Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Design Hazard and Operability Study

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

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LIST OF TERMS

ASME	American Society of Mechanical Engineers
CHPRC	CH2M HILL Plateau Remediation Company
DOE-RL	U.S. Department of Energy Richland Operations Office
ECRTS	Engineered Container Retrieval and Transfer System
HAZOP	Hazard and Operability
HEPA	High Efficiency Particulate Air (filter)
IXM	Ion exchange module
KE	105-K East (Basin)
KW	105-K West (Basin)
P&ID	Piping and Instrument Diagram
STP	Sludge Treatment Project
STS	Sludge Transport System
STSC	sludge transport and storage container

1.0 INTRODUCTION

1.1 PURPOSE

This Hazard and Operability (HAZOP) study addresses the Sludge Treatment Project (STP) Engineered Container Retrieval and Transfer System (ECRTS) preliminary design for retrieving sludge from underwater engineered containers located in the 105-K West (KW) Basin, transferring the sludge as a sludge-water slurry (hereafter referred to as "slurry") to a Sludge Transport and Storage Container (STSC) located in a Modified KW Basin Annex, and preparing the STSC for transport to T Plant using the Sludge Transport System (STS).

1.2 BACKGROUND

There are six, underwater engineered containers located in the KW Basin that, at the time of sludge retrieval, will contain an estimated volume of 5.2 m³ of KW Basin floor and pit sludge, 18.4 m³ of 105-K East (KE) Basin floor, pit, and canister sludge, and 3.5 m³ of settler tank sludge. The KE and KW Basin sludge consists of fuel corrosion products (including metallic uranium, and fission and activation products), small fuel fragments, iron and aluminum oxide, sand, dirt, operational debris, and biological debris. The settler tank sludge consists of sludge generated by the washing of KE and KW Basin fuel in the Primary Clean Machine. A detailed description of the origin of sludge and its chemical and physical characteristics can be found in HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance*.

In summary, the ECRTS retrieves sludge from the engineered containers and hydraulically transfers it as a slurry into an STSC positioned within a trailer-mounted STS cask located in a Modified KW Basin Annex. The slurry is allowed to settle within the STSC to concentrate the solids and clarify the supernate. After a prescribed settling period the supernate is decanted. The decanted supernate is filtered through a sand filter and returned to the basin. Subsequent batches of slurry are added to the STSC, settled, and excess supernate removed until the prescribed quantity of sludge is collected. The sand filter is then backwashed into the STSC. The STSC and STS cask are then inerted and transported to T Plant.

The ECRTS conceptual design has been completed and is documented in PRC-STP-00166, *CD-1 Report for the Sludge Treatment Project Engineered Container Retrieval and Transfer System*. Hazard analyses, accident analyses, and control decisions were performed in support of the ECRTS conceptual design culminating in the issuance of PRC-STP-00156, *Sludge Treatment Project Engineered Container Retrieval and Transfer System Conceptual Safety Design Report*. Following U.S. Department of Energy, Richland Operations Office (DOE-RL) approval of the conceptual design, work began on the ECRTS preliminary design. As documented in PRC-STP-00346, *Sludge Treatment Project Engineered Container Retrieval and Transfer System Draft Preliminary Design Hazard and Operability Study*, and PRC-STP-00382, *Sludge Treatment Project Engineered Container Retrieval and Transfer System Draft Preliminary Design Hazard Analysis Supplement 1*, hazard analyses of an early draft of the preliminary

design were performed in order to provide early integration of safety into the preliminary design process.

In accordance with the guidance in DOE-STD-1189-2008, *Integration of Safety into the Design Process*, this HAZOP study confirms and adds details to the conceptual design hazard analyses and the draft preliminary design HAZOP study.

1.3 SCOPE

This HAZOP study addresses the following process steps:

1. Retrieving sludge from an Engineered Container
2. Transferring the slurry to an STSC
3. Decanting the STSC
4. Backwashing the Sand Filter into the STSC
5. Purging the STSC with nitrogen
6. Purging the STS cask with nitrogen
7. Pressurizing the STS cask with nitrogen
8. Adding flocculant to the slurry during transfer
9. Adding flocculant to the supernate
10. Automatically flushing the transfer line
11. Recovering excess sludge from an over-filled STSC.

This HAZOP does not address the transportation of STSCs to T Plant. Transportation safety will be addressed by the submittal of a Shipment Evaluation Checklist in accordance with the requirements of DOE/RL-2001-36, *Hanford Sitewide Transportation Document*.

This HAZOP study does not address construction and equipment installation activities at the KW Basin. Hazards associated with such activities will be addressed by the Occupational Safety and Health Program (e.g., automated job hazard analysis). Construction and equipment installation activities will also be subject to the Unreviewed Safety Question process relative to their potential for impacts to existing 100 K Area nuclear facilities.

2.0 FACILITY AND PROCESS DESCRIPTION SUMMARY

The facility and process description summaries provided below are supported by process flow diagrams and piping and engineering diagrams (P&IDs) provided in Appendix A and the information contained in HNF-41051.

2.1 FACILITY DESCRIPTION SUMMARY

Engineered container retrieval and transfer operations will be conducted in the existing KW Basin and at a new Modified KW Basin Annex. Material transfers between the KW Basin and the Modified KW Basin Annex will be performed using hose-in-hose transfer lines located within an above-ground shielded hose chase running between the two structures.

2.1.1 Sludge Transportation and Storage Containers

Engineered container retrieval and transfer operations will use two different STSC designs, one for settler tank sludge and one for KW and KE Basin containerized sludge. The two designs are the same except that the STSC for settler tank sludge contains an inner cylinder as described below.

An STSC used for settler tank sludge is an ASME Section VIII pressure vessel rated at 150 psi. It is approximately 10 ft tall and 5 ft in diameter with elliptical heads top and bottom, and contains a centrally located inner cylinder. The STSC shell and bottom elliptical head are constructed of ½-in. thick stainless steel, and the top elliptical head is constructed of ¾-in. thick stainless steel. The inner cylinder is constructed of ¼-in thick stainless steel and is approximately 24 in. in diameter. The top of the inner cylinder is welded to a flange that bolts to the STSC 26-in. diameter nozzle. The bottom of the cylinder, which is closed by an elliptical head, extends to near the bottom of the STSC.

There are eight holes in the inner cylinder. Four are located at the top where the cylinder is welded to the flange. Another four are located approximately ½-in. above the tangent line of the top elliptical head, which is approximately 17 in. below the flange. The holes are 4 in. diameter and are equally spaced around the diameter of the cylinder. The annular region created by the inner cylinder contains sludge whereas the inside of the cylinder contains water which provides a heat transfer mechanism for heat generated by radiolytic decay and by the reaction of uranium metal with water. The design capacity of an STSC for settler tank sludge is approximately 2.89 m³ when filled to a level 1.5 in. below the tangent line of the top elliptical head.

As previously stated, an STSC used for KE and KW containerized sludge is the same design as that used for settler tank sludge except there is no inner cylinder. The design capacity of an STSC for KE and KW containerized sludge is approximately 3.5 m³ when filled to a level 1.5 in. below the tangent line of the top elliptical head.

Both STSC designs are provided with a skirt around the bottom elliptical head. The skirt is provided with an index notch that is located and sized such that an STSC can be properly placed in an STS cask in only one orientation. The tops of both STSC designs are provided with nozzles for process connections.

The decant pump suction nozzle is connected to a floating decant suction head located inside the STSC. The overflow recovery nozzle is connected to an overflow recovery tool which is permanently installed inside the STSC. In addition to the nozzles, two lifting fixtures are located on the top of the STSC with a safe working load of 20,000 lbs.

Another design feature of the STSCs is an internal sloped fin that extends from the top tangent line to the bottom of the STSC at a slope of 5 degrees. The function of this fin is to provide an obstruction that will collapse a rising plug of sludge, should such a plug occur due to the formation of a vessel spanning bubble during storage for an extended period of time. A vessel spanning bubble can occur when the shear strength of the sludge is sufficiently high to hinder the release of gases generated in the sludge. As documented in PNNL-19345, *The Disruption of Vessel-Spanning Bubbles with Sloped Fins in Flat-Bottom and 2:1 Elliptical-Bottom Vessels*, tests using sludge surrogates in a cylindrical container demonstrate the a sloped fin inside the STSC provides sufficient obstruction to cause sludge plug failure.

2.1.2 105-K West Basin

Fuel Storage Basin. The 105-KW fuel storage basin is a below-ground, reinforced-concrete rectangular pool approximately 125 ft x 67 ft. The walls of the basin are 20 ft-9 in. high, with a nominal operating water depth of 15 ft-10 in. to 16 ft-10 in. at 105-KW Basin. The basin floor is a 2-ft thick (nominal) reinforced-concrete mat. Reinforcing steel connects the basin mat to the walls. An operating deck of steel grating is suspended over the basin. The operating deck is at ground elevation.

The basin is covered by a one-story steel superstructure. The exterior walls are steel-framed with corrugated asbestos cement panels. The superstructure consists of roof trusses and purlins that transfer loads to structural support columns. The roof structure supports the floor grating, flexible transfer crane, and a series of monorails over the basins. The 105-KW fuel storage basin has a structural cantilevered roof with metal-seamed panels located above and extending 10 ft north of the original basin roof.

Engineered Containers. There are six Engineered Containers (SCS-CON-210 through -260) that rest on the floor of the KW Basin. The containers are rigid, self-supporting, free-standing structures of bolted stainless steel construction. The dimensions of the containers are approximately 13-ft high by 5-ft wide by 11 ft 10 in. long. The containers are further described in HNF-SD-WM-SAR-062, *KW Basin Final Safety Analysis Report*, Section 2.5.10, "105-KW Sludge Containerization System."

Engineered Containers SCS-CON-210 and -220 contain KW Basin floor and pit sludge. Engineered Container SCS-CON-230 contains sludge retrieved from the settler tanks.

Engineered Containers SCS-CON-240, -250, and -260 contain KE Basin floor, pit, and canister sludge. Table 2-1 provides the average depth and volume of sludge in the containers.

Table 2-1. Estimated Sludge Volumes and Depth in Engineered Containers.*

	KW Originating		Settler Tank Sludge	KE Originating		
	SCS-CON-210	SCS-CON-220		SCS-CON-240	SCS-CON-250	SCS-CON-260
Average Sludge Depth	3.6 ft	1.8 ft	3.25 ft	2.7 ft	5.7 ft	6.0 ft
Sludge Volume	4.22 m ³	1.0 m ³	3.5 m ³	2.6 m ³	7.7 m ³	8.1 m ³

*From Table 2-1, HNF-41051, 2009, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance*, Rev. 7, CH2M HILL Plateau Remediation Company, Richland, Washington.

KE = 105-K East.

KW = 105-K West.

Sludge Retrieval. Sludge will be retrieved from the Engineered Containers by use of a hydrolance, which is a proprietary sludge retrieval device manufactured by Xago Nuclear Ltd. The Xago HydroLance™¹ has three principal components: a Coanda fluidizer head, high pressure fluidizing jets, and an eductor. The Coanda head provides local fluidization of the sludge to allow insertion of the HydroLance into the sludge bed. The fluidizing jets, mounted at the end of the hydrolance, function to periodically mobilize the sludge bed within the Engineered Container to facilitate efficient sludge retrieval. The eductor provides the motive force to transfer the sludge-water slurry out of the container to an in-line booster pump.

The Xago HydroLance™ operates using Ion Exchange Module (IXM) water supplied from either the Basin Water Recirculation and Cooling System or the Skimmer Water Cleanup System. These systems are described in HNF-SD-WM-SAR-062, Section 2.5.7, "Basin Water System." A fluidizing pump (STP-P-52) provides IXM water at approximately 42 gpm and 385 psi to the fluidizing jets. A motive flow pump (STP-P-51) provides IXM water at approximately 32 gpm and 175 psi to the eductor, and approximately 9 gpm to the Coanda head.

The hydrolance transfers approximately 70 gpm of retrieved slurry at a nominal solids content of 5 vol% through an underwater hose to a skid-mounted, underwater booster pump (ECRT-P-101). To minimize plugging, the hose is 1.5 in. in diameter, which is six times the diameter of the largest sludge particles. At a flow rate of 70 gpm, the velocity in the hose is 12.7 ft/s, which is greater than the critical velocity of 12.3 ft/s required to avoid settling of solids in the transfer

¹ Xago Hydrolance™ is a registered trademark of NuVision Engineering

line, as calculated in PRC-STP-00021, *Preliminary Hydraulic Analysis for Direct Loading of Sludge Transport and Storage Containers*.

The booster pump is required to overcome pressure loss in the approximately 235 ft of transfer hose and piping and the approximately 35-ft elevation gain from the basin floor to the transfer line service box in the Modified KW Basin Annex. The booster pump is a skid-mounted, industrial hose pump (similar in design to a peristaltic pump) located on the basin floor. The pump provides the motive force to pump slurry to the STSC at approximately 70 gpm and 100 psi. Pressure relief is provided by two downstream rupture disks. The slurry is transferred by an underwater hose to the ingress/egress pipe. The ingress/egress pipe provides the transition from the underwater transfer line to the above water transfer line. A second ingress/egress pipe provides the transition point for the transfer of filtered STSC supernate from the Modified KW Basin Annex to the basin.

A 50-gallon flush tank (ECRT-T-101) is located on the basin deck. This tank is used to automatically flush the slurry transfer line downstream of the booster pump given a loss of power or activation of the Nuclear Safety Shutdown interlock sequence (I-1) which de-energizes the booster pump. The tank, pressurized with air, is connected to a normally closed valve which is connected by a hose to a nozzle on the discharge side of the booster pump.

2.1.3 Inter-Facility Transfer Lines

There are four transfer lines between the KW Basin and the Modified KW Basin Annex housed within a shielded hose chase. A slurry transfer line (and an associated spare) is used to transfer slurry from the KW Basin to the Modified KW Basin Annex; a decant line is used to transfer filtered STSC supernate from the Modified KW Basin Annex sand filter vault to the KW Basin; and an IXM water line is used to transfer IXM water to the Modified KW Basin Annex. The slurry transfer line can also be used to transfer slurry from the STSC back to an engineered container in the KW Basin in the event of an STSC overflow.

The slurry transfer lines and decant line are of hose-in-hose construction with associated leak detection. The hoses are made of ethylene-propylene-diene monomer material. The lines are housed within a covered, concrete trench that provides shielding to reduce the dose rate to facility workers. The inner hose is 1.5 in. in diameter, and the outer hose is 4 in. in diameter. The IXM water line is a single hose. Heat trace is provided for freeze protection.

At the KW Basin, the slurry transfer line and decant line connect to the two ingress/egress pipes where they penetrate the KW Basin building wall. At the Modified KW Basin Annex, the slurry transfer line and decant line transition from an exterior shielded hose chase to an interior shielded hose chase.

The annular space of the slurry transfer line hose-in-hose and decant line hose-in-hose drain back to the K West Basin via their respective ingress-egress pipes. The ingress/egress pipes are equipped with leak detectors to detect liquid in the annular region and shut down the associated transfer pumps.

2.1.4 Modified KW Basin Annex

The Modified KW Basin Annex is located approximately 10 ft north of the new north wall of the 105 KW Fuel Transfer System Annex. It consists of a Sludge Loading Bay, a Mechanical Equipment Room, a High-Efficiency Particular Air (HEPA) Filter Room, stair enclosure, and personnel Change Room.

The Modified KW Basin Annex is a steel frame and reinforced-concrete structure approximately 53 ft long, 29.5 wide, and 39 ft high. The facility is provided with a 14-ft wide, 16-foot high roll-up door on the east side. The Sludge Transport System STS trailer is backed into the facility through the roll-up door, positioned on a truck scale, and aligned with process equipment. It is then disconnected from the tractor. The STS consists of a trailer with a work platform and handrails providing access to the transportation cask. The cask, which contains an empty STSC when it arrives at the facility, is anchored to, and is an integral part of, the trailer. A 10-ton bridge crane is provided to remove the cask lid to provide access to the top of the STSC and to assist in making and breaking STSC nozzle connections. The Modified KW Annex has a mezzanine located approximately 20 ft above the facility floor and positioned above the STS trailer work platform.

Inside the Modified KW Basin Annex, the slurry transfer line and decant line are housed within a shielded vault structure, referred to as the hose-in-hose shielded duct. The shielded duct terminates at the transfer line service box located on the Modified KW Basin Annex mezzanine. The slurry transfer line is routed from the transfer line service box directly to the STSC. The decant line is routed to the decant pump box within a shielded trough. From the decant pump box, the decant line is routed to directly to the STSC.

The transfer line service box contains piping and valves normally configured for slurry transfers to the STSC. In the event the STSC is filled with a quantity of sludge that exceeds established limits, the system can be reconfigured to remove sludge from the STSC using the overflow recovery tool and return it to an engineered container in the KW Basin via the slurry transfer line. An air-operated, double-diaphragm pump (i.e., ECRT-P-301) located in the box provides the motive force for the transfer. IXM water is provided to the box to backflush lines as necessary, and to spray down the interior of the box in the event of a loss of primary containment. A leak detector, interlocked to shut down booster pump ECRT-P-101, IXM water pumps ECRT-P-51 and -52, and the overflow recovery pump, is located within the box.

The decant pump box contains piping and valves for decanting the STSC to the sand filter (and from there back to the KW Basin) and for transferring sand filter backwash to the STSC. An air-operated, double-diaphragm pump (i.e., decant pump ECRT-P-201) located in the box provides the motive force for decanting the STSC. For sand filter backwashing operations, the system is reconfigured to bypass the decant pump. IXM water is provided to the decant pump box to backflush lines as necessary and to spray down the interior of the box in the event of a loss of primary containment; a leak detector, interlocked to shut down the decant pump and IXM water pumps, is located within the box.

The sand filter system is located inside a modular shielded housing, referred to as the sand filter enclosure. The sand filter enclosure is located on the floor level of the Modified KW Basin Annex. The sand filter system is comprised of two cylindrical type vertical sand filters configured in parallel. The filter housings are 24-in. in diameter and 56-in. in height. The sand filters media is comprised of anthracite, sand, garnet and quartz materials. Each sand filter is connected to the ventilation system via a vent line that is opened to perform an air sparge of the filter media. The sand filter enclosure contains piping and valves for filtering the supernate and transferring it to the KW Basin, and for backwashing the sand filter and transferring it to the STSC via the decant pump box. IXM water is provided to the enclosure for backwashing the sand filter and to spray down the interior of enclosure in the event of a loss of primary containment. A leak detector, interlocked to shut down the decant pump and IXM water is located within the enclosure.

2.1.5 Modified KW Basin Annex Confinement Ventilation System

The Modified KW Annex is serviced by a confinement ventilation system. In summary, approximately 4,800 cfm of conditioned air is supplied to the facility. The supply air is comprised of approximately 3200 cfm of outside air and 1600 cfm of recirculated air. Approximately 4100 cfm of air is HEPA-filtered and exhausted through a stack to the environment via redundant HEPA filter trains located in a filter room on the south side of the Modified KW Basin. There is approximately 900 cfm of inleakage air.

The confinement ventilation system maintains negative air pressure differentials such that air flows from areas of lower contamination potential to areas of higher contamination potential. Four ventilation zones (1, 2, 3, and 3A) have been defined. Zone 1 provides primary confinement and services the STSC. A passive, inlet HEPA filter on Nozzle F2 provides inlet air, and the STSC is exhausted by the ventilation system through a connection at Nozzle F1. The ventilation system will maintain a pressure of -1.0 in. wc. with respect to atmosphere with both process lines disconnected. The resultant airflow (approximately 150 cfm) is more than adequate to compensate for volume displacement due to sludge filling and sand filter backwash cycles. A minimum airflow rate of 1 cfm into the container is always ensured to dilute hydrogen generated by the sludge (see Section 2.1.7, "Auxiliary Ventilation System). Air from the STSC passes through a moisture separator prior to HEPA filtration.

Zone 2 provides secondary confinement and services transfer line service box, decant pump box, and the sand filter enclosure, which are maintained at a pressure of -0.5 in. wc. relative to atmosphere. The transfer line service box and decant pump box are directly exhaust by the ventilation system. The sand filter enclosure is indirectly exhausted via its hose-in-hose connection to the decant pump box (i.e., the air flows through the annular region between the two hoses).

Zone 3 provides tertiary confinement and services the remainder of the Modified KW Basin Annex. This area of the facility will be maintained free of contamination and respiratory protection will not be required during normal operations. This Zone is maintained at a pressure

of -0.05 in. wc. relative to atmosphere when all facility doors are closed. Zone 3A also provides tertiary confinement and services the filter room. It is maintained at a pressure of -0.08 in. wc. relative to atmosphere. The change room and stair enclosure are operated at atmospheric pressure and have no zone designation.

2.1.6 Inert Gas System

The inert gas system provides nitrogen gas to purge the STSC and STS cask. The system is comprised of a nitrogen bottle station (located outside the northwest corner of the Modified KW Basin Annex) and associated piping, hoses, pressure regulators, valving, and pressure and flow instrumentation. After STSC process lines have been disconnected and nozzles capped, the breather inlet filter is removed and a purge line connected. After the STSC has been purged, the ventilation exhaust line is disconnected from the STSC and the nozzle capped. The nitrogen supply is then disconnected and a sintered metal filter placed on the nozzle.

The STS cask is also inerted with nitrogen to prevent hydrogen generated by the sludge from reaching a flammable concentration. To inert the cask, a vent port tool is connected to the cask lid and the ventilation exhaust line. A second vent port tool is connected to the side of the STS cask near the bottom, and to the nitrogen gas supply. After filling the cask with nitrogen, the vent port tools are disconnected and the ports on the STS cask configured for shipment.

2.1.7 Auxiliary Ventilation System

The auxiliary ventilation system is designed to provide active ventilation to the STSC in the event of failure of the process ventilation system. A minimum ventilation flow rate of 1 cfm is provided through a connection to a nitrogen bottle station, located adjacent to the inert gas system bottles, but operating independently of that system. Flow of nitrogen is activated automatically upon detection of low flow (i.e., < 5 cfm) in the STSC inlet ventilation line. As documented in PRC-STP-00301, *STP – ECRTS – Thermal and Gas Analyses for Sludge Transport and Storage Container (STSC) in Modified KW Annex*, modeling of hydrogen generation in a fully loaded STSC demonstrates that a ventilation flow rate of 1 cfm is adequate to ensure the hydrogen concentration remains below 25% under worst-case environmental conditions.

2.2 PROCESS DESCRIPTION SUMMARY

HNF-41051, Section 5.3, "Operating Modes," describes nine operating modes for filling an STSC with sludge and preparing it for transportation to T Plant.

