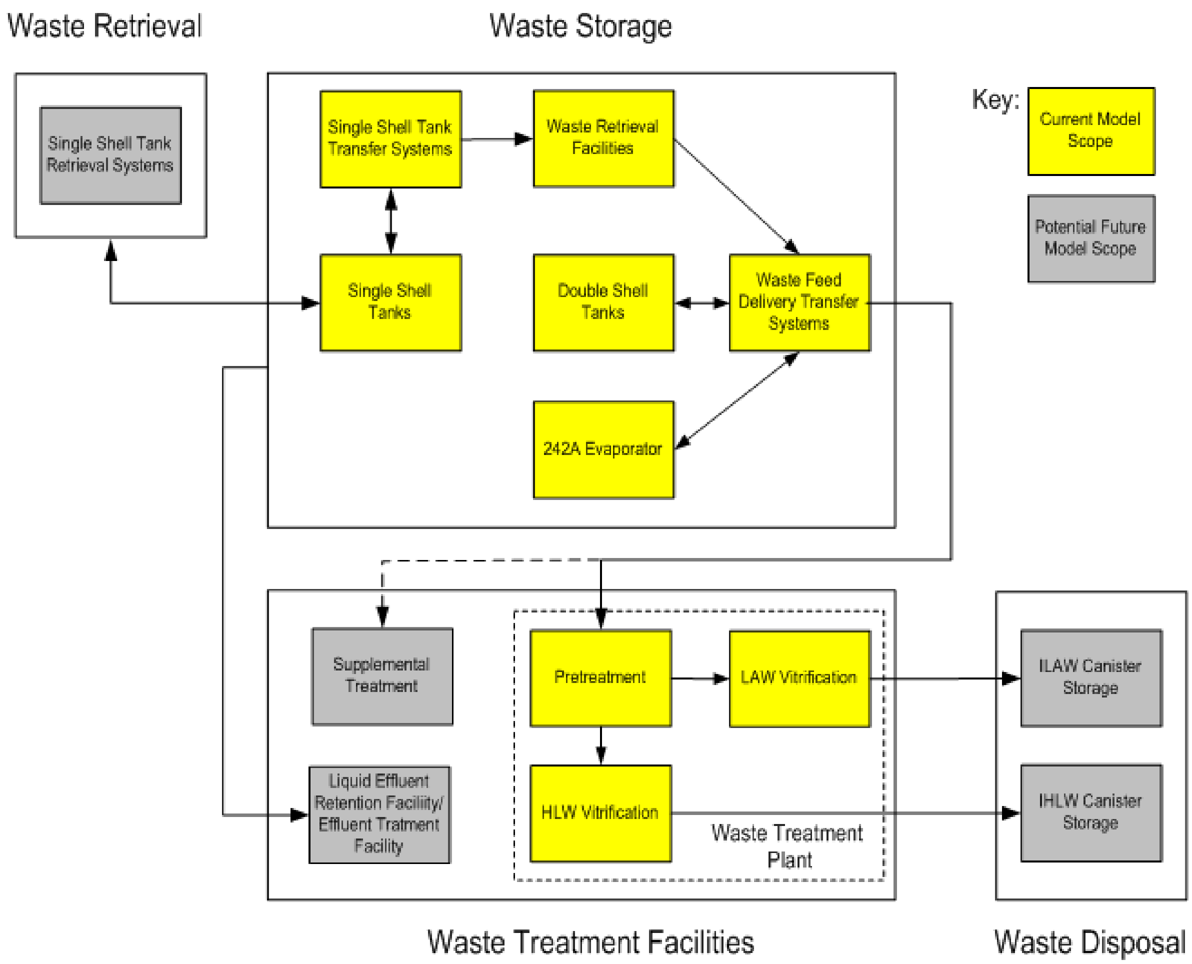

Figure 1. Waste Feed Delivery Operations Research Model Scope

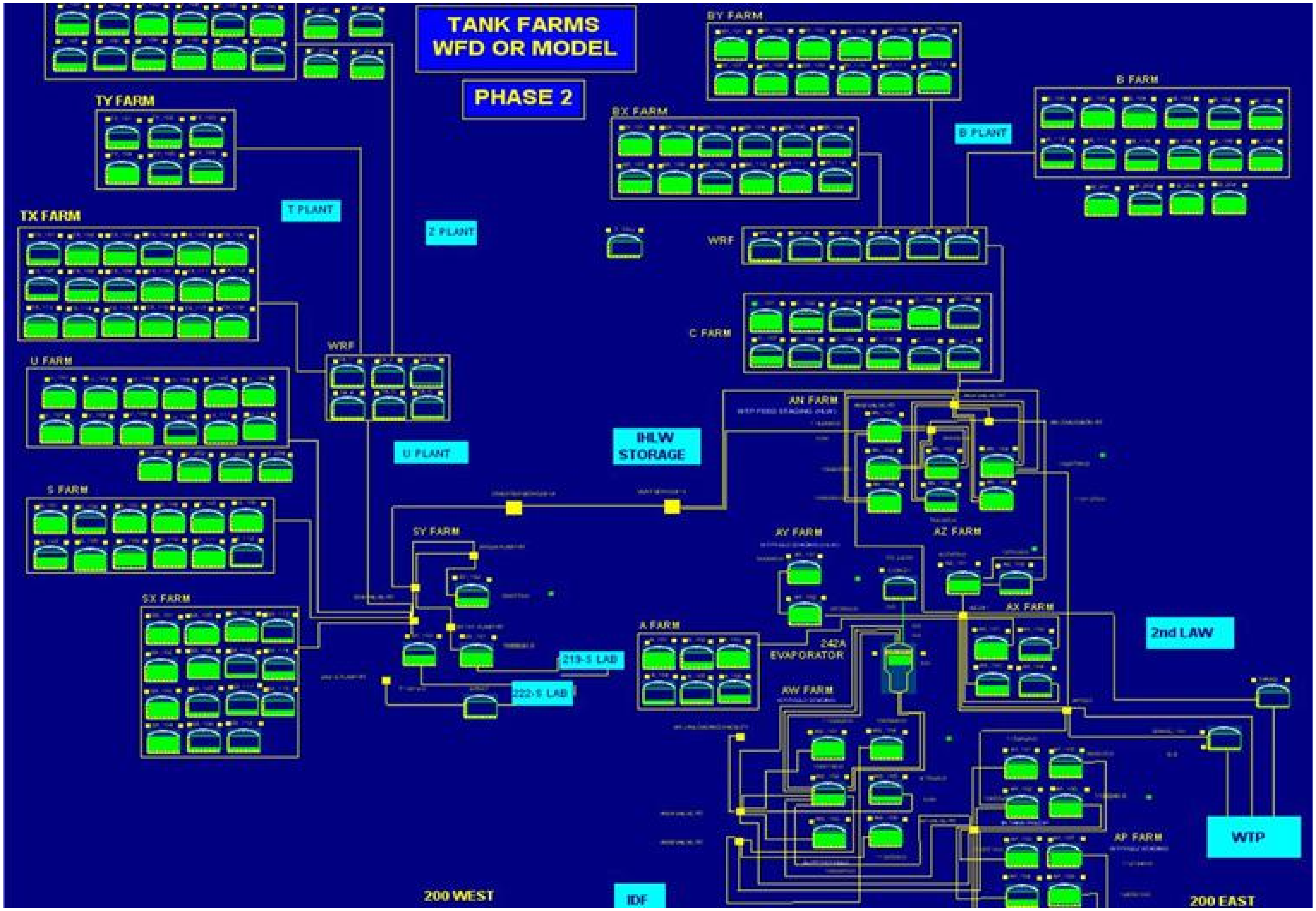

Figure 2. Hanford Waste Feed Delivery Operations Research Model

Model Inputs And Outputs

The Waste Feed Delivery OR Model uses an Excel interface to enter input parameters and display model outputs. The model is very detailed in that it includes more than 177 tanks, more than 525 individual components including mixer pumps, transfer pumps, valves, jumpers, leak detection instruments and more than 300 possible transfer routes with up to eight alternative transfer routes for each individual transfer and more than 20,000 input variables. Example input parameters include waste transfer sequences, transfer route equipment, tank start volumes, volumetric flow rates and equipment RAM data (e.g. Mean Time Between Failures and Mean Time To Repair values).

The Waste Feed Delivery OR Model simulates the waste transfers in the tank farms until all single-shell tanks and double-shell tanks have been emptied and all transfers have been made from the tank farms to the WTP. During and at the end of the model run, the model outputs are recorded in an Excel spreadsheet. Example outputs include waste transfer sequences, equipment utilization and downtime statistics to identify key bottleneck areas. Fig. 4 provides a summary of the Waste Feed Delivery OR Model input and output data.

Model Inputs

The tank farms OR model inputs include single-shell tank and double-shell tank equipment configurations, waste transfer sequences, tank start volumes, transfer route data and equipment RAM data.

The Waste Feed Delivery OR Model interfaces with the HTWOS model output via an Excel spreadsheet. There are more than 4,000 transfers in the HTWOS model output file, which identifies sending and receiving tanks, the volume of material transferred, and the date when the transfer occurred. The transfer list includes waste movement, chemical additions to tanks, and flushing of transfer lines following a waste transfer.