2.2.1 Operating Mode 1: Preparing STSC

An STSC arrives at the Modified KW Basin Annex pre-loaded in an STS cask. Once the trailer is properly positioned on the truck scale, the tractor is decoupled from the trailer and driven away from the facility.

The bridge crane is used to remove the STS cask lid which is placed on the transport trailer. The empty weight of the STSC/STS cask on the transport trailer is then obtained. The slurry transfer line, decant/backwash line, instrumentation, and exhaust ventilation connections are then made at the appropriate STSC nozzles. The slurry transfer line and decant/backwash lines are connected to the STSC using a pipe-in-pipe coaxial connector. The STSC is then filled with water by connecting an IXM water line to a nozzle on the 26-in. flange. Water is added to the STSC to the fill limit of 3.5 m³ (or 2.89 m³ for settler tank sludge) as indicated by the liquid level instrumentation. The IXM water line is then disconnected from the STSC and the purge outlet line is attached to the nozzle. The liquid level in the STSC and the weight of the water-filled STSC/STS cask on the trailer are recorded. The IXM water in the STSC is then transferred to the KW Basin using the decant pump. For this transfer, the sand filter is bypassed. The STSC is now ready to receive sludge.

2.2.2 Operating Mode 2: Sludge Transfer into STSC

The bottom sections of the Engineered Containers are divided into eight separate compartments. To retrieve sludge, a hoist will be used to position the hydrolance over one of the eight bottom compartments. The IXM water to the Coanda head is then turned on (i.e., motive water pump ECRT-P-51) and the hydrolance is lowered near the bottom of the sludge bed. The fluidizing jets are pulsed using fluidizing pump ECRT-P-52 to undercut layers of sludge above the hydrolance. The sludge fluidized by the jets flows freely to and into the hydrolance suction created by the eductor and is transferred to booster pump ECRT-P-101 which pumps the sludge to the STSC. The weight of the sludge above the undercut section causes the sludge bed to collapse down and toward the hydrolance suction. When no more fluidized sludge is available, the fluidizing jets are pulsed to again undercut the sludge causing a collapse. This process is repeated until as much sludge as possible is retrieved from that location. The hydrolance is then retrieved, lowered over a different container compartment, and sludge retrieval re-initiated.

The rate at which sludge is retrieved principally depends on the frequency at which the fluidizing jets are operated. The flowsheet value at which sludge is retrieved is nominally 5 vol. % solids. The retrieved sludge-water slurry will vary in volume percent solids content ranging up to approximately 15 vol. % based on equipment testing with simulants. Operators use readings from a percent solids meter (AI-710-101) as an aid in operating the fluidizing jets.

The in-basin flocculant addition system may be used during sludge retrieval and transfer to add flocculant to the slurry in order to enhance sludge settling in the STSC. Flocculant is injected at the suction-side of booster pump ECRT-P-101.

The STSC design capacity defines the volume of nominally 5 vol. % solids slurry that is transferred in a given batch. At 70 gpm and assuming an empty STSC, it takes approximately 10 minutes to reach the 2.89 m³ design capacity for settler tank sludge, and 13 minutes to reach the 3.5 m³ design capacity for the remaining containerized sludge. Differential weight is the primary process control parameter indicating the quantity of sludge in an STSC.

The containerized sludge that originated in the KW and KE Basin is assumed to settle in an STSC to 26 and 25 vol. % solids, respectively. Settler tank sludge is assumed to settle to 30 vol.% solids. The volume of KW and KE settled sludge in an STSC is limited to the values listed in Table 2-2 so that the sludge remains contained within the STSC in the event that sludge expansion due to gas generation and oxide formation were to occur at the safety basis expansion rates. The volume of settler tank sludge in an STSC is limited to protect thermal and gas generation analysis assumptions.

Table 2-2. Maximum Settled Sludge Volume per Sludge Transport and Storage Container.*

Sludge Type	STSC Design Capacity (m ³)	Safety Basis Combined Sludge Expansion Factor	Maximum Sludge Volume (m ³)	Volume of Water Above Settled Sludge (m ³)
KE Containerized Sludge	3.5	1.66	2.1	1.4
KW Containerized Sludge	3.5	2.13	1.6	1.9
Settler tank Sludge	2.89	3.04	0.5	2.39

*From Table 3-2, HNF-41051, 2011, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance*, Rev. 7, CH2M HILL Plateau Remediation Company, Richland, Washington.

KE = 105-K East.

KW = 105-K West.

STSC = Sludge Transport and Storage Container.

2.2.3 Operating Mode 3: Flush Transfer Line

Due to expected variations in the volume percent solids contained in the retrieved sludge-water slurry, multiple batches of slurry must be retrieved, settled, and excess supernate decanted in order to fill an STSC to the maximum sludge volumes shown in Table 2-3. Following each batch transfer of slurry into the STSC, the transfer line is flushed with KW Basin water. To perform the flush, the hydrolance is withdrawn from the sludge in the engineered container while still operating, which allows basin water to flush solids forward to the booster pump. Flow through the hydrolance is then stopped. Basin water is then introduced into the suction side of the booster pump at valve ECRT-AOV-101 to complete the line flush. A total of approximately 50 gallons (0.19 m³) of basin water is added to the STSC during a flush.

In the event of a loss of power or activation of the Nuclear Safety Shutdown interlock (I-1), the slurry transfer line on the discharge side of the booster pump is automatically flushed with 50 gallons of water from flush tank ECRT-TK-101.

2.2.4 Operating Mode 4. Add Flocculant to Decant from STSC

After allowing the retrieved sludge slurry to settle for approximately 16 hours, the supernatant in the STSC is recirculated at 20 gpm through decant pump ECRT-P-201 and piping in the Decant Pump Box, the Transfer Line Service Box and back into the STSC. The decant pump is an air operated, double-diaphragm pump. The turbidity of the STSC supernatant is measured during recirculation. If the supernatant turbidity is in excess of 210 NTUs (90 mg/L), the Annex Flocculant Addition System is used to add flocculant through an inline mixer in the Decant Pump Box.

2.2.5 Operating Mode 5: Decant Supernate from STSC

Once the supernate turbidity is determined to be acceptable, the supernate is withdrawn from the STSC through the floating decant head and transferred to the sand filter. The sand filter is assumed to remove 100% of particles $\geq 5 \mu\text{m}$ in size. The filtered supernate is returned to the KW Basin via the decant line.

After decanting the excess supernate, the liquid level in the STSC and the weight of the STSC/STS cask on the trailer are recorded. The buoyant sludge weight in the STSC is determined to ensure the STSC is not overfilled with sludge. Additional batches of slurry are retrieved from an engineered container and transferred into the STSC as previously described until the maximum allowable sludge quantity is reached in the STSC.

2.2.6 Operating Mode 6: Backwash Sand Filter to STSC

Following the last decant of supernate from the STSC, the solids captured by the sand filter are backwashed to the STSC. The backwash is performed using IXM water from the Basin Water Skimmer System. The transfer line used to send the sand filter backwash into the STSC is the same transfer line used to decant supernate from the STSC. The decant pump is bypassed to enable the transfer of the sand filter backwash solution and solids into the STSC. After the filter backwash has been performed, the backwash line is flushed with approximately one and one-half line volumes of IXM water. The liquid level in the STSC and the weight of the STSC/STS on the trailer are recorded. The mass of settled sludge in the STSC is determined to ensure the STSC is not overfilled with sludge.

2.2.7 Operating Mode 7: Remove Excess Sludge from STSC

An overflow recovery tool is permanently installed in each STSC for use in the event that excess sludge needs to be removed from the STSC. To use the tool, blanks on the overflow recovery nozzle are removed and the overflow recovery tool is connected via hoses to IXM dilution water,

overflow recovery fluidizing water pump ECRT-P-302, and overflow recovery pump ECRT-P-301. Underwater in the K West Basin, the slurry transfer line is disconnected from the discharge side of the booster pump and connected to an overflow recovery nozzle on an engineered container. The overflow recovery tool uses IXM water from the fluidizing water pump to fluidize sludge in the STSC, which is diluted with IXM dilution water and then pumped via the slurry transfer line to an engineered container in K West Basin by the overflow recovery pump. The overflow recovery pump is an air operated, double-diaphragm pump. Following the removal of excess sludge, the overflow recovery pump and slurry transfer line are flushed with IXM water to the engineered container and to the STSC. The IXM water line and the slurry pump line are then disconnected from the overflow recovery tool and the nozzle blank re-installed.

2.2.8 Operating Mode 8: Disconnect Piping from STSC and Inert STSC with Nitrogen

A final flush of the fill and decant transfer lines are made using IXM water to remove residual solids. The air release valves on the slurry transfer line and decant line are then opened and the coaxial connectors are lifted approximately 2 inches to allow the lines to drain from the high point to the STSC. The slurry transfer line, decant line, and instrumentation, are then removed from the STSC nozzles. The 4-in. diameter ventilation line is also disconnected from the STSC and capped, leaving only the purge inlet and purge outlet lines connected. The slurry transfer line, decant line, and nozzles on the STSC are surveyed and decontaminated as necessary. The lines are then placed into their storage area on the mezzanine and the STSC nozzles are capped.

To prevent hydrogen generated by the sludge from reaching a flammable concentration in the STSC, the STSC is inerted with nitrogen from the Inert Gas System. To inert the STSC, the valve on the supply vent HEPA filter is closed and the nitrogen gas supply valve is opened. The STSC is purged with nitrogen until the oxygen concentration in the purge outlet line is less than 0.1% as measured by an oxygen analyzer. After the STSC has been successfully inerted, the purge outlet line is disconnected from the STSC and the nozzle capped. The nitrogen purge inlet is then disconnected and a NucFil®² filter placed on the nozzle. A final radiological survey of the STSC is conducted and the lid placed back on the STS cask.

2.2.9 Operating Mode 9: Inert/Pressurize STS Cask with Nitrogen

To prevent hydrogen generated by the sludge from reaching a flammable concentration in the STS cask, the cask is inerted with nitrogen from the Inert Gas System. To inert the cask, a vent port tool is connected to the cask lid. A drain port tool is then connected to the side of the STS cask near the bottom. The drain port tool is connected to the Inert Gas System and the STS cask is purged with nitrogen gas until the oxygen concentration is less than 0.1% as measured by an oxygen analyzer. The vent port tool is then removed.

² NucFil® is a registered trademark of Nuclear Filter Technology

The STS cask must be pressurized with nitrogen to between 3 and 15 psig. Pressurizing to greater than 3 psig prevents air inleakage during transportation. Pressurizing to less than 15 psig ensures that the STS cask will not exceed its pressure rating during transportation. To pressurize the cask, needle valve ECRT-V-607 is opened and the cask pressurized to within the required range as indicated on pressure indicator PI-760-606. The drain port tool is then disconnected. The tractor is then reconnected to the STS trailer and the shipment transported to T Plant for interim storage.

2.3 OPERATING SEQUENCE AND INTERLOCK DEFINITION

PRC-STP-00358, *Operating Sequence and Interlock Definition Document for the Engineered Container Retrieval and Transfer System (ECRTS)*, describes the ECRTS operating sequence, process inputs, and interlock definitions. The process and safety interlocks are described below. All process and safety interlocks are designed to fail safe, i.e., loss of signal in the interlock loop will assert the interlock and cause the control functions to occur. Interlock circuits utilize fail safe normally open contacts that are energized for normal operation. Indicators for status of permissives will illuminate upon loss of permissive.

2.3.1 Nuclear Safety Shutdown Interlock I-1

Interlock I-1 is the Nuclear Safety Shutdown Interlock. The purpose of the interlock is to prevent or mitigate accidents that could cause a spray release of slurry. Interlock I-1 will be asserted and indicated by any of the events shown in Table 2-3.

Table 2-3. Nuclear Safety Shutdown Interlock I-1

I-1 Initiating Event	Detector*	Indicator*
Sludge transfer hose leak	LDE/LDK-710-101	ECRT-IL-104
Transfer line service box leak	LDE/LDK-710-102	ECRT-IL-116
Transfer hose nozzle leak	LDE/LDK-710-103	ECRT-IL-117
Seismic switch activation	VS-710-103A/B	ECRT-IL-133
Transfer timer timeout	KS-710-101	ECRT-IL-134

*See piping and instrumentation diagrams provided in Appendix A.

Assertion of Interlock I-1 will cause the following actions:

- Sludge transfer booster pump ECRT-P-101 shuts down via a signal from ECRT-PNL-102 to a safety significant contactor in ECRT-PNL-105. This interrupts the 480 AC power to the pump motor.
- Triggers Decant Interlock I-2

- Triggers Process Emergency Stop Interlock I-3
- Energizes basin audible/visible alarm on ECRT-ANN-103
- Overfill recovery pump ECRT-P-103 shuts down via a signal from ECRT-PNL-103 to safety significant solenoid valve ECRT-SOV-762 to close ECRT-AOV-761 air supply.

2.3.2 Decant Interlock I-2

Decant Interlock I-2 will be asserted and indicated by any of the events shown in Table 2-4.

Table 2-4. Decant Interlock I-2

I-2 Initiating Event	Detector*	Indicator*
Decant hose leak	LDE/LDK-720-201	ECRT-IL-201
Decant nozzle leak	LDE/LDK-720-204	ECRT-IL-217
Decant pump box leak	LDE/LDK-720-202	ECRT-IL-205
Sand filter enclosure leak	LDE/LDK-720-203	ECRT-IL-220
Decant stream high turbidity	ASH-720-202	ECRT-IL-221
Decant pump loss of suction	ASH-720-202	PI-720-201
Emergency stop on PNL-101	ECRT-ES-1	ECRT-IL-13, ECRT-ANN-201
Emergency stop on PNL-102	ECRT-ES-2	ECRT-IL-13, ECRT-ANN-201
Emergency stop on PNL-103	ECRT-ES-3	To be determined

*See piping and instrumentation diagrams provided in Appendix A.

Assertion of Interlock I-2 will cause the following actions:

- Closes ECRT-AOV-760, shutting down the decant pump ECRT-P-201
- Shuts down annex flocculant pump ECRT-P-204
- Indicates an I-2 trip on ECRT-ANN-201.

2.3.3 Process Emergency Stop Interlock I-3

Process Emergency Stop Interlock I-3 serves to shut down all flows into the STSC and open the transfer line bladder flush valve. Interlock I-3 will be asserted and indicated by the events shown in Table 2-5.

Table 2-5. Process Emergency Stop Interlock I-3

I-3 Initiating Event	Detector*	Indicator*
Assertion of Interlock I-1	N/A	ECRT-IL-120
Loss of electrical power	N/A	N/A
High-high level in the STSC	LSH-740-402	ECRT-IL-402
Emergency Stop button at ECRT-PNL-101 is pressed	ECRT-ES-1	ECRT-IL-13, ECRT-ANN-201
Emergency Stop button at ECRT-PNL-201 is pressed	ECRT-ES-2	ECRT-IL-13, ECRT-ANN-201
Indication of a general fault by ECRT-PNL-101	ECRT-ES-3	ECRT-IL-119
Emergency stop on PNL-103	ECRT-ES-3	To be determined

*See piping and instrumentation diagrams provided in Appendix A.

Assertion of Interlock I-3 will cause the following actions:

- Shutdown of motive flow pump ECRT-P-51 (via ECRT-VFD-51)
- Shutdown of fluidizing pump ECRT-P-52 (via ECRT-VFD-52)
- Shutdown of sludge transfer booster pump ECRT-P-101 (via ECRT-VFD-101)
- Closes annex IXM water supply valve ECRT-AOV-701
- Closes overflow recovery AODD pump air supply valve ECRT-AOV-761
- Shutdown of overflow recovery motive water pump ECRT-P-302
- Opens IXM bladder flush valve ECRT-AOV-102
- Energizes audible and visible indication of an I-3 trip on ECRT-ANN-201
- Energizes basin/EOC audible/visible alarm on ECRT-PNL-101 and -102.

2.3.4 Normal Process Shutdown Interlock I-4

Interlock I-4 is the Normal Process Shutdown Interlock. All of the permissive conditions shown in Table 2-6 are required to de-assert Interlock I-4 and enable a slurry transfer.

Table 2-6. Normal Process Shutdown Interlock I-4 (two sheets)

I-4-Permissive	Detector*	Indicator*
Transfer line ECRT-H-107 connected	ZS-710-109	ECRT-IL-118
Transfer line ECRT-H-203 connected	ZS-720-205	ECRT-IL-218

Table 2-6. Normal Process Shutdown Interlock I-4 (two sheets)

I-4-Permissive	Detector*	Indicator*
STSC normal S/D not reached	LSHH-740-401	To be determined
Transfer line bladder flush valve ECRT-AOV-113 enabled	ZS-710-111	ECRT-IL-13, ECRT-ANN-201

*See piping and instrumentation diagrams provided in Appendix A.

Loss of any I-4 permissive will assert Interlock I-4 and cause the following actions:

- Shutdown of sludge transfer booster pump ECRT-P-101 (via ECRT-VFD-101)
- Closes IXM water inlet valve ECRT-AOV-1
- Indicates an I-4 trip on ECRT-ANN-201.

2.3.5 Normal Process Flush Interlock I-5

Normal Process Flush Interlock I-5 will be asserted and indicated by the events shown in Table 2-7.

Table 2-7. Normal Process Flush Interlock I-5

I-5-Initiating Event	Detector*	Indicator*
STSC flush level reached	LSH-740-401	ECRT-IL-121
STSC weight setpoint reached	DWSH-740-401	ECRT-IL-121

*See piping and instrumentation diagrams provided in Appendix A.

Assertion of Interlock I-5 will cause the following actions:

- Open flush valve ECRT-AOV-101 (via solenoid ECRT-SOV-101)
- Shutdown of motive flow pump ECRT-P-51 (via ECRT-VFD-51)
- Indicates an I-5 trip on ECRT-ANN-201
- Shutdown of basin flocculant pump ECRT-P-203.

3.0 METHODOLOGY

10 CFR 830, *Nuclear Facility Safety*, requires the documented safety analysis of a Hazard Category 2 nuclear facility to evaluate normal, abnormal, and accident conditions. For guidance on the evaluation of normal and abnormal operations, 10 CFR 830 refers to DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, Section 3.3, "Hazard Analysis."

As discussed in Section 3.3 of DOE-STD-3009-94, the experience and judgment of the hazard analysts are used to select a hazard evaluation technique. A graded approach is applied wherein a technique is selected that is sufficiently detailed to provide an appropriately comprehensive examination of hazards given the complexity of the operation and the degree of design maturity. For the ECRTS preliminary design, two hazard analysis techniques have been selected, i.e., HAZOP and What-If.

The HAZOP methodology was developed for application in the chemical industry and is best suited to processes with defined material and energy flow paths. Accordingly, the HAZOP methodology is applied to the following ECRTS processes:

- Retrieving sludge from an Engineered Container
- Transferring the slurry to an STSC
- Decanting the STSC
- Backwashing the Sand Filter into the STSC
- Purging the STSC with nitrogen
- Purging the STS cask with nitrogen
- Pressurizing the STS cask with nitrogen
- Adding flocculant to the slurry during transfer
- Adding flocculant to the supernate
- Automatically flushing the transfer line
- Recovering excess sludge from an over-filled STSC.

As described in *Guidelines for Hazard Evaluation Procedures* (AIChE 2008), in a HAZOP study a group of experienced people systematically review a process to determine if deviations from the design or operational intent can lead to undesirable consequences. Such deviations represent abnormal conditions, and the resulting undesirable consequences can be categorized as either an operational upset (e.g., delay in processing) or as a specific hazardous condition (e.g., uncontrolled release). Accidents occur when abnormal conditions that can result in a hazardous condition are not prevented or controlled.

The What-If methodology is applied to ECRTS activities that do not have defined material and energy flow paths. Examples include driving the STS trailer into the Modified KW Basin Annex, removing the STS cask lid, and connecting process lines to the STSC. The What-If methodology is also used to address natural phenomenon hazards and external events. As described in AIChE 2008, a What-If analysis is performed by an experienced group of people who identify possible abnormal situations, their consequences, and possible safeguards. As with the HAZOP

methodology, the consequences can be an operational upset or a specific hazardous condition. The What-If hazard analyses are documented separately in PRC-STP-00473, *Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Design Hazard Analysis Supplement 1*.

3.1 IDENTIFICATION OF UNDESIRABLE CONSEQUENCES

3.1.1 Process Parameters and Nodes

A HAZOP uses a fixed set of guidewords that are applied to specific process parameters. For example, the guide word “no” combined with the process parameter “flow” results in the deviation “no flow.” For each deviation the possible causes, consequences, and controls are then identified. The process parameters and deviations used in the ECRTS HAZOP study are shown in Table 3-1.

Table 3-1. Process Parameters and Deviations
(two sheets)

Process Parameter	Deviation
Flow	No
	Low
	High
	Reverse
	Misdirected
Pressure	Low
	High
Concentration	No
	Low
	High
Composition	Other
Structural Integrity	Leak
	Rupture
Level	Low
	High
Temperature	Low
	High

Table 3-1. Process Parameters and Deviations
(two sheets)

Process Parameter	Deviation
Time Procedure	Too short/fast/soon
	Too long/slow/late
	Skip action
	Wrong action

Sections of equipment with definite boundaries (e.g., a line between two vessels) within which process parameters are investigated for deviations are referred to as nodes. For the preliminary design HAZOP study, the ECRTS design and operations were sectioned into the following nodes:

- Node 1. Sludge Retrieval
 - 1.a. IXM Water to Xago Hydrolance™ Fluidizing Jets
 - 1.b. IXM Motive Water to Xago Hydrolance™
- Node 2. Sludge Transfer
 - 2.a. Engineered Container to Ingress/Egress Pipe
 - 2.b. Ingress/Egress Pipe to STSC
 - 2.c. STSC
 - 2.d. STSC Ventilation
- Node 3. STSC Decant
- Node 4. Sand Filter Backwash
- Node 5. STSC Nitrogen Purge
- Node 6. STS Nitrogen Purge
- Node 7. STS Cask Pressurization
- Node 8. In-Basin Flocculant Addition System
- Node 9. Annex Flocculant Addition System
 - 9.a. Flocculant Tank to In-Line Mixer
 - 9.b. Decant Recirculation
- Node 10. Transfer Line Automatic Flush

Node 11 Overfill Recovery

- 11.a IXM Water to Recovery Tool Fluidizing Jets
- 11.b IXM Water to Recovery Tool Dilution Water
- 11.c STSC to Pump ECRT-P-301
- 11.d Pump ECRT-P-301 to Engineered Container.

For each node, the design intent for each applicable process parameter has been defined. These define the boundaries of normal operations.

3.1.2 Design Media

The draft preliminary design HAZOP was performed based on the P&IDs available at the time of its performance. Preliminary design work continued during and after completion of the draft preliminary HAZOP study resulting in a revised set of P&IDs (see Appendix A). Nuclear safety and process engineering personnel performed a sheet-by-sheet comparison of the two sets of diagrams and generated an annotated set of P&IDs that identified additions, deletions, and revisions. The comparison is documented in PRC-STP-00440, *Sludge Treatment Project Engineered Container and Retrieval and Transfer System Preliminary Design Hazard Analysis P&ID Comparison*.

3.1.3 HAZOP Team

At the draft preliminary design stage, undesirable consequences were identified by a team of subject matter experts from the following CHPRC organizational disciplines:

- STP Nuclear Safety
- 100 K Area Nuclear Safety
- STP Radiological Control
- 100 K Area Radiological Control
- STP Operations
- 100 K Area Operations
- STP Occupational Safety and Health
- 100 K Area Occupational Safety and Health
- ECRTS Engineering.

Additional attendees included representatives from the following organizational disciplines:

- ECRTS Engineering
- STP Quality Assurance
- 100 K Emergency Preparedness
- Criticality Safety
- Transportation Safety

- T Plant Nuclear Safety
- DOE-RL Nuclear Safety.

To evaluate the impact of the design changes that occurred since completion of the draft preliminary design HAZOP study, nuclear safety personnel and the responsible design authority for a given node reviewed each previously evaluated process parameter deviation and the associated undesirable consequences using the annotated P&IDs contained in PRC-STP-00440. This review resulted in a redline/strikeout set of revised HAZOP study tables that were submitted to the HAZOP team for review, comment, and concurrence.

In support of the preliminary design, additional HAZOP team meetings were held to evaluate STS Cask Pressurization and Overfill Recovery. STS Cask Pressurization was partially addressed in the draft preliminary design HAZOP study as part of the STS Purge node. During the P&ID comparison review it was determined that cask pressurization should be addressed as a separate node. Overfill Recovery was not addressed in the draft preliminary design HAZOP because the design was not sufficiently mature to warrant evaluation at that time.

A list of HAZOP meeting attendees is provided in Appendix B.

3.2 UNMITIGATED FREQUENCY AND CONSEQUENCE ESTIMATES

Unmitigated radiological consequence and frequency levels were assigned to hazardous conditions identified by the HAZOP study. The onsite and offsite radiological consequence levels are shown in Tables 3-2 and 3-3, respectively.

Table 3-2. Collocated Worker and Offsite Public Consequence Levels.*

Consequence Level	Collocated Worker (100 m)	Offsite Public
High	> 100 rem	> 25 rem
Moderate	≥ 25 rem	≥ 5 rem
Low	< 25 rem	< 5 rem

*From Table 2-1, PRC-STD-NS-8739, *CHPRC Safety Analysis and Risk Assessment Handbook (SARAH)*, Rev. 0..

Table 3-3. Frequency Levels*

Frequency Level	Frequency
Anticipated	Above 1E-2/yr
Unlikely	1E-4 to 1E-2/yr
Extremely Unlikely	1E-6 to 1E-4/yr
Beyond Extremely Unlikely	Below 1E-6/yr

*Derived from Table 2-2, PRC-STD-NS-8739.

For each hazardous condition evaluated for the offsite public and collocated worker, an evaluation of the unmitigated consequence to the facility worker was performed to determine if the hazardous condition could result in prompt death, serious injury, or a significant radiological exposure. In accordance with the suggested evaluation criterion in DOE-STD-1189-2008, Appendix C, "Facility Worker Hazard Evaluation," a significant radiological exposure was defined as 100 rem total effective dose equivalent. If it was judged that the hazardous condition could result in prompt death, serious injury, or a significant radiological exposure, then a "High" facility worker consequence was assigned.

4.0 RESULTS

4.1 HAZARD AND OPERABILITY STUDY RESULTS

4.1.1 HAZOP Tables

The results of the HAZOP study are documented in tabular format in Appendix C. The table column headings are as follows:

Item: This column assigns a unique identifier to each process parameter and associated deviation.

Process Parameter: This column identifies the process parameter being studied, e.g., “flow.” Refer to Table 3-1 for listing of process parameters.

Deviation: This column identifies the deviation being studied, e.g., “no” flow. Refer to Table 3-1 for a listing of deviations.

Cause: This column identifies the cause or causes for the deviation. For example, a no flow condition could be caused by a closed valve.

Consequences: This column identifies the consequences associated with the process parameter deviation.

Candidate Controls: This column identifies engineered and administrative controls that could be credited with preventing or mitigating the consequences of the process deviation.

Remarks: This column documents review team discussions and design details pertinent to the evaluation of the process derivation.

4.1.2 Identified Hazardous Conditions

The hazardous conditions identified by the HAZOP study are:

- Spray release
- Splash and splatter/pool release
- Hydrogen deflagration
- STSC overpressurization
- Radiological Control
 - Airborne radioactive material
 - Contamination
 - High external dose rate

- Industrial Safety
 - Hose whip
 - Oxygen deficient atmosphere.

The hose whip and oxygen deficient atmosphere hazardous conditions are considered to be standard industrial hazards that are addressed by the Occupational Safety and Health safety management program.

The HAZOP study did not explicitly identify a nuclear criticality as a hazardous condition. However, the sludge stored in the six engineered containers in the KW Basin contains more than a minimum critical mass of fissile material such that an inadvertent nuclear criticality must be addressed. As documented in PRC-STP-00163, *Criticality Safety Evaluation for Engineered Container and Settler Sludge Retrieval, Transfer, Transportation, and Interim Storage (Phase 1)*, it is anticipated that future criticality safety evaluation reports prepared for ECRTS will demonstrate that a criticality cannot occur due to the form and distribution of the fissile material.

4.2 UNMITIGATED FREQUENCY AND CONSEQUENCE LEVEL RESULTS

The unmitigated frequency and consequence levels assigned to each hazardous condition are documented in Appendix D. The majority of the hazardous conditions were assigned an “Anticipated” frequency based on human error or a mechanical failure as the initiating event. The facility worker, collocated worker, and offsite public unmitigated consequence levels for hazardous conditions resulting in an uncontrolled release of radioactive material, a hydrogen deflagration, and an STS cask overpressurization are summarized in Table 4-1. The consequence levels in Table 4-1 were assigned based on accident analysis consequences reported in PRC-STP-CN-N-00401, *Sludge Treatment Project Engineered Container Retrieval and Transfer System Draft Preliminary Design Accident Analysis*.

4.3 ACCIDENT SELECTION

The hazardous conditions listed in Table 4-1 require accident analysis to quantify the unmitigated consequences. The results of the accident analysis will then be used to select, as necessary, safety structures, systems, and components.

Table 4-2 identifies the specific HAZOP table entries (i.e., Item No.) that resulted in a hazardous condition warranting accident analysis.

Table 4-1. Summary of Unmitigated Frequency and Consequence Levels

Hazardous Condition	Source Material ¹	Unmitigated Frequency	Unmitigated Consequence		
			Facility Worker	Onsite	Offsite
Spray Leak	Slurry (retrieval and transfer)	A	H	H	L
	STSC supernate	A	L	L	L
	Sand filter backwash	A	L	L	L
	Slurry (overflow recovery line failure)	A	H	H	L
	Slurry (overflow recovery diaphragm pump failure)	A	L	L	L
Splash and Splatter/Pool	Slurry (retrieval and transfer)	A	L	L	L
	STSC supernate	A	L	L	L
	Sand filter backwash	A	L	L	L
	Slurry (overflow recovery line failure)	A	L	L	L
	Slurry (overflow recovery diaphragm pump failure)	A	L	L	L
Hydrogen Deflagration	STSC	A	H ²	L	L
	Transfer Line Service Box	A	H ²	L	L
	Decant Pump Box ³	A	H ²	L	L
	Sand Filter ³	A	H ²	L	L
	Sand Filter Enclosure ³	A	H ²	L	L
Overpressurization	Sludge slurry	A	L	L	L

¹Consequences based on settler tank sludge which has a higher radionuclide inventory than KE or KW Basin sludge. For a given hazardous condition (e.g., spray release) the consequences vary as a function of the estimated volume percent solids.

²A high consequence is assigned to the facility worker for hydrogen deflagrations based on the potential for prompt death or serious injury.

³PRC-STP-CN-N-00401 does not analyze hydrogen deflagrations in the Decant Pump Box, sand filter, or Sand Filter Enclosure. The low consequences are qualitatively assigned based on the low consequences calculated for deflagrations in the STSC and Transfer Line Service Box.

A = Anticipated
H = High
L = Low
M = Moderate

Table 4-2. Correlation of Hazardous Conditions to HAZOP Table Entries
(three sheets)

Hazardous Condition	Source Material	HAZOP Item No.*		
Spray Leak Release	Sludge slurry	1.a-4	2.b-5.d	10-4
		1.b-4	2.b-7	11.d-5.a
		2.a-4	2.b-10	11.d-7
		2.b-3	2.b-12	11.d-8
		2.b-4.a	8-4.a	11.d-9
		2.b-5.b	8-4.b	
		2.b-5.c		
	STSC supernate	3-7	3-17.b	9.b-5.c
		3-9.a	9.a-4	9.b-7
		3-13.a	9.a-6	9.b-13.a
		3-13.b	9.a-7	9.b-13.b
		3-13.c	9.a-13.a	9.b-16
		3-13.d	9.a-13.b	9.b-17
	Sand filter backwash	4-7		
		4-13.a		
		4-13.b		
Splash and Splatter/Pool Release	Sludge slurry	1.a-4	2.d-14	11.c-2
		1.b-4	8-4.a	11.c-4
		2.a-4	8-4.b	11.c-8
		2.b-3	10-4	11.c-11
		2.b-4.a	11.a-3	11.d-1
		2.b-4.b	11.a-4	11.d-2
		2.b-5.a	11.a-7	11.d-5.a
		2.b-5.b	11.a-8	11.d-5.d
		2.b-5.c	11.a-10	11.d-6
		2.b-5.d	11.b-3	11.d-7
		2.b-7	11.b-4	11.d-8
		2.b-10	11.b-7	11.d-9
		2.b-12	11.b-8	11.d-12
		2.c-10.a	11.b-10	
		2.c-10.b	11.c-1	

Table 4-2. Correlation of Hazardous Conditions to HAZOP Table Entries
(three sheets)

Hazardous Condition	Source Material	HAZOP Item No.*		
Splash and Splatter/Pool Release (continued)	STSC Supernate	3-5.a	3-13.d	9.b-5.b
		3-5.b	3-16	9.b-5.c
		3-5.c	3-17.b	9.b-5.d
		3-5.d	4-4	9.b-5.e
		3-5.e	8-4.a	9.b-5.f
		3-5.f	8-4.b	9.b-7
		3-5.g	9.a-4	9.b-13.a
		3-7	9.a-6	9.b-13.b
		3-9.a	9.a-7	9.b-16
		3-13.a	9.a-13.a	9.b-17
		3-13.b	9-a.13.b	
		3-13.c	9.b-5.a	
	Sand filter backwash	4-5.a	4-5.e	4-12.a
		4-5.b	4-5.f	4-13.a
		4-5.c	4-7	4-13.b
		4-5.d		
Hydrogen Deflagration	STSC	2.c-7.a	5-14	11.b-11
		2.c-10.b	5-16	11.c-1
		2.c-10.d	11.a-1	11.c-2
		2.d-1	11.a-2	11.c-3
		2.d-2	11.a-3	11.c-9
		2.d-10.b	11.a-5	11.c-11
		2.d-13	11.a-6	11.d-1
		5-1	11.a-9	11.d-2
		5-5.a	11.a-11	11.d-3
		5-5.b	11.b-1	11.d-6
		5-9	11.b-2	11.d-7
		5-10.a	11.b-5	11.d-10
		5-10.b	11.b-6	11.d-12
		5-12.b	11.b-9	
		5-13		
	STS Cask	6-1	6-13.a	7-7.b
		6-5	6-13.b	7-8.a
		6-7.a	6-14	7-8.b
		6-7.b	6-16	7-9
		6-9	7-1	7-11.a
		6-10.a	7-4	7-11.b
		6-10.b	7-5	7-12
		6-11	7-7.a	7-14

Table 4-2. Correlation of Hazardous Conditions to HAZOP Table Entries
(three sheets)

Hazardous Condition	Source Material	HAZOP Item No.*		
Hydrogen Deflagration (continued)	Transfer Line Service Box	2.b-5.a 2.b-12 9.b-5.b	9.b.-7 9.b-13.b	9.b-17
	Decant Pump Box ²	3-5.a 3-5.b 3-13.c	9.a-7 9.a-13.a 9.b-5.a	9.b-7 9.b-13.b 9.b-17
	Sand Filter ²	4-16		
	Sand Filter Enclosure ²	3-13.b 3-13.c	4-13.a 4-13.b	
STS Cask Overpressurization	Sludge slurry	2.c-7.a 2.c-10.b 2.c-10.d 5-13 6-13.a 6-13.b 7-3 7-7.a 7-7.b 7-13 11.a-1 11.a-2	11.a-5 11.a-6 11.a-9 11.a-11 11.b-1 11.b-2 11.b-5 11.b-6 11.b-9 11.b-11 11..c-1 11.c-2	11.c-3 11.c-9 11.c-11 11.d-1 11.d-2 11.d-3 11.d-6 11.d-7 11.d-10 11.d-12

*See Appendices C and D

4.4 PEER REVIEW

A peer review of this Hazard and Operability Study was performed in accordance with the requirements of PRC-PRO-NS-700, *Safety Basis Development*. The peer review is documented in Appendix E.

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APPENDIX A
PROCESS FLOW DIAGRAMS AND
PIPING AND INSTRUMENTATION DRAWINGS

Figure A-1. STP ECRTS Process System PFD (H-1-92300, Rev. G, Sheet 1 of 2)

Figure A-2. STP ECRTS Process System PFD (H-1-92300, Rev. G, Sheet 2 of 2)

Figure A-3. STP ECRTS Process System P&ID Legend (H-1-92301, Rev. M, Sheet 1 of 13)

Figure A-4. STP ECRTS Process System Retrieval P&ID (H-1-92301, Rev. M, Sheet 2 of 13)

Figure A-5. STP ECRTS Process System Transfer P&ID (H-1-92301, Rev. M, Sheet 3 of 13)

Figure A-7. STP ECRTS Process System Decant P&ID (H-1-92301, Rev. L, Sheet 5 of 13)

Figure A-8. STP ECRTS Process System Transfer P&ID (H-1-92301, Rev. M, Sheet 6 of 13)

Figure A-9. STP ECRTS Process System Transfer STSC P&ID (H-1-92301, Rev. M, Sheet 7 of 13)

Figure A-10. Process System Ventilation P&ID (H-1-92301, Rev. L, Sheet 8 of 13)

Figure A-14. STP ECRTS Process System Flocculant P&ID (H-1-92301, Rev. K, Sheet 12 of 13)

APPENDIX B
HAZARD AND OPERABILITY STUDY MEETING ATTENDEES

Table B-1. ECRTS Draft Preliminary Design HAZOP Meeting Participants

August 9, 10 and 12, 2010

Name	Organization	Dates Present		
		8/9	8/10	8/12
HAZOP Team				
Craig Carro	STP Nuclear Safety – Facilitator	X	X	X
Robin Sullivan	PNNL - Scribe	X	X	X
Ralph Crowe	STP Nuclear Safety	X	X	X
Gail Chaffee	100 K Area Nuclear Safety	X	X	X
Lindsay Nelsen	STP Radiological Control	X	–	–
Gary Hastings	100 K Area Radiological Control	X	X	X
Steve Burke	100 K Area Operations	X	–	–
Jeff Broussard	100 K Area Operations	–	X	X
Jim Mathews	STP Operations	X	X	X
Dewey Burbank	ECRTS Process Engineering	X	X	X
Daniel Wood	100 K Area Occupational Safety and Health	X	X	–
Daren Schwartz	100 K Area Occupational Safety and Health			X
Shaun Dunfee	STP Occupational Safety and Health	X	–	–
Additional Attendees				
Dennis Hamilton	ECRTS Project Manager	X	X	X
Rick Raymond	STP Chief Engineer	X	X	–
Jim Frederickson	ECRTS Engineering Manager	X	–	–
John Dearing	ECRTS Engineering	X	–	X

Table B-1. ECRTS Draft Preliminary Design HAZOP Meeting Participants
August 9, 10 and 12, 2010

Name	Organization	Dates Present		
		8/9	8/10	8/12
Mark Hall	ECRTS Engineering	X	–	–
Geoff Barnes	ECRTS Engineering	–	X	–
Tarandeep Dhaliwal	ECRTS Engineering	–	–	X
Jim Criddle	ECRTS Engineering	–	–	X
Bob Meichle	STP Nuclear Safety	X	X	X
Joel Cannon	STP Quality Assurance	X	X	X
Rick Garza	100 K Area Emergency Preparedness	X	–	X
Raymond Puigh	Criticality Safety	X	X	–
Alvia Bridges	Transportation Safety	X	–	X
Jake Jacobs	SWOC Nuclear Safety	–	–	X
Greg Morgan	RL Nuclear Safety	X	–	–
Dennis Clapp	RL Nuclear Safety	X	X	–

Table B-2. ECRTS Preliminary Design HAZOP Meeting Participants Overfill Recovery May 31, 2011	
NAME	ORGANIZATION
HAZOP Team	
Craig Carro	STP Nuclear Safety - Facilitator
Bob Meichle	STP Nuclear Safety - Scribe
Paul Patterson	100-K Area Nuclear Safety
Daren Schwartz	100 K Area Occupational Safety and Health
Dewey Burbank	ECRTS Process Engineering
Susan Omberg Carro	STP Fire Protection Engineering
Darryl Willoughby	100 K Area Operations
Additional Attendees	
Rick Raymond	STP Chief Engineer, SDIT Chair
Gary Franz	STP Nuclear Safety Lead
Dennis Hamilton	ECRTS Project Manager
John Dearing	ECRTS Seismic Design Engineer
Jim Criddle	ECRTS Engineering
Harold Mashaw	ECRTS Engineering
Tom Vincent	Design Agent (AREVA)
Greg Morgan	RL Nuclear Safety

Table B-3. ECRTS Preliminary Design HAZOP Meeting Participants STS Cask Pressurization June 14, 2011	
NAME	ORGANIZATION
HAZOP Team	
Craig Carro	STP Nuclear Safety – Facilitator
Bob Meichle	STP Nuclear Safety - Scribe
Lindsay Nelsen	STP Radiological Control
Dewey Burbank	ECRTS Process Engineering
Susan Omberg Carro	STP Fire Protection Engineering
Daren Schwartz	100 K Area Occupational Safety and Health
Darryl Willoughby	100 K Area Operations
Additional Attendees	
Gary Franz	STP Nuclear Safety Lead
Jim Frederickson	ECRTS Engineering Manager
John Dearing	ECRTS Seismic Design Engineer
Harold Mashaw	ECRTS Engineering
Tom Vincent	Design Agent (AREVA)

APPENDIX C
HAZARD AND OPERABILITY STUDY RESULTS

APPENDIX C
HAZARD AND OPERABILITY STUDY RESULTS

Table C-1. Normal Operating Conditions, Node 1.a., Sludge Retrieval – IXM Water to Xago Hydrolance™ Fluidizing Jets		
Process Parameter	Design Intent	Remarks
Flow	42 gpm	Motive force is fluidizing pump ECRT-P-52. The 42 gpm is the flow rate when the fluidizing jets are pulsed. When the jets are not pulsed, 2-13 gpm flows to the fluidizing jets via bypass flow orifice ECRT-FO-1.
Pressure	Upstream of pump ECRT-P-52 = 100-130 psi Downstream of pump ECRT-P-52 = 385 psi	When the operators pulse the fluidizing jets, valve ECRT-AOV-2 opens and high pressure water is directed to the jets.
Concentration	Not applicable	The Skimmer Water Cleanup System takes basin water and pumps it first through a sand filter (for water clarity) and then through an IXM (to remove ionic species). The IXM water concentration is not a critical attribute of Xago Hydrolance™ operability, i.e., fluidizing jet performance would be identical using basin water versus IXM water.
Composition	Not applicable	There are no other process fluids at the KW Basin that could be inadvertently connected or directed to the Xago pump skid.
Structural Integrity	Maintain integrity under normal operating conditions	The IXM water lines are a combination of piping and hoses.
Level	Not applicable	There are no vessels associated with this node.
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin are maintained at a temperature of 10-15 °C. The IXM water is approximately the same temperature as the basin water, i.e., the pumps of the Skimmer Water Cleanup System do not impart significant thermal energy to the water. Fluctuations in basin water temperature occur very slowly. The IXM water temperature is not a critical attribute of Xago Hydrolance™ operability, i.e., fluidizing jet performance would be identical for a wide range of basin water temperatures.
Time Procedure	Periodic pulses lasting 3 to 10 seconds	The fluidizer jets are pulsed to undercut layers of sludge above the Xago Hydrolance™. Operators pulse the jets based on readings from the % solids meter (AI-710-101).