The Excel spreadsheet was modified to include tank inventories, transfer flow rates and sample turnaround times. An additional spreadsheet was developed that incorporates waste transfer routes and identifies the items of equipment that will be required for each transfer. DST transfer routes were developed for each unique double-shell tank to double-shell tank, double-shell tank to evaporator, and double-shell tank to WTP transfer that occurs in the Waste Feed Delivery OR Model. The model assumes that other equipment, e.g. single-shell tank and associated transfer equipment, will function as and when required. More than 300 unique transfer routes derived from the Hanford tank farms routing diagrams have been incorporated into the model.

An OR model must be populated with good equipment reliability and maintenance data in order to realistically evaluate the impact of equipment breakdowns on actual throughput and mission timescales. Equipment reliability and maintenance data was gathered to the extent possible from previous operating experience at Hanford, the Savannah River Site, and published generic data bases.

Essentially, all items of equipment that could potentially stop, pause, or delay a waste transfer within the tank farms, excluding the single-shell tanks and associated transfer system equipment, was included in the model. Equipment reliability data was included for more than 525 individual components including mixer pumps, transfer pumps, valves, jumpers, leak detection instruments, and other equipment associated with the 28 double-shell tanks and Hanford's 242-A Evaporator.

Most operations are subject to a degree of uncertainty. For example, the length of time a transfer pump will run without breaking down and the time it takes to get it running again vary between different transfer pumps and different maintenance personnel, or between the same transfer pump on one shift and another. In many instances, the influence of this variability is a significant aspect of the operation being investigated, and therefore can have a major impact on the validity of the model. The tank farms equipment failures were modeled using a random sample from a distribution.

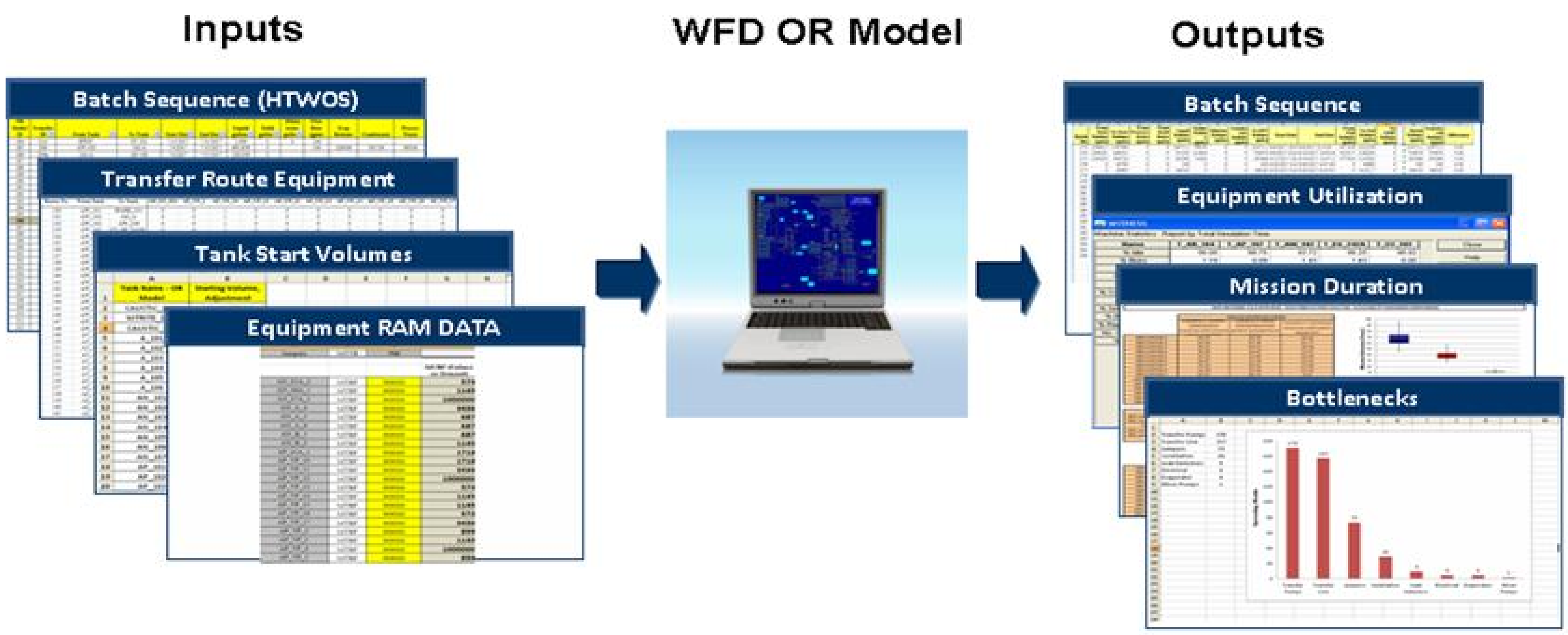

Figure 3. Waste Feed Delivery Operations Research Model Inputs and Outputs

Model Outputs

Validation and verification activities were performed after model development to ensure that the Waste Feed Delivery OR Model met the intended requirements and produced results within an acceptable range.