Table C-2. HAZOP Results, Node 1.a., Sludge Retrieval – IXM Water to Xago Hydrolance™ Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.a-1	Flow	No	<ul style="list-style-type: none"> No IXM water supply from the Skimmer Water Cleanup System A normally-open valve is closed Fluidizing jets are plugged 	<p>Operational Upset:</p> <p>If there is no flow to the fluidizing jets because there is no IXM water supply, then there will be no water to the fluidizing jets and there will be no motive water. Booster pump ECRT-P-101 will continue to operate but will be suction-starved. The Xago Hydrolance™ could plug. The rupture disk downstream of booster pump ECRT-P-101 could rupture.</p> <p>If there is no flow to the fluidizing jets because valve ECRT-V-701 or ECRT-AOV-1 is closed, then there will be no water to the fluidizing jets and there will be no motive water. Consequences are as stated above.</p> <p>If there is no flow to the fluidizing jets because valve ECRT-V-6 or valve ECRT-V-8 is closed, then sludge in the Engineered Container will not be undercut and thus will not collapse into the zone of influence of the Coanda head. This will result in a reduced vol% solids content of the retrieved sludge which could result in additional fill/decant cycles.</p> <p>If there is no flow to the fluidizing jets because valve ECRT-V-8 is closed, then fluidizing pump ECRT-P-52 would deadhead and could overheat. Deadheading the pump would result in high pressure in the line downstream of the pump (see Item 1.a-6 below).</p>	<ul style="list-style-type: none"> Valve position indicators IXM water pressure instrumentation (PT-700-1B, -2B, -3B) IXM water flow rate instrumentation (FIT-700-1, -2) % solids instrumentation (AE-710-101) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	<p>It would be readily apparent to operators at the start-up of retrieval operations if there was no IXM water supply.</p> <p>Fluidizing pump ECRT-P-52 is a centrifugal pump. If it was not operating IXM water would still flow through the pump at the flow rate and pressure provided by the IXM water system.</p> <p>Valves ECRT-AOV-1 is an air-operated valve. The valve close on loss of air. The valve also closes on loss of power to solenoid-operated valve ECRT-SOV-1.</p> <p>If ECRT-AOV-2 fails to open it does not result in a “no flow” condition to the fluidizer jets because of flow through bypass flow orifice ECRT-FO-1. The flow rate through this orifice is 2-13 gpm.</p>

Table C-2. HAZOP Results, Node 1.a., Sludge Retrieval – IXM Water to Xago Hydrolance™ Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.a-2	Flow	Low	<ul style="list-style-type: none"> Low IXM water supply flow rate from the Skimmer Water Cleanup System Fluidizing pump ECRT-P-52 not operating Fluidizing pump ECRT-P-52 speed low A normally-open valve is partially closed Fluidizing jets are partially plugged Valve ECRT-AOV-2 is closed 	<p>Operational Upset:</p> <p>If there is low flow to the fluidizing jets because there is a low flow rate from the IXM water supply, then sludge in the Engineered Container may not be effectively undercut and thus will not collapse into the zone of influence of the Coanda head. This will result in a reduced vol% solids content of the retrieved sludge which could result in additional fill/decant cycles.</p> <p>If there is low flow to the fluidizing jets because of a low pump speed or because valve ECRT-V-701 or ECRT-AOV-1 is partially closed, then sludge in the Engineered Container may not be effectively undercut and thus will not collapse into the zone of influence of the Coanda head. The consequences are as stated above.</p> <p>If there is low flow to the fluidizing jets because valve ECRT-V-6 or valve ECRT-V-8 is partially closed, then sludge in the Engineered Container may not be effectively undercut and thus will not collapse into the zone of influence of the Coanda head. The consequences are as stated above.</p>	<ul style="list-style-type: none"> Valve position indicators IXM water pressure instrumentation (PT-700-1B, -2B, -3B) IXM water flow rate instrumentation (FIT-700-1, -2) % solids instrumentation (AE-710-101) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	<p>Fluidizing pump ECRT-P-52 is a centrifugal pump. If it was not operating IXM water would still flow through the pump at the flow rate and pressure provided by the IXM water system.</p> <p>The fluidizing pump speed is controlled by variable frequency drive ECRT-VFD-52. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p>
1.a-3	Flow	High	Fluidizing pump ECRT-P-52 speed high	<p>Operational Upset:</p> <p>If there is high flow to the fluidizing jets, then the vol% solids could be temporarily reduced and sludge could flow out of the Engineered Container into the basin.</p>	<ul style="list-style-type: none"> IXM water flow rate instrumentation (FIT-700-2) % solids instrumentation (AE-710-101) 	<ul style="list-style-type: none"> Procedures Training 	<p>The fluidizing pump speed is controlled by variable frequency drive ECRT-VFD-52. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p>

Table C-2. HAZOP Results, Node 1.a., Sludge Retrieval – IXM Water to Xago Hydrolance™ Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.a-4	Flow	Reverse	Booster pump ECRT-P-101 runs in reverse (see remarks)	<p>Uncontrolled Release/Radiological Control:</p> <p>If booster pump ECRT-P-101 runs in reverse, then sludge/basin water could flow into the fluidizing jet IXM water supply line to a point above the basin water (see remarks).</p> <p>If the fluidizing jet IXM water supply line failed due to the pressure generated by pump ECRT-P-101, then a spray or splash and splatter/pool release could occur.</p> <p>If air is pumped into an Engineered Container, then it will bubble to the surface of basin water and could result in elevated airborne radioactivity levels.</p>	<ul style="list-style-type: none"> IXM water pressure instrumentation (PT-700-1B, -3B) IXM water flow rate instrumentation (FIT-700-1, -2) Check valve ECRT-CV-2 	<ul style="list-style-type: none"> Procedures Training Pre-operational testing Radiological Control Program 	<p>Fluidizing pump ECRT-P-52 is a centrifugal pump. Once installed correctly, as verified by pre-operational testing, it cannot pump in the reverse direction even if the blade rotation is reversed.</p> <p>The design of booster pump ECRT-P-101 is such that it can be operated in the reverse direction. However, there are no plans to operate the pump in reverse.</p> <p>Operating the pump in reverse would be one option for clearing a plugged Xago Hydrolance™ or transfer line. However, other means to clear a plug exist. For example, IXM water can be connected to basin water flush valve ECRT-AOV-101 and used to flush the line in the reverse direction.</p> <p>If booster pump ECRT-P-101 was run in reverse, then the sludge in the line and basin water would be pumped out of the Coanda head and into the Engineered Container. In order for sludge/basin water to be forced into the fluidizing jets, the sludge in the container around the fluidizing jet zone of influence would need to be sufficiently strong to not yield to the pressure of the reverse flow. This is considered to be an extremely unlikely event.</p>
1.a-5	Flow	Misdirected (to sludge mobilization tool)	Valve ECRT-V-8 closed and valve ECRT-V-9 open-	<p>Operational Upset:</p> <p>If valve ECRT-V-8 is closed and valve ECRT-V-9 is open, then fluidizing jet water will be misdirected to the sludge mobilization tool. Sludge in the Engineered Container will not be undercut in the vicinity of the Xago Hydrolance™ and thus will not collapse into the zone of influence of the Coanda head. This will result in a reduced vol% solids content of the retrieved sludge which could result in additional fill/decant cycles</p>	Valve position indicators	<ul style="list-style-type: none"> Procedures Training Operations verifies proper system configuration 	

Table C-2. HAZOP Results, Node 1.a., Sludge Retrieval – IXM Water to Xago Hydrolance™ Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.a-6	Flow	Misdirected (to Xago Hydrolance™ motive water connection)	Operator error in making hose connections	Operational Upset: If fluidizing jet hose ECRT-H-2 was erroneously connected to the Xago Hydrolance™ motive water connector; and motive water hose ECRT-H-4 was connected to the fluidizing jet connector, then sludge would not be efficiently retrieved because (1) the motive water would not fluidize the sludge effectively and (2) the fluidizing jet flow rate is low when the jets are not operated.	None	<ul style="list-style-type: none"> Procedures Training Operations verifies proper system configuration 	There are two Xago Hydrolances™ in the basin; one located in the center bay and one located in the east bay. Erroneous process connections could occur when switching retrieval operations from one bay to the next. The connections are made at the grating level.
1.a-7	Pressure	Low	<ul style="list-style-type: none"> Fluidizing pump ECRT-P-52 not operating Fluidizing pump speed low 	Operational Upset: If the fluidizing jet pressure was low, then sludge in the Engineered Container may not be effectively undercut and thus will not collapse into the zone of influence of the Coanda head. This will result in a reduced vol% solids content of the retrieved sludge which could result in additional fill/decant cycles.	<ul style="list-style-type: none"> IXM water pressure instrumentation (PT-700-3B) IXM water flow rate instrumentation (FIT-700-2) % solids instrumentation (AE-710-101) 	<ul style="list-style-type: none"> Procedures Training 	
1.a-8	Pressure	High	<ul style="list-style-type: none"> Fluidizing pump speed high A normally-open valve is closed Fluidizing jets are plugged 	Uncontrolled Release/Industrial Safety: If the pressure is high, then the fluidizing jet IXM water supply line could fail at a location above the basin water. This would result in a spill of IXM water (see remarks). If the failure occurred in hose ECRT-H-9, located above the basin water, then the hose could potentially whip and injure a facility worker.	<ul style="list-style-type: none"> Valve position indicators Piping designed in accordance with B31.3, "Process Piping." IXM water pressure instrumentation (PT-700-3B) Hose tie-downs 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Radiological Control Program Industrial Safety Program 	Relative to B31.3, the piping and hoses are designed to withstand the deadhead pressure of fluidizing pump ECRT-P-52. Spills of IXM water constitute a minor radiological hazard to facility workers based on operational experience at the KW Basin.

Table C-2. HAZOP Results, Node 1.a., Sludge Retrieval – IXM Water to Xago Hydrolance™ Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.a-9	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure Manufacturing flaw Procurement error 	<p>Uncontrolled Release/Industrial Safety:</p> <p>If the fluidizing jet IXM water supply line failed at a location above the basin water, then IXM water would be spilled (see remarks).</p> <p>If a rupture of hose ECRT-H-9 occurred, then the hose, located above the basin water could potentially whip and injure a facility worker.</p>	<ul style="list-style-type: none"> Piping designed in accordance with B31.3, "Process Piping." IXM water pressure instrumentation (PT-700-3B) Hose tie-downs 	<ul style="list-style-type: none"> Procedures Training Hydro testing Quality Assurance Program Radiological Control Program Industrial Safety Program 	<p>Relative to B31.3, the piping and hoses designed to withstand the deadhead pressure of fluidizing pump ECRT-P-52.</p> <p>Spills of IXM water constitute a minor radiological hazard to facility workers based on operational experience at the KW Basin.</p>
1.a-10	Time Procedure	Too short	<ul style="list-style-type: none"> Operator error Equipment failure (ECRT-HS-8, ECRT-SOV-2, ECRT-AOV-2) Loss of instrument air 	<p>Operational Upset:</p> <p>If the fluidizing jet pulse duration is too short, then sludge in the Engineered Container will not be undercut and thus will not collapse into the zone of influence of the Coanda head. This will result in a reduced vol% solids content of the retrieved sludge which could result in additional fill/decant cycles.</p>	<ul style="list-style-type: none"> % solids instrumentation (AE-710-101) Valve ECRT-AOV-2 position and fault condition indicator instrumentation (ZSO-700-7, and -8) 	<ul style="list-style-type: none"> Procedures Training 	<p>To operate the fluidizing jets, the operator presses and holds the "start fluidizing" switch. This increases the speed of ECRT-P-52 and opens valve ECRT-SOV-2 that provides instrument air to valve ECRT-AOV-2 which then opens permitting IXM water flow to the fluidizing jets. The jets are typically pulsed for of duration of 3 to 10 seconds. In this deviation, the duration of the pulses is less than 3 seconds.</p>
1.a-11	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Equipment failure (ECRT-HS-8, ECRT-SOV-2, ECRT-AOV-2) 	<p>Operational Upset:</p> <p>If the fluidizing jet pulse duration is too long, then the average vol% solids content of the retrieved sludge will be lower than desired which could result in additional fill/decant cycles.</p> <p>In the extreme case where the jets are turned on and left on, then 42 gpm of IXM water would be added to the Engineered Container while only ~30 gpm net would be withdrawn by the transfer system. Consequently, ~12 gpm of sludge/water slurry would flow from the engineered container into the basin.</p>	<ul style="list-style-type: none"> % solids instrumentation (AE-710-101) Valve ECRT-AOV-2 position and fault condition indicator instrumentation (ZSO-700-7, and -8) IXM water flow rate instrumentation (FIT-700-2) 	<ul style="list-style-type: none"> Procedures Training 	<p>In this deviation, the duration of the pulses is greater than 10 seconds.</p>

Table C-2. HAZOP Results, Node 1.a., Sludge Retrieval – IXM Water to Xago Hydrolance™ Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.a-12	Time Procedure	Skip action	Operator error	Operation Upset: If the fluidizing jets are not pulsed, then sludge will not be mobilized and drawn into the Coanda head. This will result in a reduced vol% solids content of the retrieved sludge which could result in additional fill/decant cycles.	% solids instrumentation (AE-710-101)	<ul style="list-style-type: none">• Procedures• Training	
1.a-13	Time Procedure	Wrong action (too frequent)	<ul style="list-style-type: none">• Operator error• Erroneous % solids indication	Operational Upset: If the operator pulses the fluidizing jets too frequently, then the average vol% solids of the retrieved sludge will be higher than desired. If the frequency is sufficiently high, the consequences are the same as pulsing for too long, i.e., the average vol% solids content of the retrieved sludge will be lower than desired.	% solids instrumentation (AE-710-101)	N/A	In this deviation, operators pulse the fluidizing jets more frequently than required.

Table C-3. Normal Operating Conditions, Node 1.b., Sludge Retrieval – IXM Motive Water to Xago Hydrolance™		
Process Parameter	Design Intent	Remarks
Flow	Nominally 41 gpm	Motive force is motive flow pump ECRT-P-51. Variable frequency drive (ECRT-VFD-510) varies the speed of the motive flow pump as a function of the flow rate at the booster pump suction as measured by flow element FE-710-101. The speed is increased or decreased to maintain a flow rate of approximately 70 gpm.
Pressure	Upstream of pump ECRT-P-51 = 100-130 psi Downstream of pump ECRT-P-51 = 213 psi	None
Concentration	Not applicable	The Skimmer Water Cleanup System takes basin water and pumps it first through a sand filter (for water clarity) and then through an IXM (to remove ionic species). The IXM water composition/concentration is not a critical attribute of Xago Hydrolance™ operability, i.e., Coanda performance would be identical using basin water versus IXM water.
Composition	Not applicable	There are no other process fluids at the KW Basin that could be inadvertently connected or directed to the Xago pump skid.
Structural Integrity	Maintain integrity under normal operating conditions	The IXM water lines are a combination of piping and hoses.
Level	Not applicable	There are no vessels associated with this node.
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin is maintained at a temperature of 10-15 °C. The IXM water is approximately the same temperature as the basin water, i.e., the pumps of the Skimmer Water Cleanup System do not impart significant thermal energy to the water. Fluctuations in basin water temperature occur very slowly. The IXM water temperature is not a critical attribute of Xago Hydrolance™ operability, i.e., Coanda head performance would be identical for a wide range of basin water temperatures.
Time Procedure	The motive water is turned on prior to lowering the Xago Hydrolance™ into the sludge	A portion of the motive water flow is directed to the Coanda head which fluidizes the sludge near the bottom of the Xago Hydrolance™ thus allowing it to penetrate the sludge column and be lowered to the bottom of the Engineered Container.

Table C-4. HAZOP Results, Node 1.b., Sludge Retrieval – IXM Motive Water to Xago Hydrolance™							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.b-1.a	Flow	No (at start-up)	<ul style="list-style-type: none">• No IXM water supply from the Skimmer Water Cleanup System• A normally-open valve is closed	<p>Operational Upset:</p> <p>If there is no motive water flow because there is no IXM water supply, or because valve ECRT-V-701, ECRT-AOV-1, ECRT-V-3, or valve ECRT-V-5 is closed, then there will be no motive water. Consequently, it may not be possible to lower the Xago Hydrolance™ into the sludge bed.</p> <p>Booster pump ECRT-P-101 will continue to operate but will be suction-starved. The Xago Hydrolance™ could plug. The rupture disk downstream of booster pump ECRT-P-101 could rupture.</p> <p>If there is no motive water flow because valve ECRT-V-5 is closed, then motive flow pump ECRT-P-51 would deadhead and could overheat. Deadheading the pump would result in high pressure in the line downstream of the pump (see Item 1.b-6 below).</p>	<ul style="list-style-type: none">• Valve position indicators• IXM water pressure instrumentation (PT-700-1B, -2B, -3B)• IXM water flow rate instrumentation (FIT-700-1, -2)• % solids instrumentation (AE-710-01)	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration	<p>It would be readily apparent to operators at the start-up of retrieval operations if there was no IXM water supply.</p> <p>Motive pump ECRT-P-51 is a centrifugal pump. If it was not operating IXM water would still flow through the pump at the flow rate and pressure provided by the IXM water system.</p> <p>Valves ECRT-AOV-1 is an air-operated valve. The valve close on loss of air. The valve also closes on loss of power to solenoid-operated valve ECRT-SOV-1.</p>

Table C-4. HAZOP Results, Node 1.b., Sludge Retrieval – IXM Motive Water to Xago Hydrolance™							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.b-1.b	Flow	No (during operation)	<ul style="list-style-type: none"> No IXM water supply from the Skimmer Water Cleanup System A normally-open valve is closed 	<p>Operational Upset:</p> <p>If there is no motive water flow because there is no IXM water supply, or because valve ECRT-V-701, ECRT-AOV-1, ECRT-V-3, or valve ECRT-V-5 is closed, then there will be no motive water.</p> <p>Booster pump ECRT-P-101 will continue to operate but will be suction-starved. The Xago Hydrolance™ could plug. The rupture disk downstream of booster pump ECRT-P-101 could rupture.</p> <p>If there is no motive water flow because valve ECRT-V-5 is closed, then motive flow pump ECRT-P-51 would deadhead and could overheat. Deadheading the pump would result in high pressure in the line downstream of the pump (see Item 1.b-6 below).</p>	<ul style="list-style-type: none"> Valve position indicators IXM water pressure instrumentation (PT-700-1B, -2B, -3B) IXM water flow rate instrumentation (FIT-700-1, -2) % solids instrumentation (AE-710-01) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	Motive pump ECRT-P-51 is a centrifugal pump. If it was not operating IXM water would still flow through the pump at the flow rate and pressure provided by the IXM water system.
1.b-2	Flow	Low	<ul style="list-style-type: none"> Low IXM water supply flow rate from the Skimmer Water Cleanup System Motive flow pump ECRT-P-51 not operating Motive flow pump ECRT-P-51 speed low A normally-open valve is partially closed 	<p>Operational Upset:</p> <p>Similar to the no flow deviation, if the motive water flow is low because of a low flow rate from the IXM water supply, booster pump ECRT-P-101 will continue to operate but will be suction-starved. The Xago Hydrolance™ could plug. The rupture disk downstream of booster pump ECRT-P-101 could rupture.</p> <p>If there is low motive water flow because valve ECRT-V-701 or ECRT-AOV-1 is partially closed, then booster pump ECRT-P-101 will continue to operate but will be suction-starved. The consequences are as stated above.</p>	<ul style="list-style-type: none"> Valve position indicators IXM water pressure instrumentation (PT-700-1B, -2B, -3B) IXM water flow rate instrumentation (FIT-700-1) % solids instrumentation (AE-710-01) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	Motive flow pump ECRT-P-51 is a centrifugal pump. If it was not operating IXM water would still flow through the pump at the flow rate and pressure provided by the IXM water system.

Table C-4. HAZOP Results, Node 1.b., Sludge Retrieval – IXM Motive Water to Xago Hydrolance™							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.b-3	Flow	High	Motive flow pump ECRT-P 5 speed high	<p>Operational Upset:</p> <p>If the motive water flow rate is high but less than 70 gpm, then the vol% solids content of the retrieved sludge will be reduced.</p> <p>If the motive water flow rate is greater than 70 gpm, then only IXM water would be transferred and flow in excess of 70-gpm would be directed into the Engineered Container.</p>	<ul style="list-style-type: none"> IXM water pressure instrumentation (PT-700-3B) IXM water flow rate instrumentation (FIT-700-1) % solids instrumentation (AE-710-01) 	<ul style="list-style-type: none"> Procedures Training 	
1.b-4	Flow	Reverse	Booster pump ECRT-P-101 runs in reverse (see remarks)	<p>Uncontrolled Release/Radiological Control:</p> <p>If booster pump ECRT-P-101 runs in reverse, then sludge/basin water could flow into the motive water IXM water supply line to a point above the basin water.</p> <p>If the motive water IXM water supply line failed due to the pressure generated by pump ECRT-P-101, then a spray or splash and splatter/pool release could occur.</p> <p>If air is pumped into an Engineered Container, then it will bubble to the surface of basin water and could result in elevated airborne radioactivity levels.</p>	<ul style="list-style-type: none"> IXM water pressure instrumentation (PT-700-1B, -2B) IXM water flow rate instrumentation (FIT-700-1) Check valves ECRT-CV-1 and ECRT-CV-3 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program 	See Table C-2, Item 1.a-4
1.b-5	Flow	Misdirected (to basin)	Pressure safety valve ECRT-PSV-1 inadvertently opens	<p>Operational Upset:</p> <p>If pressure safety valve ECRT-PSV-1 is open, then all or a portion of the motive water will be directed into the basin. Sludge will not be retrieved or will be retrieved at a reduced rate.</p>	None	None	

Table C-4. HAZOP Results, Node 1.b., Sludge Retrieval – IXM Motive Water to Xago Hydrolance™							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.a.-6	Flow	Misdirected (to Xago Hydrolance™ fluidizing jet connection)	Operator error in making hose connections	Operational Upset: If motive water hose ECRT-H-4 was erroneously connected to the Xago Hydrolance™ fluidizing jet connector and fluidizing hose ECRT-H-2 was connected to motive water connector, then sludge would not be efficiently retrieved because (1) the motive water would not fluidize the sludge effectively and (2) the fluidizing jet flow rate is low when the jets are not operated.	None	<ul style="list-style-type: none"> Procedures Training Operations verifies proper system configuration 	There are two Xago Hydrolances™; one located in the center bay and one located in the east bay. Process connection errors could occur when switching retrieval operations from one bay to the next. The connections are made at the grating level.
1.b-6	Pressure	Low	<ul style="list-style-type: none"> Motive flow pump ECRT-P-51 not operating Motive flow pump speed set incorrectly 	Operational Upset: If the motive water pressure is low, then the flow rate will be low. Booster pump ECRT-P-101 will continue to operate but will be suction-starved. The Xago Hydrolance™ could plug. The rupture disk downstream of booster pump ECRT-P-101 could rupture.	<ul style="list-style-type: none"> IXM water pressure instrumentation (PT-700-2B) IXM water flow rate instrumentation (FIT-700-2) % solids instrumentation (AE-710-01) 	<ul style="list-style-type: none"> Procedures Training 	
1.b-7	Pressure	High	<ul style="list-style-type: none"> A normally-open valve is closed Booster pump ECRT-P-101 not operating 	Uncontrolled Release/Industrial Safety: If the pressure is high, then the motive water IXM water supply line could fail at a location above the basin water. This would result in a spill of IXM water (see remarks). If the failure occurred in hose ECRT-H-10, located above the basin water, then the hose could whip and potentially injure a facility worker.	<ul style="list-style-type: none"> Pressure safety valve ECRT-PSV-1 Valve position indicators IXM water pressure instrumentation (PT-700-2B) Hose tie-downs 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Radiological Control Program Industrial Safety Program 	Pressure safety valve ECRT-PSV-1 provided for compliance with B31.3, "Process Piping." Spills of IXM water constitute a minor radiological hazard to facility workers based on operational experience at the KW Basin.

Table C-4. HAZOP Results, Node 1.b., Sludge Retrieval – IXM Motive Water to Xago Hydrolance™							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
1.b-8	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure Manufacturing flaw Procurement error 	<p>Uncontrolled Release/Industrial Safety:</p> <p>If the motive water IXM water supply line failed at a location above the basin water, then IXM water would be spilled (see remarks).</p> <p>If a rupture of hose ECRT-H-10 occurred, then the hose could whip and potentially injure a facility worker.</p>	<ul style="list-style-type: none"> IXM water pressure instrumentation (PT-700-3B) Hose tie-downs 	<ul style="list-style-type: none"> Procedures Training Hydro testing Quality Assurance Program Radiological Control Program Industrial Safety Program 	Spills of IXM water constitute a minor radiological hazard to facility workers based on operational experience at the KW Basin.
1.b-9	Time Procedure	Too fast	<ul style="list-style-type: none"> Operator error Hoist control failure 	<p>Operational Upset:</p> <p>If the Xago Hydrolance™ is lowered too quickly into the sludge, then the hydrolance could become plugged. Booster pump ECRT-P-101 will continue to operate but will be suction-starved. The rupture disk downstream of booster pump ECRT-P-101 could rupture</p>	<ul style="list-style-type: none"> Hoist operates at fixed speed % solids instrumentation (AE-710-01) 	<ul style="list-style-type: none"> Procedures Training 	The Xago Hydrolance™ is lowered into the sludge by the use of a hoist.
1.b-10	Time Procedure	Too slow	<ul style="list-style-type: none"> Operator error Hoist control failure 	<p>Operational Upset:</p> <p>If the Xago Hydrolance™ is lowered too slowly, then there will be a reduced vol% solids content of the retrieved sludge which could result in additional fill/decant cycles.</p>	<ul style="list-style-type: none"> Hoist operates at fixed speed % solids instrumentation (AE-710-01) IXM water flow rate instrumentation (FT-700-2) 	<ul style="list-style-type: none"> Procedures Training 	
1.b-11	Time Procedure	Skip action	Operator error	<p>Operation Upset:</p> <p>If the Xago Hydrolance™ is not lowered into the sludge, then only IXM water would be transferred to the STSC.</p>	% solids instrumentation (AE-710-01)	<ul style="list-style-type: none"> Procedures Training 	
1.b-12	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There are no wrong actions that an operator could make relative to lowering the Xago Hydrolance™ in addition to the deviations too fast, too slow, and skip action.

Table C-5. Normal Operating Conditions, Node 2.a., Sludge Transfer – Engineered Container to Ingress/Egress Pipe

Process Parameter	Design Intent	Remarks
Flow	70 gpm	Motive force is booster pump ECRT-P-101
Pressure	Upstream of pump ECRT-P-101 = -5 to 0 psi At booster pump ECRT-P-101 discharge = 80-100 psi	The discharge pressure is a function of the vol% solids in the sludge. A higher vol% solids will result in a higher discharge pressure.
Concentration	KE/KW sludge: minimum average 5 vol% solids Settler tank sludge: minimum average 2 vol% solids	For engineered containers 210, 220, 240, 250, and 260 the as-settled sludge in the containers is 24-25 vol% solids. For engineered container 230 (which contains settler tank sludge) the as-settled sludge in the container is 30 vol% solids. During transfers, operators control the volume percent solids by pulsing the fluidizing jets based on readings from the percent solids meter. The process flowsheet concentration is an average of at least 5 vol% solids for KE/KW sludge and at least 2 vol% solids for settler tank sludge. In testing conducted with KW sludge simulant, the Xago Hydrolance™ transferred an average 10.3 vol% solids with a peak of 16.3 vol% solids. In testing with settler tank sludge simulant, the average was 4.4 vol% solids with a peak of 8.1 vol% solids.
Composition	Addressed in Node 2.c	Deviations from the intended composition of the transfer are initiated in this node (i.e., Xago Hydrolance™ inserted into wrong engineered container) but the associated potential consequences occur at the STSC. Deviations in composition are therefore addressed in Node 2.c, “Sludge Transfer – STSC.”
Structural Integrity	Maintain integrity under normal operating conditions	The transfer lines from the engineered containers to the ingress/egress pipe are a combination of piping and hoses.
Level	Not applicable	Level is “not applicable” because there are no vessels associated with this node. However, this node is part of the Sludge Transfer node which does include transfer to the STSC. STSC normal operating fill levels, which determine the time procedure of the transfer, are as follows: KE/KW sludge = 3.31 m ³ of slurry Settler tank sludge = 2.7 m ³ of slurry. The STSC level is specifically addressed in Node 2.c., “Sludge Transfer - STSC.”
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin is maintained at a temperature of 10-15 °C. The sludge in the containers and the IXM motive water and fluidizing jet water are approximately the same temperature as the basin water. Accordingly, the sludge transfer will also be approximately the same temperature as the basin water. A calculation of the temperature increase due to booster pump operation indicates a less than 0.5 °F temperature increase.

Table C-5. Normal Operating Conditions, Node 2.a., Sludge Transfer – Engineered Container to Ingress/Egress Pipe

Process Parameter	Design Intent	Remarks
Time Procedure	KE/KW sludge: First fill = nominally 13 minutes Settler tank sludge: First fill = nominally 10 minutes	For KE/KW sludge, 3.31 m ³ of slurry is transferred into an STSC. For settler tank sludge the volume transferred is 2.7 m ³ . At the planned transfer rate of 70 gpm, it takes approximately 13 minutes to transfer 3.31 m ³ , and approximately 10 minutes to transfer 2.7 m ³ . Following the first fill/decant cycle, additional sludge transfers will be of shorter duration.

Table C-6. HAZOP Results, Node 2.a., Sludge Transfer – Engineered Container to Ingress/Egress Pipe							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.a-1	Flow	No	<ul style="list-style-type: none"> Booster pump ECRT-P-101 is not operating A normally-open valve downstream of booster pump ECRT-P-101 is closed Transfer line plugged 	<p>Operational Upset:</p> <p>If there is no flow, then sludge will not be transferred to the STSC.</p> <p>If there is no flow in the transfer line and motive flow pump ECRT-P-5 continues to operate, then 41 gpm of IXM water will be pumped into the Engineered Container. This would disturb the sludge bed and result in a carry-over of sludge into the basin.</p> <p>If there is no flow because a normally open valve is closed, then booster pump ECRT-P-101 would deadhead. This would result in high pressure in the transfer line downstream of the pump and opening of rupture disk ECRT-PSE-101 or -102 leading to a discharge of sludge under the basin water surface (see Item 2.a-6 below).</p>	<ul style="list-style-type: none"> Booster pump “on” indicator light (ECRT-IL-110) Valve position indicators Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PT-710-101, -102) STSC level instrumentation (LE-740-401) Rupture disks ECRT-PSE-101 and -102. 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control on basin water level 	Rupture disks provided for compliance with B31.3, “Process Piping.”
2.a-2	Flow	Low	<ul style="list-style-type: none"> Booster pump ECRT-P-101 speed low A normally-open valve is partially closed Transfer line partially plugged 	<p>Operational Upset:</p> <p>If there is low flow in the transfer line, then it will take longer to fill the STSC to the required level.</p> <p>If the flow rate is low enough, then solids will not be transferred and could plug the line.</p> <p>If the line becomes completely plugged, then it would deadhead the pump resulting in a high pressure in the transfer line downstream of the pump (see Item 2.a-6 below).</p>	<ul style="list-style-type: none"> Valve position indicators Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PTI-710-101, -102) STSC level instrumentation (LE-740-401) Rupture disks ECRT-PSE-101 and -102 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control on basin water level 	<p>Rupture disks provided for compliance with B31.3, “Process Piping.”</p> <p>Rupture disks ECRT-PSE-101 and -102 prevent the uncontrolled release above the basin water as addressed in Node 2.b.</p> <p>The booster pump speed is controlled by variable frequency drive ECRT-VFD-101. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p>

Table C-6. HAZOP Results, Node 2.a., Sludge Transfer – Engineered Container to Ingress/Egress Pipe							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.a-3	Flow	High	Booster pump ECRT-P-101 speed high	<p>Operational Upset:</p> <p>If the flow rate is high, then the STSC will be filled faster.</p> <p>If the flow rate is sufficiently high, then the booster pump will become suction-starved. This could cause rupture disk ECRT-PSE-101 or -102 downstream of the pump to rupture and sludge would be released under the basin water surface.</p>	<ul style="list-style-type: none"> Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PI-710-101, -102) STSC level instrumentation (LE-740-401) Rupture disks ECRT-PSE-101 and -102 	<ul style="list-style-type: none"> Procedures Training Administrative control on basin water level 	<p>Rupture disks provided for compliance with B31.3, "Process Piping."</p> <p>Rupture disks ECRT-PSE-101 and -102 prevent the uncontrolled release above the basin water as addressed in Node 2.b.</p> <p>The booster pump speed is controlled by variable frequency drive ECRT-VFD-101. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p>
2.a-4	Flow	Reverse	<p>Booster pump ECRT-P-101 runs in reverse (see remarks)</p> <p>See also Table C-8, Item 2.b-4</p>	<p>Uncontrolled Release/Radiological Control:</p> <p>The consequences are as stated in Table C-2, Item 1.a-4, and Table C-4, Item 1.b-4.</p>	<ul style="list-style-type: none"> Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PT-710-101, -102) Check valves ECRT-CV-1 and ECRT-CV-3 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program 	See Table C-2, Item 1.a-4
2.a-5	Pressure	Low	<ul style="list-style-type: none"> Booster pump ECRT-P-101 speed low Low vol% solids 	<p>Operational Upset:</p> <p>If the booster pump speed is low, then the flow rate will be low. The consequences are as stated in Item 2.a-2 above.</p> <p>If the slurry concentration is low, then the booster pump discharge pressure will be low.</p>	<ul style="list-style-type: none"> Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PT-710-101, -102) STSC level instrumentation (LE-740-401) 	<ul style="list-style-type: none"> Procedures Training 	

Table C-6. HAZOP Results, Node 2.a., Sludge Transfer – Engineered Container to Ingress/Egress Pipe							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.a-6	Pressure	High	<ul style="list-style-type: none"> Booster pump ECRT-P-101 speed high A normally-open valve is closed Transfer line plugged High vol% solids 	<p>Operational Upset:</p> <p>If the booster pump speed is high, then the flow rate will be high and the STSC will be filled faster.</p> <p>If the pressure is sufficiently high, then rupture disk ECRT-PSE-101 or -102 would fail and sludge would be released under the basin water surface.</p> <p>In an unmitigated scenario where no credit is taken for the rupture disks, then high pressure could result in a transfer line failure and, for this particular node, sludge would be released under the basin water surface.</p>	<ul style="list-style-type: none"> Valve position indicators Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PT-710-101, -102) Rupture disks ECRT-PSE-101 and ECRT-PSE-102 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control on basin water level 	<p>Rupture disks provided for compliance with B31.3, "Process Piping."</p> <p>Rupture disks ECRT-PSE-101 and -102 prevent the uncontrolled release above the basin water as addressed in Node 2.b.</p>
2.a-7	Concentration	No	<p>Xago Hydrolance™ not lowered into sludge due to:</p> <ul style="list-style-type: none"> Operator error Hoist control failure 	<p>Operational Upset:</p> <p>If the Xago Hydrolance™ is not lowered into the sludge, then only IXM water and basin water will be transferred to the STSC. This would result in an additional fill/decant cycle.</p>	<p>% solids instrumentation (AE-710-101)</p>	<ul style="list-style-type: none"> Procedures Training 	
2.a-8	Concentration	Low	<ul style="list-style-type: none"> Fluidizing jet maloperation (see Table C-2) High motive water flow rate Xago Hydrolance™ lowered too slow 	<p>Operational Upset:</p> <p>If the vol% solids is low, then additional fill/decant cycles will be required.</p>	<ul style="list-style-type: none"> % solids instrumentation (AE-710-101) IXM water pressure instrumentation (PT-700-1B, -2B, -3B) IXM water flow rate instrumentation (FIT-700-1, -2) 	<ul style="list-style-type: none"> Procedures Training 	

Table C-6. HAZOP Results, Node 2.a., Sludge Transfer – Engineered Container to Ingress/Egress Pipe							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.a-9	Concentration	High	<ul style="list-style-type: none"> • Xago Hydrolance™ lowered into sludge too fast • Fluidizing jets pulsed too frequently 	<p>Operational Upset:</p> <p>If the vol% solids is too high, then sludge may settle out in the transfer line and form a plug. If a plug forms and booster pump ECRT-P-101 continues to operate, then rupture disk ECRT-PSE-101 or -102 would fail and sludge would be released under the surface of the basin water.</p> <p>In an unmitigated scenario where no credit is taken for the rupture disk, then high pressure could result in a transfer line failure and, for this particular node, sludge would be released under the surface of the basin water.</p>	<ul style="list-style-type: none"> • % solids instrumentation (AE-710-101) • Flow rate instrumentation (FIT-710-101) • Pressure instrumentation (PT-710-101, -102) • Rupture disk ECRT-PSE-101 and -102 	<ul style="list-style-type: none"> • Procedures • Training • Administrative control on basin water level 	Rupture disks provided for compliance with B31.3, "Process Piping."
2.a-10	Composition	Other	See Table C-10, Item 2.c-7	See Table C-10, Item 2.c-7	See Table C-10, Item 2.c-7	See Table C-10, Item 2.c-7	Deviations from the intended composition of the transfer are initiated in this node (i.e., Xago Hydrolance™ inserted into wrong engineered container) but the associated potential consequences occur at the STSC. Deviations in composition are therefore addressed in Node 2.c, "Sludge Transfer – STSC."
2.a-11	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> • High pressure (see Item 2.a-6 above) • Pulsation damper failure • Manufacturing flaw • Procurement error 	<p>Operational Upset:</p> <p>For this particular node, if the transfer line failed, sludge would be released under the surface of the basin water</p>	<ul style="list-style-type: none"> • Flow rate instrumentation (FIT-710-101) • Pressure instrumentation (PT-710-101, -102) 	<ul style="list-style-type: none"> • Procedures • Training • Hydro testing • Visual observation • Quality Assurance Program • Administrative control on basin water level 	
2.a-12	Time Procedure	Too fast	High flow rate (see Item 2.a-3 above)	<p>Operational Upset:</p> <p>If the flow rate is high, then the STSC will be filled to the required level in a shorter time period.</p>	<ul style="list-style-type: none"> • Flow rate instrumentation (FIT-710-101) • Pressure instrumentation (PT-710-101, -102) • STSC level instrumentation (LE-740-401) 	<ul style="list-style-type: none"> • Procedures • Training 	

Table C-6. HAZOP Results, Node 2.a., Sludge Transfer – Engineered Container to Ingress/Egress Pipe							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.a-13	Time Procedure	Too slow	Low flow rate (see Item 2.a-2 above)	Operational Upset: If the flow rate is low, then it will take longer to fill the STSC to the required level.	<ul style="list-style-type: none">• Flow rate instrumentation (FIT-710-101)• Pressure instrumentation (PT-710-101, -102)• STSC level instrumentation (LE-740-401)	<ul style="list-style-type: none">• Procedures• Training	
2.a-14	Time Procedure	Skip action	N/A	N/A	N/A	N/A	There is no skipped action associated with this node.
2.a-15	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There is no wrong action associated with this node.

Table C-7. Normal Operating Conditions, Node 2.b., Sludge Transfer – Ingress/Egress Pipe to STSC

Process Parameter	Design Intent	Remarks
Flow	70 gpm	Motive force is booster pump ECRT-P-101
Pressure	At booster pump ECRT-P-101 discharge = 80 -100 psi	The discharge pressure is a function of the vol% solids in the sludge. A higher vol% solids will result in a higher discharge pressure.
Concentration	KE/KW sludge: minimum average 5 vol% solids Settler tank sludge: minimum average 2 vol% solids	For engineered containers 210, 220, 240, 250, and 260 the as-settled sludge in the containers is 24-25 vol% solids. For engineered container 230 (which contains settler tank sludge) the as-settled sludge in the container is 30 vol% solids. During transfers, operators control the volume percent solids by pulsing the fluidizing jets based on readings from the percent solids meter. The process flowsheet concentration is an average of at least 5 vol% solids for KE/KW sludge and at least 2 vol% solids for settler tank sludge. In testing conducted with KW sludge simulant, the Xago Hydrolance™ transferred an average 10.3 vol% solids with a peak of 16.3 vol% solids. In testing with settler tank sludge simulant, the average was 4.4 vol% solids with a peak of 8.1 vol% solids.
Composition	KE/KW sludge is to be transferred to an STSC that does not contain an inner core Settler tank sludge to transferred to an STSC that contains and inner core	Deviations in composition are addressed in Node 2.c, "Sludge Transfer – STSC."
Structural Integrity	Maintain integrity under normal operating conditions	The transfer lines from the engineered containers to the ingress/egress pipe are a combination of piping and hoses.
Level	Not applicable	Level is "not applicable" because there are no vessels associated with this node. However, this node is part of the Sludge Transfer node which does include transfer to the STSC. STSC normal operating fill levels, which determine the time procedure of the transfer, are as follows: KE/KW sludge = 3.3 m ³ of slurry Settler tank sludge = 2.7 m ³ of slurry. The STSC level is specifically addressed in Node 2.c., "Sludge Transfer - STSC."
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin is maintained at a temperature of a 10-15 °C. The sludge in the containers and the IXM motive water and fluidizing jet water are approximately the same temperature as the basin water. Accordingly, the sludge transfer will also be approximately the same temperature as the basin water. A calculation of the temperature increase due to booster pump operation indicates a less than 0.5 °F temperature increase.

Table C-7. Normal Operating Conditions, Node 2.b., Sludge Transfer – Ingress/Egress Pipe to STSC

Process Parameter	Design Intent	Remarks
Time Procedure	KE/KW sludge: First fill = 13 minutes Settler tank sludge: First fill = 10 minutes	For KE/KW sludge, 3.31 m ³ of slurry is transferred into an STSC. For settler tank sludge the volume transferred is 2.7 m ³ . At the planned transfer rate of 70 gpm, it takes approximately 13 minutes to transfer 3.31 m ³ , and approximately 10 minutes to transfer 2.7 m ³ . Following the first fill/decant cycle, additional sludge transfers will be of shorter duration.

Table C-8. HAZOP Results, Node 2.b., Sludge Transfer – Ingress/Egress Pipe to STSC

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.b-1	Flow	No	See Table C-6, Item 2.a-1	See Table C-6, Item 2.a-1	See Table C-6, Item 2.a-1	See Table C-6, Item 2.a-1	See Table C-6, Item 2.a-1
2.b-2	Flow	Low	See Table C-6, Item 2.a-2	See Table C-6, Item 2.a-2	See Table C-6, Item 2.a-2	See Table C-6, Item 2.a-2	See Table C-6, Item 2.a-2
2.b-3	Flow	High	Booster pump ECRT-P-101 speed high	<p>Uncontrolled Release:</p> <p>If the flow rate is high because booster pump ECRT-P-101 speed is high, then the booster pump will become suction-starved. This could cause rupture disk ECRT-PSE-101 or -102 downstream of the booster pump to rupture and sludge would be released under the basin water surface.</p> <p>In an unmitigated scenario where no credit is taken for the rupture disks, then the transfer line downstream of the booster pump could fail (see remarks). This could result in an airborne spray or splash and splatter/pool release of sludge.</p> <p>See also Item 2.b-6 below.</p>	<ul style="list-style-type: none"> Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PT-710-101, -102) Rupture disks ECRT-PSE-101 and -102 Secondary containment with leak detection Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training 	<p>If the booster pump was suction-starved and a rupture disk did not rupture, it is possible that the transfer line downstream of the booster pump could fail. The booster pump speed is controlled by variable frequency drive ECRT-VFD-101. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p> <p>Rupture disks provided for compliance with B31.3, "Process Piping."</p>
2.b-4.a	Flow	Reverse	Booster pump ECRT-P-101 runs in reverse	See Table C-6, Item 2.a-4	See Table C-6, Item 2.a-4	See Table C-6, Item 2.a-4	See Table C-6, Item 2.a-4
2.b-4.b	Flow	Reverse	Siphon from STSC (see remarks)	<p>Uncontrolled Release:</p> <p>If sludge was siphoned from the STSC due to a breach in the transfer line, then a splash and splatter/pool release could occur.</p>	<ul style="list-style-type: none"> Secondary containment with leak detection Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training 	<p>For a siphon to occur: (1) the liquid level in the STSC would need to be above the level of the distributor heads, and (2) a breach in the transfer line below the elevation of the liquid level would need to occur prior to opening the transfer line high-point siphon break. If a siphon occurred, sludge would then be drawn from the STSC until it reached the level of the distributor heads at which point a siphon break would be established.</p> <p>If the STSC was full of sludge, approximately 190 gallons could be siphoned out.</p>

Table C-8. HAZOP Results, Node 2.b., Sludge Transfer – Ingress/Egress Pipe to STSC

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.b-5.a	Flow	Misdirected (into Transfer Line Service Box)	<ul style="list-style-type: none"> Valving error such that sludge enters box via IXM water spray nozzles Valving error such that sludge enters box via siphon break Valving error such that sludge enters box via sump pump 	<p>Uncontrolled Release:</p> <p>If sludge is misdirected into the Transfer Line Service Box, then a splash and splatter/pool release would occur.</p> <p>Hydrogen Deflagration:</p> <p>If sludge is misdirected into the Transfer Line Service Box, then hydrogen generated by the sludge could accumulate in the box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Valve position indicators Check valve ECRT-CV-106 (on sump pump transfer line) Secondary containment with leak detection Transfer Line Service Box active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Leak detection alarm response Modified KW Basin Annex is unmanned during decant operations 	
2.b-5.b	Flow	Misdirected (into Transfer Line Service Box IXM water supply)	Valving error	<p>Uncontrolled Release:</p> <p>If sludge is misdirected into the Transfer Line Service Box IXM water supply, then a spray or splash and splatter/pool release could occur.</p>	<ul style="list-style-type: none"> Valve position indicators Isolation valve ECRT-AOV-104 Check valve ECRT-CV-105 Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations 	
2.b-5.c	Flow	Misdirected (into decant/flocculant recirculation line)	Valving error	<p>Uncontrolled Release:</p> <p>If sludge is misdirected into the decant/flocculant recirculation line, then the line could be overpressurized and fail resulting in as spray or splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Valve position indicators Isolation valve ECRT-AOV-105 Check valve ECRT-CV-202 Secondary containment with lead detection Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations 	Check valve ECRT-CV-202 is located in the Decant Box.