The Waste Feed Delivery OR Model results from the model run with no equipment RAM activated were checked against the HTWOS model output file that comprised the sequence of waste transfers over the mission. The model correctly simulated the sequence of the waste transfers identified in the HTWOS output file and then produced a similar mission duration estimates to those predicted by the HTWOS model. The model results from the model run with equipment RAM activated were checked by making a comparison between the actual equipment downtime percentages from the model and hand-calculated equipment downtime percentages. By comparing the two, the model could be validated using downtimes reflective of those we would expect to see in the tank farms, thereby validating the model and providing confidence that results from this model will be comparable to actual system performance.

Several “what if’ scenarios were performed using the model to assess the impacts of RAM on Tank Farms performance and overall mission timescales. Each scenario was based on different maintenance strategy that could be implemented in the Tank Farms.

For each scenario, a bottleneck analysis (Fig. 5) was performed to identify which items of equipment had a high utilization and which items of equipment were the least reliable and had a significant impact on the mission. Initial results showed that the reliability of transfer lines, transfer pumps and jumpers had the biggest impact on the mission. These results will feed into the planning for future tank farm maintenance strategies and underpin critical spare parts lists.

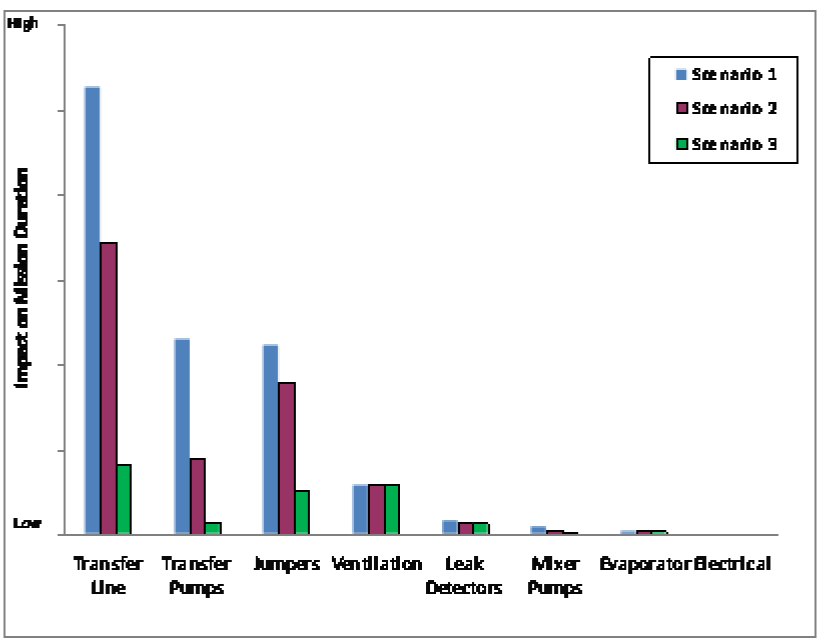

Figure 5. Bottleneck Analysis

CONCLUSIONS

It is never too early in a project to develop OR models, and the effort required and return on investment should not be underestimated. Early model development identifies constraints on throughput, performance and operability at a time when the issues are easily resolved and the cost impact is less.

Development of additional modeling tools such as the Waste Feed Delivery OR Model will help mitigate operational risks and further improve long term planning confidence. The HTWOS system plan outputs together with the results from the Waste Feed Delivery OR Model will enable key decision makers to identify and mitigate reliability-related cost and schedule drivers. This knowledge will prepare the tank farms for safe and efficient operations, provide early equipment and resource management, reduce operations and maintenance costs and provide throughput and mission timescale assurance.

Results from the OR model will be used in conjunction with other studies to help identify possible areas for improvement in current tank farm maintenance strategies that could increase tank farms throughput and reduce mission timescales. Examples of future improvements that may be considered include: installation of redundant items of equipment (e.g. transfer pumps); identification of critical spare parts; required on-site maintenance capabilities; shift scheduling; and craft and labor availability.

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