Table C-8. HAZOP Results, Node 2.b., Sludge Transfer – Ingress/Egress Pipe to STSC

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.b-5.d	Flow	Misdirected (to overflow recovery pump)	Valving error	Uncontrolled Release: If the slurry flow is misdirect to the overflow recovery pump, then booster pump ECRT-P-101 will deadhead resulting in high pressure in the transfer line. In an unmitigated scenario where no credit is taken for the rupture disks, then high pressure could result in a transfer line failure resulting in an airborne spray or splash and splatter/pool release.	<ul style="list-style-type: none"> Valve position indicators Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PT-710-101, -102) Rupture disks ECRT-PSE-101 and -102 Secondary containment with leak detection Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	Rupture disks provided for compliance with B31.3, "Process Piping."
2.b-6	Pressure	Low	See Table C-6, Item 2.a-5	See Table C-6, Item 2.a-5	See Table C-6, Item 2.a-5	See Table C-6, Item 2.a-5	See Table C-6, Item 2.a-5
2.b-7	Pressure	High	<ul style="list-style-type: none"> Booster pump ECRT-P-101 speed high A normally-open valve is closed Transfer line plugged 	Uncontrolled Release: In an unmitigated scenario where no credit is taken for the rupture disks, then high pressure could result in a transfer line failure resulting in an airborne spray or splash and splatter/pool release.	<ul style="list-style-type: none"> Valve position indicators Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PT-710-101, -102) Rupture disks ECRT-PSE-101 and -102 Secondary containment with leak detection Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	Secondary containment includes the hose-in-hose transfer line and the transfer line service box. Rupture disks provided for compliance with B31.3, "Process Piping."
2.b-8	Concentration	No	See Table C-6, Item 2.a-7	See Table C-6, Item 2.a-7	See Table C-6, Item 2.a-7	See Table C-6, Item 2.a-7	See Table C-6, Item 2.a-7
2.b-9	Concentration	Low	See Table C-6, Item 2.a-8	See Table C-6, Item 2.a-8	See Table C-6, Item 2.a-8	See Table C-6, Item 2.a-8	See Table C-6, Item 2.a-8

Table C-8. HAZOP Results, Node 2.b., Sludge Transfer – Ingress/Egress Pipe to STSC

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.b-10	Concentration	High	<ul style="list-style-type: none"> Xago Hydrolance™ lowered into sludge too fast Fluidizing jets pulsed too frequently 	<p>Operational Upset:</p> <p>If the vol% solids is too high, then sludge may settle out in the transfer line and form a plug. If a plug forms and booster pump ECRT-P-101 continues to operate, then rupture disk ECRT-PSE-101 would fail and sludge would be released under the surface of the basin water.</p> <p>Uncontrolled Release:</p> <p>In an unmitigated scenario where no credit is taken for the rupture disk, then high pressure could result in a transfer line failure resulting in an airborne spray or splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PE-710-101, -102) Rupture disks ECRT-PSE-101 and -102 Secondary containment with leak detection Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training 	Rupture disks provided for compliance with B31.3, "Process Piping."
2.b-11	Composition	Other	See Table C-10, Item 2.c-7	See Table C-10, Item 2.c-7	See Table C-10, Item 2.c-7	See Table C-10, Item 2.c-7	Deviations in composition are addressed in Node 2.c, "Sludge Transfer – STSC."
2.b-12	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure (see Item 2.b-7 above) Pulsation damper failure Manufacturing flaw Procurement error External event 	<p>Uncontrolled Release:</p> <p>If the transfer line leaks or ruptures, then there will be an airborne spray or splash and splatter/pool release.</p> <p>Hydrogen Deflagration:</p> <p>If the transfer line leaks or ruptures inside the transfer line service box, then sludge would be spilled into the box. Hydrogen generated by the sludge could accumulate in the box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Flow rate instrumentation (FI-710-101) Pressure instrumentation (PI-710-101, -102) Rupture disk ECRT-PSE-101 and -102 Secondary containment with leak detection Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Hydro testing Quality Assurance Program Leak detection alarm response 	Rupture disks provided for compliance with B31.3, "Process Piping."
2.b-13	Time Procedure	Too fast	See Table C-6, Item 2.a-12	See Table C-6, Item 2.a-12	See Table C-6, Item 2.a-12	See Table C-6, Item 2.a-12	See Table C-6, Item 2.a-12
2.b-14	Time Procedure	Too slow	See Table C-6, Item 2.a-13	See Table C-6, Item 2.a-13	See Table C-6, Item 2.a-13	See Table C-6, Item 2.a-13	See Table C-6, Item 2.a-13
2.b-15	Time Procedure	Skip action	N/A	N/A	N/A	N/A	There is no skipped action associated with this node.

Table C-8. HAZOP Results, Node 2.b., Sludge Transfer – Ingress/Egress Pipe to STSC

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.b-16	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There is no wrong action associated with this node.

Table C-9. Normal Operating Conditions, Node 2.c., Sludge Transfer – STSC

Process Parameter	Design Intent	Remarks
Flow	70 gpm	Sludge flows into the STSC at 70 gpm.
Pressure	-1 in. wg	The Modified KW Annex ventilation system maintains the STSC at negative air pressure differential relative to the surrounding room.
Concentration	Not applicable (see as-settled sludge level)	The volume percent solids in the STSC is a function of the volume percent solids of the slurry transferred in; consequences associated with high and low solids in the transfer lines are addressed in Tables C-3-, C-5, and C-7. Relative to the sludge in the STSC, the volume percent solids is addressed as a limit on the volume of the as-settled sludge; see table entry for “as-settled sludge level.”
Composition	KE/KW sludge is to be transferred into an STSC that does not contain an inner core Settler tank sludge is to be transferred into an STSC that contains an inner core	There are two STSC designs: one for KE and KW Basin sludge stored in Engineered Containers 210, 220, 240, 250, and 260, and one for settler tank sludge stored in Engineered Container 230. The difference in design is that the STSC for settler tank sludge containers an inner cylinder. The annular region created by the inner cylinder contains sludge whereas the inside of the cylinder contains water which provides a heat transfer mechanism for heat generated by radiolytic decay and by the reaction of uranium metal with water.
Structural Integrity	Maintain integrity under normal operating conditions	The STSC is a pressure vessel rated at 150 psi.
Level	<u>Slurry level:</u> KE/KW sludge = 3.3 m ³ of slurry Settler tank sludge = 2.7 m ³ of slurry	When the slurry level in the STSC reaches the first level switch set (LS-740-401), indicator light ECRT-IL-401 on retrieval/transfer control panel ECRT-PNL-101 is activated. Operators then begin to raise the Xago Hydrolance™ from the sludge. Booster pump ECRT-P-101 continues to pump 70 gpm to the STSC but the volume percent solids decreases as the Xago Hydrolance™ is withdrawn from the sludge. When the slurry level reaches the second level switch (LSH-740-401), interlock I-5 is activated which shuts off the IXM water supply to the Hydrolance™ and opens basin water valve ECRT-AOV-101. Booster pump ECRT-P-101 continues to pump 70 gpm to the STSC but is now pumping basin water which flushes sludge from the transfer line. When the slurry level reaches the third level switch (LSHH-740-401), interlock I-4 is activated which shuts off booster pump ECRT-P-101.
	<u>As-settled sludge level:</u> KE sludge = 2.1 m ³ KW sludge = 1.6 m ³ Settler tank sludge = 0.5 m ³	The KE and KW sludge volume limits are established so that sludge would still be contained within the STSC in the event of safety basis sludge expansion. If the limits were exceeded, then the expanding sludge could escape the STSC through vent ports during storage at T Plant. The settler sludge volume limit is established to maintain thermal stability. The actual as-settled sludge level in the STSC is not measured. What is measured is the differential weight between an STSC filled with water and an STSC filled with water and sludge. Using the as-settled sludge densities in HNF-SD-WM-TI-015, Vol 2, the differential weight can be correlated to an as-settled sludge volume.
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin is maintained at a temperature of a 10-15 °C. The sludge in the containers and the IXM motive water and fluidizing jet water are approximately the same temperature as the basin water. Accordingly, the sludge transferred to the STSC will also be approximately the same temperature as the basin water. A calculation of the temperature increase due to booster pump operation indicates a less than 0.5 °F temperature increase.
Time Procedure	KE/KW sludge: First fill = 13 minutes Settler tank sludge: First fill = 10 minutes	For KE/KW sludge, 3.31 m ³ of slurry is transferred into an STSC. For settler tank sludge the volume transferred is 2.7 m ³ . At the planned transfer rate of 70 gpm, it takes approximately 13 minutes to transfer 3.31 m ³ , and approximately 10 minutes to transfer 2.7 m ³ . Following the first fill/decant cycle, additional sludge transfers will be of shorter duration.

Table C-10. HAZOP Results, Node 2.c., Sludge Transfer – STSC							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.c-1	Flow	No	<ul style="list-style-type: none"> Booster pump ECRT-P-101 is not operating A normally-open valve downstream of booster pump ECRT-P-101 is closed 	Operational Upset: If there is no flow, then sludge will not be transferred to the STSC.	<ul style="list-style-type: none"> Valve position indicators Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PE-710-101, -102) STSC level instrumentation (LE-740-401) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	
2.c-2	Flow	Low	<ul style="list-style-type: none"> Booster pump ECRT-P-101 speed low A normally-open valve is partially closed 	Operational Upset: If the flow rate is low, then it will take longer to fill the STSC to the required level.	<ul style="list-style-type: none"> Valve position indicators Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PT-710-101, -102) STSC level instrumentation (LE-740-401) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	
2.c-3	Flow	High	Booster pump ECRT-P-101 speed high	Operational Upset: If the flow rate is high, then the STSC will be filled faster.	<ul style="list-style-type: none"> Flow rate instrumentation (FIT-710-101) Pressure instrumentation (PE-710-101, -102) STSC level instrumentation (LE-740-401) 	<ul style="list-style-type: none"> Procedures Training 	
2.c-4.a	Flow	Reverse	Booster pump ECRT-P-101 runs in reverse	See Table C-6, Item 2.a-4	See Table C-6, Item 2.a-4	See Table C-6, Item 2.a-4	See Table C-6, Item 2.a-4
2.c-4.b	Flow	Reverse	Siphon from STSC	See Table C-8, Item 2.b-4.b	See Table C-8, Item 2.b-4.b	See Table C-8, Item 2.b-4.b	See Table C-8, Item 2.b-4.b
2.c-5	Pressure	Low	See Table C-12, Item 2.d-5	See Table C-12, Item 2.d-5	See Table C-12, Item 2.d-5	See Table C-12, Item 2.d-5	Under normal operating conditions, the ventilation system maintains a pressure of -1 in. wg in the STSC during transfers. The STSC ventilation system is specifically addressed in Node 2.d.

Table C-10. HAZOP Results, Node 2.c., Sludge Transfer – STSC

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.c-6	Pressure	High	See Table C-12, Item 2.d-6	See Table C-12, Item 2.d-6	See Table C-12, Item 2.d-6	See Table C-12, Item 2.d-6	Under normal operating conditions, the ventilation system maintains a pressure of -1 in. wg in the STSC during transfers. The STSC ventilation system is specifically addressed in Node 2.d.
2.c-7.a	Composition	Other (settler tank sludge retrieved instead of KE/KW sludge)	Xago Hydrolance™ lowered into incorrect Engineered Container due to operator error	<p>Overpressurization:</p> <p>The STSC sludge limits have been established, in part, to prevent the sludge from reaching a temperature of approximately 100 °C in order to prevent excessive headspace pressures. If the Xago Hydrolance™ is erroneously lowered into SCS-CON-230, then settler tank sludge would be retrieved into an STSC without an annulus. Placing settler tank sludge in an STSC without an annulus could result in the sludge temperature reaching 100 °C and overpressurizing the STS cask.</p> <p>Hydrogen Deflagration:</p> <p>The STSC sludge limits have been established, in part, to control the hydrogen concentration in the headspace of the STSC. Placing settler tank sludge in an STSC without an annulus could result in a hydrogen deflagration.</p>	<ul style="list-style-type: none"> • Overfill recovery tool • Modified KW Basin Annex confinement ventilation • STSC active ventilation • Auxiliary ventilation system • Nitrogen gas purge • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Administrative control on shipping window 	<p>If the deviation was discovered, the overfill recovery tool could be used to remove the majority of the settler tank sludge from the STSC without an inner core and return it to SCS-CON-230.</p> <p>There is no labeling at the grating level to indicate which Engineered Container is below. The location of Engineered Containers is known from facility general arrangement drawings. Specifically, SCS-CON-210, -220, and -230 are located in the Bay 2 (center bay) in a left to right sequence when facing north. SCS-CON-240, -250, and -260 are located in Bay 1 (east bay) in a left to right sequence when facing north.</p>

Table C-10. HAZOP Results, Node 2.c., Sludge Transfer – STSC

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.c-7.b	Composition	Other (KE/KW sludge retrieved instead of settler tank sludge)	Xago Hydrolance™ lowered into incorrect Engineered Container due to operator error	Radiological Control: If the Xago Hydrolance™ is erroneously lowered into a container other than SCS-CON-230, then KE or KW Basin sludge would be retrieved into an STSC with an inner core. This could result in higher than expected dose rates at the top of the STSC. In addition, If the sludge were to subsequently expand at the safety basis expansion rate, then sludge could escape the STSC during long-term storage at T Plant.	Overfill recovery tool	<ul style="list-style-type: none"> • Procedures • Training • Radiological Control Program. 	If the deviation was discovered, the overfill recovery tool could be used to remove the majority of the KE/KW sludge from the STSC with an inner core and return it the originating Engineered Container.
2.c-7.c	Composition	Other (KE sludge retrieved instead of KW sludge)	Xago Hydrolance™ lowered into incorrect Engineered Container due to operator error	Operational Upset: If the Xago Hydrolance™ is erroneously lowered into SCS-CON-240, -250, or -260 instead of SCS-CON-210 or -220, then KE sludge would be retrieved instead of KW sludge. There are no associated hazardous conditions.	None	<ul style="list-style-type: none"> • Procedures • Training 	If the deviation was discovered, then additional sludge could be added to the STSC up to the KE sludge level limit.
2.c-7.d	Composition	Other (KW sludge retrieved instead of KE sludge)	Xago Hydrolance™ lowered into incorrect Engineered Container due to operator error	Radiological Control (T Plant): If the Xago Hydrolance™ is erroneously lowered into SCS-CON-210 or 220 instead of SCS-CON-240, -250, or -260, then KW sludge would be retrieved instead of KE sludge. Consequently, the STSC volume limit for KW sludge would be exceeded. If the sludge were to subsequently expand at the safety basis expansion rate, then sludge could escape the STSC during long-term storage at T Plant.	Overfill recovery tool	<ul style="list-style-type: none"> • Procedures • Training • Radiological Control Program 	If the deviation was discovered, the overfill recovery tool could be used to remove KW sludge to within the KW sludge level limit.

Table C-10. HAZOP Results, Node 2.c., Sludge Transfer – STSC

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.c-8	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure (see Table 2-12, Item 2.d-6.b) Manufacturing flaw Corrosion 	<p>Uncontrolled Release:</p> <p>For non-pressurized scenarios, if the breach occurred above the liquid level, then contaminated air could exit the STSC.</p> <p>For non-pressurized scenarios, if the breach occurred below the liquid level, then sludge would leak into the STS cask.</p> <p>The consequences of a leak due to high pressure are as stated in Table 2-12, Item 2.d-6b.</p>	<ul style="list-style-type: none"> STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Hydro testing Quality Assurance Program 	The STSC active ventilation system maintains a negative air pressure differential of -1 in. wg.
2.c-9.a	Level (slurry)	Low	<ul style="list-style-type: none"> Instrumentation and control failure Booster pump ECRT-P-101 failure Loss of electrical power 	<p>Operational Upset:</p> <p>If the transfer is stopped when the slurry level is low, then additional fill/decant cycles would be required.</p>	None	None	
2.c-9.b	Level (as-settled sludge)	Low	<ul style="list-style-type: none"> Instrumentation and control failure Operator error 	<p>Operational Upset:</p> <p>If an STSC is sent to T Plant with a low as-settled sludge level, then additional STSCs will be required to complete the project.</p>	None	None	
2.c-10.a	Level (KE/KW slurry)	High	Instrumentation and control failure	<p>Uncontrolled Release:</p> <p>If the KE/KW slurry transfer is not stopped, then the STSC will be overfilled and slurry will be pumped into the 4-in and 1-in. ventilation exhaust lines and into the 1-in. ventilation inlet line leading to a splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training 	High level switch LSH-740-402 and emergency stop switch ECRT-ES-1 activate sequence I-3 which shuts of booster pump ECRT-P-101 and IXM water pumps ECRT-P-51, and -52.

Table C-10. HAZOP Results, Node 2.c., Sludge Transfer – STSC

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.c-10.b	Level (settler tank slurry)	High	Instrumentation and control failure	<p>Uncontrolled Release:</p> <p>If the settler tank slurry transfer is not stopped, then the STSC will be overfilled and slurry will be pumped into the 4-in and 1-in. ventilation exhaust lines and into the 1-in. ventilation inlet line leading to a splash and splatter/pool release.</p> <p>Overpressurization:</p> <p>Thermal modeling of settler tank sludge in an STSC with an annulus assumes that the core region is filled with water. If the settler sludge level is high, then a small amount of sludge could enter the core region. If a large amount of sludge was present in the core region, then the sludge temperature could eventually reach 100 °C and overpressurize the STS cask.</p> <p>Hydrogen Deflagration:</p> <p>Gas generation analyses of settler sludge in an STSC with an annulus assume that the core region if filled with water. If the settler sludge level is high, then a small amount of sludge could enter the core region. If a large amount of sludge was present in the core region, a hydrogen deflagration could occur.</p>	<ul style="list-style-type: none"> Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Modified KW Basin Annex confinement ventilation STSC active ventilation Auxiliary ventilation system Nitrogen gas purge Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Administrative control on shipping window 	<p>It is unlikely that a large amount of sludge could enter the core region. The core region and STSC are initially filled with IXM water to a specified level. The volume of the core region above this level is approximately 33 gallons. Thus if the STSC were to be overfilled, the maximum amount of settler slurry that could enter the core region would be 33 gallons at 5 vol% solid, which is equivalent to 0.02 m³ of as-settled sludge.</p> <p>A worst-case scenario would be if there was no IXM water in the core region and the STSC was overfilled. As IXM water is supplied to the STSC by overfilling the core region, if there was no IXM water in the core region there would be no IXM water in the STSC. This condition would be readily apparent to operators who record the weight of the STSC when it is empty and again when it is filled with water.</p>
2.c-10.c	Level (KE/KW as-settle sludge)	High	<ul style="list-style-type: none"> Instrumentation and control failure Operator error 	<p>Radiological Control (T Plant)</p> <p>If the as-settled sludge level is high and the sludge was to subsequently expand at the safety basis expansion rate, then sludge could escape the STSC during long-term storage at T Plant.</p>	<ul style="list-style-type: none"> Differential weight switch DWSH-740-401 STSC level indicator LIT-740-401 Truck weight indicator WIT-740-401 Overfill recovery tool 	<ul style="list-style-type: none"> Procedures Training STSC sludge limit verification Radiological Control Program 	<p>The STSC as-settled sludge limits for KE and KW sludge (2.1 and 1.6 m³, respectively) are based on ensuring that sludge it still contained in the STSC during storage at T Plant</p> <p>Differential weight switch DWSH-740-401 activates interlock I-5 which opens the basin flush valve and terminates the slurry transfer. The switch is set to prevent exceeding as-settled sludge limits.</p>

Table C-10. HAZOP Results, Node 2.c., Sludge Transfer – STSC							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.c-10.d	Level (settler tank as-settled sludge)	High	<ul style="list-style-type: none">• Instrumentation and control failure• Operator error	<p>Overpressurization:</p> <p>Settler tank sludge limits have been established, in part, to prevent the sludge from reaching a temperature of 100 °C in order to prevent excessive headspace pressures. If the as-settled sludge level is high, then the sludge temperature could reach 100 °C and overpressurize the STS cask.</p> <p>Hydrogen Deflagration:</p> <p>The settler tank sludge limits have been established, in part, to control the hydrogen concentration in the headspace of the STSC. If the as-settled sludge level is high, then a hydrogen deflagration could occur.</p>	<ul style="list-style-type: none">• Differential weight switch DWSH-740-401• STSC level indicator LIT-740-401• Truck weight indicator WIT-740-401• Overfill recovery tool• Modified KW Basin Annex confinement ventilation• STS active ventilation• Auxiliary ventilation system• Nitrogen gas purge• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• STSC sludge limit verification• Administrative control on shipping window	As stated in HNF-41051, the STSC as-settled sludge limit for settler tank sludge (0.5 m ³) is based thermal and hydrogen gas generation analyses to avoid exceeding a temperature of 100 °C.
2.c-11	Time Procedure	Too fast	See Table C-6, Item 2a-12	See Table C-6, Item 2a-12	See Table C-6, Item 2a-12	See Table C-6, Item 2a-12	See Table C-6, Item 2a-12
2.c-12	Time Procedure	Too slow	See Table C-6, Item 2.a-13	See Table C-6, Item 2.a-13	See Table C-6, Item 2.a-13	See Table C-6, Item 2.a-13	See Table C-6, Item 2.a-13
2.c-13	Time Procedure	Skip action	N/A	N/A	N/A	N/A	There is no skipped action associated with this node.
2.c-14	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There is no wrong action associated with this node.

Table C-11. Normal Operating Conditions, Node 2.d., Sludge Transfer – STSC Ventilation

Process Parameter	Design Intent	Remarks
Flow	5 cfm (at -1 in. wg)	The ventilation system is credited with maintaining a flow rate of > 1 cfm when sludge is present in the STSC to prevent flammable concentrations of Hydrogen in the STSC headspace.
Pressure	-1 in. wg	The Modified KW Annex ventilation system maintains the STSC at negative air pressure differential relative to the surrounding room.
Concentration	<u>Inlet:</u> Not Applicable	See "Composition"
	<u>Outlet:</u> Moisture <100% relative humidity Radionuclides = TBD	The allowable relative humidity for HEPA filters is 70%. The STSC exhaust air is diluted by approximately 40:1 in the HEPA filter plenum by building exhaust air. The calculated relative humidity in the HEPA filter plenum is ~50% relative humidity when exhaust from demisters ERCT-DMS-501 and -502 is saturated. Testing to-date at MASF has not detected any liquid in the STSC exhaust stream. The radionuclide content of the STSC exhaust air stream has not been quantitatively estimated.
Composition	Room Air	Room air is drawn into the STSC via inlet HEPA filter ECRT-HEPA-541 and hose ECRT-H-604. Hose ECRT-H-604 is a 1-in. hose that connects to the STSC at Nozzle S2.
Structural Integrity	Maintain integrity under normal operating conditions	The STSC ventilation flow path is a combination of hoses, ductwork and HEPA filters.
Level	5 - 17 gallons	Tank ECRT-TK-502 is a 20 gallon tank. It is equipped with high and low level alarms set at 17 and 5 gallons, respectively.
Temperature	Not applicable	Ventilation air temperature is not a process parameter that is monitored or controlled. The annex HVAC system is design to maintain a minimum temperature of 65 °F (18 °C) given an outside temperature of 0 °F, and a maximum temperature of 80 °F (27 °C) given an outside temperature of 105 °F.
Time Procedure	Not applicable	The ventilation system is connected to the STSC when process connections are first made and operates continuously until it is time to prepare the STSC for shipping (see Node 5, "STSC Purge").

Table C-12. HAZOP Results, Node 2.d., Sludge Transfer – STSC Ventilation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.d-1	Flow	No	<ul style="list-style-type: none">• Air inlet valve ECRT-V-732 closed• STSC inlet HEPA filter plugged• Exhaust fan ECRT-EF-502 or -503 not operating	<p>Hydrogen Deflagration: If there is no ventilation system flow, then a hydrogen deflagration could occur.</p> <p>Radiological Control: If there is no ventilation system flow, then the pressure in the STSC will be slightly greater than atmospheric during a transfer. See Item 2.d-6.a below.</p>	<ul style="list-style-type: none">• Valve position indicators• STSC pressure indicator PI-760-652• STSC inlet ventilation flow rate instrumentation (FS-750-651) interlocked to Auxiliary Ventilation System• Auxiliary Ventilation System• STSC inlet HEPA filter differential pressure instrumentation (DPIT-750-560)• Exhaust HEPA filter differential pressure instrumentation (DPI-750-512, and -516)• Redundant exhaust fans• Modified KW Basin Annex confinement ventilation (given operable exhaust fan)• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Radiological Control Program• Conduct of operations verifies proper system configuration	
2.d-2	Flow	Low	<ul style="list-style-type: none">• Inlet HEPA filter partially plugged• Air Inlet and outlet valves set incorrectly• Exhaust fan ECRT-EF-502 or -503 speed low	<p>Hydrogen Deflagration: If the flow rate falls below 1 cfm, then a hydrogen deflagration could occur.</p>	<ul style="list-style-type: none">• Valve position indicators• STSC pressure indicator PI-760-652• STSC inlet ventilation flow rate instrumentation (FS-750-651) interlocked to Auxiliary Ventilation System• Auxiliary Ventilation System• Exhaust HEPA filter differential pressure instrumentation (DPI-750-512, and -516)• Redundant exhaust fans• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration	

Table C-12. HAZOP Results, Node 2.d., Sludge Transfer – STSC Ventilation

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.d-3	Flow	High	<ul style="list-style-type: none"> Air inlet and outlet valves set incorrectly Exhaust fan ECRT-EF-502 or -503 speed high 	<p>Radiological Control:</p> <p>If the flow rate is high, then more aerosol may be swept out of the STSC. This could result in increased deposition in the vent line resulting in an increased dose rate and an increased potential for contamination. See also Item 2.d-8.a below.</p>	<ul style="list-style-type: none"> Valve position indicators STSC pressure indicator PI-760-652 STSC inlet ventilation flow rate instrumentation (FS-750-651) Exhaust HEPA filter differential pressure instrumentation (DPI-750-512, and -516) Redundant exhaust fans Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Conduct of operations verifies proper system configuration 	
2.d-4	Flow	Reverse	N/A	N/A	N/A	N/A	There is no motive force to create a reverse flow during transfers.
2.d-5	Pressure (absolute)	Low (less than -1.0 in. wg)	<ul style="list-style-type: none"> Air inlet and outlet valves set incorrectly Exhaust fan ECRT-EF-502 or -503 speed high 	<p>Radiological Control:</p> <p>If the pressure is low (i.e., less than -1.0 in. wg), then the flow rate will increase. If the flow rate is high, then more aerosol may be swept out of the STSC. Consequences are as stated in Item 2.d-3 above.</p>	<ul style="list-style-type: none"> Valve position indicators STSC pressure indicator PI-760-652 Exhaust HEPA filter differential pressure instrumentation (DPI-750-512, and -516) Redundant exhaust fans Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Conduct of operations verifies proper system configuration 	Under normal operating conditions, the ventilation system establishes a pressure of -1 in. wg in the STSC during transfers. The maximum negative pressure the STSC can experience is approximately -2 in. wg.

Table C-12. HAZOP Results, Node 2.d., Sludge Transfer – STSC Ventilation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.d-6	Pressure (absolute)	High (greater than -1.0 in. wg)	<ul style="list-style-type: none"> No flow (see Item 2.d-1, above) Low flow (see Item 2.d-2, above) 	Radiological Control: If the pressure in the STSC is greater than atmospheric, then the potential exists for a spread of contamination.	<ul style="list-style-type: none"> Valve position indicators STSC pressure indicator PI-760-652 STSC inlet ventilation flow rate instrumentation (ECRT-IL-651) Exhaust HEPA filter differential pressure instrumentation (DPI-750-512, and -516) Redundant exhaust fans Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Conduct of operations verifies proper system configuration 	The supply air to the STSC is room air infiltration via HEPA filter ECRT-HEPA-541. In this node, the only energy source available to pressurize the STSC is the 70 gpm transfer. Air is exhausted from the STSC via 4-in. vent line ECRT-H-501 and 1-in. vent line ECRT-H-659. There will only be a slight increase in pressure as both the 4-in. and 1 in. vents lines will still be open.
2.d-7.a	Concentration (moisture in STSC exhaust)	Low	No sludge in STSC	None	None	None	
2.d-7.b	Concentration (radionuclide in STSC exhaust)	Low	No sludge in STSC	None	None	None	
2.d-8.a	Concentration (moisture in STSC exhaust)	High	High flow rate, see Item 2.d-3 above	Radiological Control: If there is too much moisture in the exhaust air, then the HEPA filters could be damaged.	<ul style="list-style-type: none"> STSC pressure indicator PI-760-652 STSC inlet ventilation flow rate instrumentation (ERCT-IL-651) Demisters ECRT-DMS-501 and -502 Exhaust HEPA filter differential pressure instrumentation (DPI-750-512, and -516) Redundant HEPA filter trains Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program 	

Table C-12. HAZOP Results, Node 2.d., Sludge Transfer – STSC Ventilation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.d-8.b	Concentration (radionuclide in STSC exhaust))	High	High flow rate, see Item 2.d-3	Radiological Control: If the flow rate is high, then more aerosol may be swept out of the STSC. This could result in increased deposition in the vent line resulting in an increased dose rate and an increased potential for contamination.	<ul style="list-style-type: none"> • STSC pressure indicator PI-760-652 • STSC inlet ventilation flow rate instrumentation (ECRT-IL-651) • Exhaust HEPA filter differential pressure instrumentation (DPI-750-512, and -516) • Redundant exhaust fans • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Radiological Control Program 	
2.d-9	Composition (STSC inlet)	Other (nitrogen)	Air inlet and nitrogen purge valves set incorrectly	Operational Upset: When set to purge the STSC, the gas purge system flows 10 cfm of nitrogen. If the air inlet and nitrogen purge valves were set incorrectly, then the gas purge system would deliver 10 cfm of nitrogen. This is more than the normal 5 cfm of room air drawn in through HEPA ECRT-HEPA-541. The pressure in the STSC would increase above -1 in wg.	<ul style="list-style-type: none"> • Valve position indicators • STSC inlet ventilation flow rate instrumentation (ECRT-IL-651) 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration 	
2.d-10.a	Structural Integrity (STSC inlet line)	Leak/rupture	<ul style="list-style-type: none"> • Physical damage to inlet line • Hose ECRT-H-604 disconnects from STSC at nozzle S2 	Operational Upset: The inlet line is under suction. If there is leak/rupture in the line, then room air will be drawn into line via the leak/rupture. Air that is drawn in through the leak/rupture would not be filtered by inlet HEPA filter ECRT-HEPA-541.	STSC inlet ventilation flow rate instrumentation (ECRT-IL-651)	<ul style="list-style-type: none"> • Procedures • Training 	

Table C-12. HAZOP Results, Node 2.d., Sludge Transfer – STSC Ventilation

Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.d-10.b	Structural Integrity (STSC outlet line)	Leak/rupture	<ul style="list-style-type: none"> Physical damage to outlet line(s) Hose ECRT-H-501 disconnects from STSC at nozzle F1 Hose ECRT-H-659 disconnects from STSC at nozzle F2 	<p>Hydrogen Deflagration:</p> <p>If there is a leak/rupture in the outlet line, then the flow rate through the STSC will decrease. If the flow rate drops below 1 cfm, a hydrogen deflagration could occur.</p> <p>Radiological Control:</p> <p>The interior of the outlet lines will be contaminated. Although the lines are under negative pressure, if there is a leak/rupture then a spread of contamination could occur.</p>	<ul style="list-style-type: none"> STSC inlet ventilation flow rate instrumentation (FS-750-651) interlocked to Auxiliary Ventilation System Auxiliary Ventilation System Modified KW Basin Annex confinement ventilation (given operable exhaust fan) Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program 	
2.d.-10.c	Structural Integrity (exhaust HEPA filters)	Leak/rupture	<ul style="list-style-type: none"> High differential pressure (e.g., moisture build-up, particulate loading) Incorrect installation Manufacturing flaw Mechanical insult 	<p>Radiological Control:</p> <p>If the HEPA filters leak/rupture, then the exhaust air from the STSC would not be filtered, or would not be filtered as efficiently.</p>	<ul style="list-style-type: none"> Demisters ECRT-DMS-501 and -502 Exhaust HEPA filter differential pressure instrumentation (DPI-750-512, and -516) Redundant HEPA filter trains 	<ul style="list-style-type: none"> HEPA filter inspection and testing Quality Assurance Program Radiological Control Program 	
2.d-11	Level (demisters)	Low	None	None	None	None	
2.d-12	Level (demisters)	High	High moisture content of STSC exhaust air (see Item 2.d-8.a) or other inlet stream coupled with closed isolation valve ECRT-V-501)	<p>Radiological Control:</p> <p>If the liquid level in the demisters is high, then moisture will not be removed from the airstream. This could result in moisture build-up on the HEPA filters resulting in their failure.</p>	<ul style="list-style-type: none"> Demister differential pressure instrumentation DPI-750-514 and DPI-750-518 Exhaust HEPA filter differential pressure instrumentation (DPI-750-512, and -516) Redundant HEPA filter trains 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program 	

Table C-12. HAZOP Results, Node 2.d., Sludge Transfer – STSC Ventilation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
2.d-13	Level (condensate tank)	Low	<ul style="list-style-type: none">Instrumentation failureOperator error (failure to add water to tank)	<p>Radiological Control:</p> <p>If the liquid level in condensate tank ECRT-TK-502 drops below the diplegs, then the ventilation system will draw room air through the tank via the condensate tank vent. This will unbalance the confinement ventilation system airflows with the result that negative air pressure differentials may not be properly maintained leading to a spread of contamination.</p> <p>Hydrogen Deflagration:</p> <p>If the airflows are unbalanced to the point that less than 1 cfm is exhausted from the STSC, then a hydrogen deflagration could occur.</p>	<ul style="list-style-type: none">Condensate tank level instrumentation (LSL-750-501)STSC inlet ventilation flow rate instrumentation (FS-750-651) interlocked to Auxiliary Ventilation SystemAuxiliary ventilation systemModified KW Basin Annex confinement ventilationContinuous air monitors	<ul style="list-style-type: none">ProceduresTrainingRadiological Control Program	The condensate tank functions as a seal pot.
2.d-14	Level (condensate tank)	High	<ul style="list-style-type: none">High moisture content of STSC exhaust air (see Item 2.d-8.a) or other inlet air streamSTSC OverfillSand filter valving error (see Table C-14, Item 3-5.c and Table C-16, Item 4-5.c)	<p>Uncontrolled Release:</p> <p>If the liquid level in condensate tank ECRT-TK-502 is high, then the liquid can overflow the tank resulting in a splash and splatter/pool release.</p>	<ul style="list-style-type: none">Condensate tank level instrumentation (LSH-750-501)Modified KW Basin Annex confinement ventilationContinuous air monitors	<ul style="list-style-type: none">ProceduresTrainingRadiological Control Program	

Table C-13. Normal Operating Conditions, Node 3, STSC Decant		
Process Parameter	Design Intent	Remarks
Flow	10 – 40 gpm	Motive force is decant pump ECRT-P-201. Decant pump ECRT-P-201 is an air-operated, double-diaphragm (AODD) pump. In testing at MASF the decant rate is typically 20-25 gpm.
Pressure	85 psig	Pressure is controlled by the air pressure supplied to decant pump ECRT-P-201. The instrument air system produces 212 scfm of dry air at 120 psig. Pressure control valves are used to regulate the pressure to the pump.
Concentration	<u>Decanted supernate:</u> KE sludge = 11.9 g/L KW sludge = 16.8 g/L Settler tank sludge = 39.3 g/L	The concentrations shown are maximums as documented in HNF-40151. The use of flocculant may be required to lower the turbidity of the decanted supernate. See Node 8 and Node 9.
	<u>Clarified supernate:</u> ≤ 90 mg/L	The 90 mg/L value has been established to maintain adequate basin water clarity. PNNL has developed a correlation between turbidity and solids concentration; 210 NTUs roughly correlates to 90 mg/L. In testing at MASF, the clarified supernate has been between 5 and 10 NTUs.
Composition	STSC supernate	None
Level	<u>STSC level at start of decant:</u> KE/KW sludge = 925 gal Settler tank sludge = 765 gal <u>STSC level at end of final decant:</u> KE sludge = 2.1 m ³ KW sludge = 1.6 m ³ Settler tank sludge = 0.5 m ³	The level in the STSC is established by level switch LSHH-740-401. When the level reaches the setting for this switch, booster pump ECRT-P-101 is shut off. This establishes the level at the start of the decant. Level switch LSHH-740-401 is the same for both KE/KW sludge and settler tank sludge. The difference in the two volumes is due to the STSC inner cylinder used for settler tank sludge. The STSC level at the end of the final decant is assumed to be the as-settled sludge limits.
	<u>Sand filter level:</u> Typically the sand filter is full (i.e., there is no headspace) throughout the decant process	There is a headspace in the sand filters during the backwash process when the filters are partially drained preparatory to performance of an air scour. See Node 4. Testing as MASF has shown that there may be a headspace in the sand filter if the AODD pumps air into the sand filter at the end of a decant cycle.
Structural Integrity	Maintain integrity under normal operating conditions	None

Table C-13. Normal Operating Conditions, Node 3, STSC Decant		
Process Parameter	Design Intent	Remarks
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. When initially transferred to the STSC, the slurry temperature will be approximately 10-15 °C (i.e., the same as basin water). Once transferred, the slurry temperature will slowly increase based on two factors: (1) the ambient temperature in the Modified KW Basin Annex, and (2) the quantity of uranium metal in the slurry and rate of uranium metal oxidation. The annex HVAC system is design to maintain a minimum temperature of 65 °F (18 °C) given an outside temperature of 0 °F, and a maximum temperature of 80 °F (27 °C) given an outside temperature of 105 °F.
Time Procedure	Settling Time: 16 hours	The flowsheet model conservatively assumes flocculant is not added and the slurry is allowed to settle for 16 hours prior to decant.
	<u>Transfer Time:</u> KE sludge ~ 37 min KW sludge ~ 48 min Settler tank sludge ~ 67 min	The transfer times are estimates based on (1) level switch LSHH-740-401, (2) the as-settled sludge limits for an STSC as shown in Table C-9, and (3) a decant flow rate of 10 gpm. In practice, the transfer will continue until the in-line turbidity instrumentation/interlock shuts off the instrument air supply to decant pump ECRT-P-201.

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-1	Flow	No	<ul style="list-style-type: none">Decant pump ECRT-P-201 not operatingA normally-opened valve is closedSand filter media plugged	Operational Upset: If there is no flow, then the STSC will not be decanted. If there is no flow because a normally-opened valve is closed or because the sand filter media is plugged, then decant pump ECRT-P-201 will deadhead resulting in a high pressure. See item 3-7 below.	<ul style="list-style-type: none">Decant line pressure instrumentation (PT-720-202)Decant line flow instrumentation (FE-720-201)Select valves automatically positionedManual valve position indicators	<ul style="list-style-type: none">ProceduresTrainingConduct of operations verifies proper system configuration	
3-2	Flow	Low	<ul style="list-style-type: none">Low air pressure to decant pump ECRT-P-201A normally-opened valve is partially closedHigh sand filter differential pressureVacuum leak	Operational Upset: If the flow rate is low, then it will take longer to decant the STSC.	<ul style="list-style-type: none">Decant line pressure instrumentation (Pt-720-202)Decant line flow instrumentation (FE-720-201)Select valves automatically positionedManual valve position indicators	<ul style="list-style-type: none">ProceduresTrainingConduct of operations verifies proper system configuration	
3-3	Flow	High	High air pressure to decant pump ECRT-P-201	Operational Upset: If the flow rate is high, then the STSC will be decanted faster and the filtering will be less efficient. If the flow rate is sufficiently high, then channeling of the sand filter media could occur which would reduce the efficiency of the media resulting in fine particulates being returned to the basin and possible clouding of the basin water. The higher flow rate will result in a higher differential pressure across the sand filter. See also Item 3-7 below.	<ul style="list-style-type: none">Pressure control valve ECRT-PCV-760Pressure control valve ECRT-PCV-765Decant line pressure instrumentation (PT-720-201)Decant line flow instrumentation (FE-720-201)Sand filter differential pressure instrumentation (PT-720-205 and -206)	<ul style="list-style-type: none">ProceduresTraining	The maximum pump flow rate of 40 gpm may not be sufficient to cause channeling

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-4	Flow	Reverse	N/A	N/A	N/A	N/A	The only way to get reverse flow during decant would be install decant pump ECRT-P-201 backwards. Such an error would be discovered during pre-operational testing.
3-5.a	Flow	Misdirected (into Decant Pump Box)	<ul style="list-style-type: none"> Valving error such that supernate enters box via IXM water spray nozzles Valving error such that supernate enters box via siphon break 	<p>Uncontrolled Release:</p> <p>If supernate is misdirected into the Decant Pump Box, then a splash and splatter/pool release will occur.</p> <p>Hydrogen deflagration:</p> <p>If supernate is misdirected into the Decant Pump Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Manual valve position indicators Secondary confinement with leak detection Leak detection interlocked to shut off Decant pump ECRT-P-201 Decant Pump Box HEPA-filtered active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations Leak detection alarm response Visual observation 	The Decant Box is provided with Plexiglas windows that allow visual observation.
3-5.b	Flow	Misdirected (into Sand Filter Enclosure)	<ul style="list-style-type: none"> Pressure safety valve PSV-1A or -01B open Drain valve HV-03A/3B open Valving error such that supernate enters enclosure via siphon break (see remarks) 	<p>Uncontrolled Release:</p> <p>If supernate is misdirected into the Sand Filter Enclosure, then a splash and splatter/pool release will occur.</p> <p>Hydrogen Deflagration:</p> <p>If supernate is misdirected into the Sand Filter Enclosure, then hydrogen generated by the supernate could accumulate in the enclosure resulting in a deflagration.</p>	<ul style="list-style-type: none"> Manual valve position indicators Select valves automatically positioned Secondary confinement with leak detection Leak detection interlocked to shut off Decant pump ECRT-P-201 Sand Filter Enclosure HEPA-filtered active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations Leak detection alarm response 	<p>If pressure safety valve PSV-01A or -01B opens, then supernate will be directed in a controlled manner to the Sand Filter Enclosure sump.</p> <p>To get flow into the enclosure via the siphon break, valve FV-12 would have to be open.</p>

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-5.c	Flow	Misdirected (into sand filter sparge exhaust)	Valving error (FV-06A/B)	Uncontrolled Release: If supernate is misdirected into the sand filter sparge exhaust, then catch tank ECRT-TK-502 will overflow and a splash and splatter/pool release will occur.	<ul style="list-style-type: none">• Select valves automatically positioned• Catch tank level instrumentation (LSH-750-502)• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Modified KW Basin Annex is unmanned during decant operations	Valves FV-06A and FV-06B are single barriers preventing the flow of decanted supernate into the ventilation system.
3-5.d	Flow	Misdirected (into Decant Pump Box IXM water supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the Decant Pump Box IXM water supply, then a splash and splatter/pool release could occur.	<ul style="list-style-type: none">• Manual valve position indicators• Check valve ECRT-CV-201• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration• Modified KW Basin Annex is unmanned during decant operations	
3-5.e	Flow	Misdirected (into Sand Filter Enclosure IXM water supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the Sand Filter Enclosure IXM water supply, then a splash and splatter/pool release could occur.	<ul style="list-style-type: none">• Select valves automatically positioned• Check valve ECRT-CV-506	<ul style="list-style-type: none">• Procedures• Training• Modified KW Basin Annex is unmanned during decant operations• Continuous air monitors	
3-5.f	Flow	Misdirected (into Sand Filter Enclosure instrument air supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the Sand Filter Enclosure instrument air supply, then a splash and splatter/pool release could occur.	<ul style="list-style-type: none">• Select valves automatically positioned• Check valve ECRT-CV-409	<ul style="list-style-type: none">• Procedures• Training• Modified KW Basin Annex is unmanned during decant operations• Continuous air monitors	

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-5.g	Flow	Misdirected (into flocculant addition supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the flocculant addition supply, then a splash and splatter/pool release could occur.	<ul style="list-style-type: none">• Manual valve position indicators• Check valve ECRT-CV-202• Modified KW Basin Annex confinement ventilation	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration• Modified KW Basin Annex is unmanned during decant operations• Continuous air monitors	
3-5-h	Flow	Misdirected (bypass filter media)	Valving error	Operational Upset: If the filter media is bypassed, then the decanted supernate will be transferred directly to the basin which could cloud the basin water.	<ul style="list-style-type: none">• Select valves automatically positioned• Clarified supernate turbidity instrumentation (AE-720-202)	<ul style="list-style-type: none">• Procedures• Training	
3-6	Pressure	Low	Low air pressure to decant pump ECRT-P-201	Operational Upset: If the air pressure is low, then the flow rate will be low and it will take longer to decant the STSC.	Instrument air line pressure instrumentation (PT-770-766)	<ul style="list-style-type: none">• Procedures• Training	

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-7	Pressure	High	<ul style="list-style-type: none">• High air pressure to decant pump ECRT-P-201• A normally-opened valve is closed• Sand filter media plugged	Uncontrolled Release: If the pressure is high, then the decant line or sand filter could fail resulting in an airborne spray or splash and splatter/pool release.	<ul style="list-style-type: none">• Piping designed in accordance with B31.3, "Process Piping"• Select valves automatically positioned• Manual valve position indicators• Pressure control valve ECRT-PCV-760 and -765• Decant line pressure instrumentation (PT-720-202)• Sand filter differential pressure instrumentation (PT-720-205 and -206)• Secondary containment with leak detection• Leak detection interlocked to shut off Decant pump ECRT-P-201• Decant Pump Box HEPA-filtered active ventilation• Sand Filter Enclosure HEPA-filtered active ventilation• Modified KW Basin Annex confinement ventilation• Continuous air monitors• Pressure safety valve PSV-01A and -01B (see remarks)	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration• Modified KW Basin Annex is unmanned during decant operations	If Pressure safety valve PSV-01A or -01B opens, then supernate will be directed in a controlled manner to the Sand Filter Enclosure sump.
3-8.a	Concentration (decanted supernate)	Low	N/A	N/A	N/A	N/A	A low turbidity in the decanted supernate is desirable.

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-8.b	Concentration (clarified supernate)	Low	N/A	N/A	N/A	N/A	A low solids concentration in the clarified supernate is desirable.
3-9.a	Concentration (decanted supernate)	High	<ul style="list-style-type: none"> Settling time too short Operator error 	<p>Operational Upset:</p> <p>If the turbidity is too high, then the sand filter will begin to plug resulting in a high differential pressure. This would require additional backwashes.</p> <p>Uncontrolled Release:</p> <p>If the high turbidity results in plugging the sand filter, then decant pump ECRT-P-201 will deadhead resulting in a high pressure. The consequences are as stated in Item 3-7 above.</p>	<ul style="list-style-type: none"> Turbidity instrumentation (ASH-720-201) Sand filter differential pressure instrumentation (PT-720-205 and -206) Decant line pressure instrumentation (PT-720-202) Secondary containment with leak detection Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations 	
3-9.b	Concentration (clarified supernate)	High	<ul style="list-style-type: none"> Incorrect filter media Filter media channeling 	<p>Operational Upset:</p> <p>If there is a high concentration of solids in the clarified supernate, then in-basin activities will be impacted due to water clarity issues.</p>	<ul style="list-style-type: none"> Sand filter differential pressure instrumentation (PT-720-205 and -206) Clarified supernate turbidity instrumentation (AE-720-202) 	<ul style="list-style-type: none"> Procedures Training 	
3-10	Composition	Other (air)	<ul style="list-style-type: none"> Failure of turbidity instrumentation Operator error 	<p>Operational Upset:</p> <p>If the decant turbidity instrumentation fails or there is an operator error, then the pump will continue to decant the STSC until the floating decant head comes to rest on the sludge. (see remarks).</p>	<ul style="list-style-type: none"> Turbidity instrumentation (AE-720-201) Sand filter differential pressure instrumentation (PT-720-205 and -206) Decant line pressure instrumentation (PT-720-202) 	<ul style="list-style-type: none"> Procedures Training 	<p>In testing at MASF, when the floating decant head came to rest on the sludge it pumped sludge to the sand filter.</p> <p>If the AODD pump is allowed to continue operating it will begin to pump air. If air is pumped into the sand filter to the point that it dewateres the media, then the filter may not perform effectively in the future, in which case it would have to be replaced.</p>
3-11.a	Level (STSC)	Low	STSC not filled to proper level (see Table C-10, Items 2.c-9.a and .9b)	<p>Operational Upset:</p> <p>If the STSC liquid level is low, then the decant will be accomplished in a shorter period of time.</p>	<ul style="list-style-type: none"> STSC level switches LS/LSH/LSHH-740-401 	<ul style="list-style-type: none"> Procedures Training 	

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-11.b	Level (Sand Filter)	Low	<ul style="list-style-type: none"> Leaking valve (see remarks) Diaphragm failure such that air from AODD pump is entrained in decanted supernate 	Operational Upset: If the liquid level is low such that it falls below the level of the sand filter media, then the filtering efficiency of the sand filter will decrease.	<ul style="list-style-type: none"> Select valves automatically positioned Manual valve position indicators 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	If drain down valve FV-08A or -08B leaked and the siphon break was not open, then liquid in the sand filter would be siphoned to the basin to the level of the drain down valve.
3-12.a	Level (STSC)	High	STSC not filled to proper level (see Table C-10, Items 2.c-10.a and -b)	Operational Upset: If the STSC liquid level is high, then it will take longer to decant the STSC (see remarks).	<ul style="list-style-type: none"> STSC level switches LS/LSH/LSHH-740-401 	<ul style="list-style-type: none"> Procedures Training 	This Item assumes that the liquid level is higher than normal, but that the STSC has not been overfilled to the point that it overflows. Such a scenario is addressed in Node 2.c.
3-12.b	Level (Sand Filter)	High	N/A	N/A	N/A	N/A	The design intent is for the sand filter to be full (i.e., no head space)
3-13.a	Structural Integrity	Leak/rupture (diaphragm pump)	Decant pump ECRT-P-201 diaphragm failure	Uncontrolled Release: If the decant pump diaphragm failed, then supernate could enter the pump exhaust resulting in a spray or splash and splatter/pool release.	<ul style="list-style-type: none"> Decant line pressure instrumentation (PT-720-202) Decant line flow instrumentation (FE-720-201) HEPA filtration of decant pump exhaust Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Modified KW Basin Annex is unmanned during decant operations 	

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-13.b	Structural Integrity	Leak/rupture (sand filter)	<ul style="list-style-type: none"> High pressure (see Item 3-7 above) Manufacturing flaw 	<p>Uncontrolled Release:</p> <p>If the sand filter fails, then a spray or splash and splatter/pool release will occur inside the sand filter enclosure.</p> <p>Hydrogen Deflagration:</p> <p>If the sand filter fails, then decanted supernate would be spilled into the sand filter enclosure. Hydrogen generated by the supernate could accumulate in the enclosure resulting in a deflagration.</p>	<ul style="list-style-type: none"> Decant line pressure instrumentation (PT-720-202) Decant line flow instrumentation (FE-720-201) Pressure safety valve PSV-01A and -01B (see remarks) Secondary containment with leak detection Leak detection interlocked to shut off Decant pump ECRT-P-201 Sand Filter Enclosure HEPA-filtered confinement ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Quality Assurance Program Modified KW Basin Annex is unmanned during decant operations Leak detection alarm response 	If Pressure safety valve PSV-01A or -01B opens, then supernate will directed in a controlled manner to the Sand Filter Enclosure sump.
3-13.c	Structural Integrity	Leak/rupture (decant line – STSC to sand filter)	<ul style="list-style-type: none"> High pressure (see Item 3-7 above) Manufacturing flaw Hose connection decouples 	<p>Uncontrolled Release:</p> <p>If the decant line fails, then a spray or splash and splatter/pool release of STSC supernate will occur.</p> <p>Hydrogen deflagration:</p> <p>If the decant line leaks or ruptures inside the decant pump box, then decanted supernate would be spilled into the box. Hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Decant line pressure instrumentation (PT-720-202) Decant line flow instrumentation (FE-720-201) Secondary containment with leak detection Leak detection interlocked to shut off Decant pump ECRT-P-201 Decant Pump Box HEPA-filtered confinement Sand Filter Enclosure HEPA-filtered confinement ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Modified KW Basin Annex is unmanned during decant operations Leak detection alarm response 	The decant line is under suction from the STSC to decant pump ECRT-P-201.

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-13.d	Structural Integrity	Leak/rupture (decant line – sand filter to basin)	<ul style="list-style-type: none"> • Manufacturing flaw • Hose connection decouples • External event 	<p>Uncontrolled Release:</p> <p>If the decant line fails, then a spray or splash and splatter/pool release of filtered STSC supernate will occur.</p>	<ul style="list-style-type: none"> • Secondary containment with leak detection • Leak detection interlocked to shut off Decant pump ECRT-P-201 • Sand Filter Enclosure HEPA-filtered active ventilation • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Modified KW Basin Annex is unmanned during decant operations 	
3-14	Time Procedure	Too short	Instrumentation and control failure	<p>Operational Upset:</p> <p>If the decant occurs for too short a time, then less volume will be available for the subsequent slurry transfer. This will result in additional fill /decant cycles.</p>	<ul style="list-style-type: none"> • Turbidity instrumentation (AE—720-201) 	<ul style="list-style-type: none"> • Procedures • Training 	
3-15	Time Procedure	Too long	See Item 3-10 above	See Item 3-10 above	See Item 3-10 above	See Item 3-10 above	See Item 3-10 above
3-16	Time Procedure	Skip action	Operator error	<p>Uncontrolled Release:</p> <p>If the decant is not performed, the next process step is to backwash the sand filters. This would result in pumping 20-45 gpm of IXM water into the STSC. The STSC would go solid and liquid would be pumped into the 4-in and 1-in. ventilation exhaust lines and into the 1-in. ventilation inlet line leading to a splash and splatter/pool release.</p>	<ul style="list-style-type: none"> • High level switch LSH-740-402 • Emergency stop switch ECRT-ES-1 • Modified KW Basin Annex confinement ventilation 	<ul style="list-style-type: none"> • Procedures • Training • Modified KW Basin Annex is unmanned during decant operations • Continuous air monitors 	
3-17.a	Time Procedure	Wrong action (backwash instead of decant)	Operator error	See item 3-16 above	See item 3-16 above	See item 3-16 above	See item 3-16 above

Table C-14. HAZOP Results, Node 3, STSC Decant							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
3-17.b	Time Procedure	Wrong action (recirculate instead of decant)	Operator error	Operational Upset: If the supernate is recirculated instead of decanted, then no filtering of the supernate will occur (see remarks).	See Item 3-7 above.	<ul style="list-style-type: none">• Procedures• Training	Decant and recirculation operations are initiated by an operator pushing a button on the control panel. In this case, an operator erroneously pushes the recirculation button.

Table C-15. Normal Operating Conditions, Node 4, Sand Filter Backwash		
Process Parameter	Design Intent	Remarks
Flow	20-45 gpm	IXM water from the Skimmer Water Cleanup System is used to backwash the sand filters. The motive force is pump IXM-P-1 that is part of the Skimmer Water Cleanup System. The flow rate is set by throttle valve HCV-511.
Pressure	100-130 psi	The Skimmer Water Cleanup System supplies IXM water at 100 -130 psi. IXM water pressure for sand filter decant is not controlled. Subsequent to the HAZOP meetings, it was determined that the P&ID would be revised to include pressure regulation that would limit the pressure to 80-85 psi.
Concentration	<u>Solids concentration:</u> KE sludge = 100 g/L KW sludge = 73 g/L Settler tank sludge = 42 g/L	None
Composition	IXM water containing sludge solids	There are no other process fluids at the KW Basin that could be inadvertently connected and used to backwash the sand filters.
Level	<u>STSC level at start of backwash:</u> KE sludge = 2.1 m ³ KW sludge = 1.6 m ³ Settler tank sludge = 0.5 m ³ <u>STSC level at completion of backwash:</u> KE/KE sludge = 3.3 m ³ of slurry Settler tank sludge = 2.7 m ³ of slurry	The STSC level at the start of the backwash is assumed to be equal to the as-settled sludge limits, i.e., multiple fill/decant cycles have taken place and the final decant lowered the level the values shown. The liquid level in the STSC at the end of the backwash is established by level switch LSHH-740-401. LSHH-740-401 activates interlock I-4 which closes valve ECRT-AOV-701 which stops IXM water flow to the sand filters thus terminating the backwash.
	<u>Sand filter:</u> At the start of the backwash the sand filter is at the level of drain down valve FV-08A/B At the completion of the backwash the sand filter is full, i.e., there is no headspace.	None
Structural Integrity	Maintain integrity under normal operating conditions	None
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin are maintained at a temperature of 10-15 °C. The IXM water is approximately the same temperature as the basin water, i.e., the pumps of the Skimmer Water Cleanup System do not impart significant thermal energy to the water.

Table C-15. Normal Operating Conditions, Node 4, Sand Filter Backwash		
Process Parameter	Design Intent	Remarks
Time Procedure	<u>Transfer Time:</u> KE sludge ~ 7 to 15 min KW sludge ~ 10 to 23 min Settler tank sludge ~ 13 to 29 min	The transfer time estimates are based on the starting and ending STSC levels and assuming a backwash flow rate of 20-45 gpm.

Table C-16. HAZOP Results, Node 4, Sand Filter Backwash							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
4-1	Flow	No	<ul style="list-style-type: none">No IXM water supply from the Skimmer Water Cleanup SystemA normally-open valve is closedBackwash line plugged	Operational Upset: If there is no flow, then sand filter will not be backwashed. If there is no flow because a normally-opened valve is closed or because a line is plugged, then the pressure will be high (see Item 4-7 below).	<ul style="list-style-type: none">Select valves automatically controlledBackflush water volume instrumentation (FE-720-202)STSC level switches LS/LSH/LSHH-740-401Pressure instrumentation (PT-720-201)	<ul style="list-style-type: none">ProceduresTrainingConduct of operations verifies proper system configuration	
4-2	Flow	Low	<ul style="list-style-type: none">Low flow rate from the Skimmer Water Cleanup SystemThrottle valve HCV-511 set incorrectlyA normally-opened valve is partially closedSand filter media partially plugged	Operational Upset: If the flow rate is low, then solids may not be effectively backwashed from the sand filter. This will result in additional decant/backwash cycles.	<ul style="list-style-type: none">Select valves automatically controlledManual valve position indicatorsBackflush water volume (FE-720-202)STSC level switches LS/LSH/LSHH-740-401Pressure instrumentation (PT-720-201)	<ul style="list-style-type: none">ProceduresTrainingConduct of operations verifies proper system configuration	
4-3	Flow	High	<ul style="list-style-type: none">High flow rate from the Skimmer Water Cleanup SystemThrottle valve HCV-511 set incorrectly	Operational Upset: If the flow rate is high, then the sand filter media could be disturbed and flushed into the STSC.	<ul style="list-style-type: none">Select valves automatically controlledManual valve position indicatorsBackflush water volume (FE-720-202)STSC level switches LS/LSH/LSHH-740-401	<ul style="list-style-type: none">ProceduresTrainingConduct of operations verifies proper system configuration	
4-4	Flow	Reverse	Breach in the IXM water supply line results in siphoning of supernate from the STSC See also Table C-14, Item 3-5.3	Uncontrolled Release: If the IXM water supply line is breached, then STSC supernate could be siphoned from the STSC. The supernate would be filtered by a portion of the sand filter bed.	Check valve ECRT-CV-506	<ul style="list-style-type: none">ProceduresTraining	

Table C-16. HAZOP Results, Node 4, Sand Filter Backwash							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
4-5.a	Flow	Misdirected (into Sand Filter Enclosure)	<ul style="list-style-type: none"> Pressure safety valve PSV-1A or -01B open Valving error such that supernate enters enclosure via siphon break (see remarks) 	<p>Uncontrolled Release:</p> <p>If the release is via pressure safety valve PSV-1A or -01B, then sand filter backwash will be misdirected into the Sand Filter Enclosure and a splash and splatter/pool release will occur</p>	<ul style="list-style-type: none"> Manual valve position indicators Select valves automatically controlled Secondary confinement with leak detection Sand Filter Enclosure HEPA-filtered active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during backwash operations 	<p>When a backwash is performed, siphon break valve FV-12 is open and valves FV-02A and -02B are closed. If, at the start of backwash, valve FV-02A or -02B opened, then liquid would be released into the enclosure via FV-12.</p> <p>When a backwash is performed, siphon break valves FV-12 is open and drain down valves FV-08A and -08B are closed. If, at the start of backwash, valve FV-08A and -08B opened, then liquid would be released into the enclosure via FV-12.</p> <p>As shown on drawing H-1-92301, Sheet 4, the leak detector element in the Sand Filter Enclosure (LDE-720-203) activates interlock I-2. Interlock I-2 does not shut off IXM water for sand filter backwash.</p>
4-5.b	Flow	Misdirected (into Decant Pump Box)	<ul style="list-style-type: none"> Valving error such that sand filter backwash enters box via IXM water spray nozzles Valving error such that supernate enters box via siphon break 	<p>Uncontrolled Release:</p> <p>If sand filter backwash is misdirected into the Decant Pump Box, then a splash and splatter/pool release will occur.</p>	<ul style="list-style-type: none"> Manual valve position indicators Secondary confinement with leak detection Decant Pump Box HEPA-filtered active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during backwash operations 	
4-5.c	Flow	Misdirected (into sand filter sparge exhaust)	Valving error (FV-06A/B)	<p>Uncontrolled Release:</p> <p>If backwash is misdirected into the sand filter sparge exhaust, then catch tank ECRT-TK-502 will overflow and a splash and splatter/pool release will occur.</p>	<ul style="list-style-type: none"> Select valves automatically controlled Catch tank level instrumentation (LSH-750-502) Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Modified KW Basin Annex is unmanned during backwash operations 	

Table C-16. HAZOP Results, Node 4, Sand Filter Backwash							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
4-5.d	Flow	Misdirected (into Decant Pump Box IXM water supply)	Valving error	Uncontrolled Release: If sand filter backwash is misdirected into the Decant Pump Box IXM water supply, then a splash and splatter/pool release could occur.	<ul style="list-style-type: none">• Manual valve position indicators• Check valve ECRT-CV-201• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration• Modified KW Basin Annex is unmanned during backwash operations	
4-5.e	Flow	Misdirected (into Sand Filter Enclosure instrument air supply)	Valving error	Uncontrolled Release: If misdirected into the Sand Filter Enclosure instrument air supply, then a splash and splatter/pool release could occur. The release would be primarily IXM water.	<ul style="list-style-type: none">• Select valves automatically controlled• Check valve ECRT-CV-409• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Modified KW Basin Annex is unmanned during backwash operations	
4-5.f	Flow	Misdirected (into flocculant addition supply)	Valving error	Uncontrolled Release: If sand filter backwash is misdirected into the flocculant addition supply, then a splash and splatter/pool release could occur.	<ul style="list-style-type: none">• Manual valve position indicators• Check valve ECRT-CV-202• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration• Modified KW Basin Annex is unmanned during backwash operations	
4-6	Pressure	Low	<ul style="list-style-type: none">• Low water pressure from Skimmer Water Cleanup System• Throttle valve HCV-511 set incorrectly• A normally-opened valve is partially closed• Sand filter media partially plugged	Operational Upset: If the pressure is low, then solids may not be effectively backwashed from the sand filter. This will result in additional decant/backwash cycles.	<ul style="list-style-type: none">• Select valves automatically controlled• Manual valve position indicators• Differential pressure instrumentation (PT-720-205 and -206)	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration	

Table C-16. HAZOP Results, Node 4, Sand Filter Backwash							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
4-7	Pressure	High	<ul style="list-style-type: none"> High water pressure from the Skimmer Water Cleanup System Throttle valve HCV-511 set incorrectly A normally-opened valve is closed 	<p>Operational Upset:</p> <p>If the flow rate is high, then the sand filter media could be disturbed and flushed into the STSC.</p> <p>Uncontrolled Release:</p> <p>If a normally-opened valve is closed, then high pressure could result in a failure in the filter backwash system resulting in a spray or splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Piping designed in accordance with B31.3, "Process Piping" Select valves automatically controlled Manual valve position indicators Differential pressure instrumentation (PT-720-205 and -206) Pressure safety valve PSV-01A/B Secondary confinement with leak detection Sand Filter Enclosure HEPA-filtered active ventilation Decant Pump Box HEPA-filtered active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during backwash operations 	<p>If Pressure safety valve PSV-01A or -01B opens, then backwash will directed in a controlled manner to the Sand Filter Enclosure sump.</p> <p>As shown on drawing H-1-92301, Sheet 4, the leak detector element in the Sand Filter Enclosure (LDE-720-203) activates interlock I-2. Interlock I-2 does not shut off IXM water for sand filter backwash.</p> <p>As shown on drawing H-1-92301, Sheet 5, the leak detector element in the Decant Pump Box (LDE-720-202) activates interlock I-1. Interlock I-1 does not shut off IXM water for sand filter backwash.</p>
4-8	Concentration	Low	<ul style="list-style-type: none"> Low IXM water flow rate (see Item 4.2 above) Low IXM water pressure (see Item 4.6 above) 	<p>Operational Upset:</p> <p>If the solids concentration in the backwash is low, then the sand filter media is not being effectively backwashed. This will result in additional decant/backwash cycles.</p>	See Items 4.2 and 4.6 above	See Items 4.2 and 4.6 above	The concentration may normally be lower than the design intent. The concentration of solids in any given backwash evolution will depend on the quantity of solids collected on the filter media which in turn is a function of the solids concentration in the decanted supernate.
4-9	Concentration	High	N/A	N/A	N/A	N/A	A high solids concentration in the sand filter backwash is desirable.

Table C-16. HAZOP Results, Node 4, Sand Filter Backwash							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
4-10	Composition	Other (instrument air)	Valving error (see remarks)	Operational Upset: If a valving error occurs, then instrument air could be directed to the STSC via the decant/backwash line.	<ul style="list-style-type: none"> Select valves automatically controlled STSC active ventilation 	<ul style="list-style-type: none"> Procedures Training 	IXM water from the Skimmer Water Cleanup System is used to backwash the sand filters. As stated in Table C-15, there are no other process fluids at the KW Basin that could be inadvertently connected and used to backwash the sand filters. However, prior to backwashing, the sand filter is partially drained and a 5 cfm air scour is performed using instrument air. This air is normally exhausted via valve FV-07A/B to the sand filter sparge exhaust line. A valving error could occur such that the exhaust air is routed back to the STSC via the decant/backwash line.
4-11.a	Level (STSC at start of backwash)	Low	N/A	N/A	N/A	N/A	As stated in Table C-15, the STSC level at the start of the backwash is assumed to be equal to the as-settled sludge limits. The only way the level could be lower would be if the STSC failed and liquid drained into the STS cask (see Table C-10, Item 2.c-8).
4-11.b	Level (Sand Filter at start of backwash)	Low	Siphon break not opened (see remarks)	Operational Upset: If the liquid level drops below the level of the filter media, then the de-watered filter media will not perform as intended in subsequent decant/backwash cycles and would likely need to be replaced.	Select valves automatically controlled	<ul style="list-style-type: none"> Procedures Training 	In order to perform an air sparge, valve FV-08A/B is opened to establish a flow path to the sand filter sparge exhaust. If siphon break valve FV-12 is not opened, then the contents of the sand filter will be siphoned back to the basin which will de-water the sand filter media.
4-12.a	Level (STSC at end of backwash)	High	Instrumentation and control failure	Uncontrolled Release: If the backwash is not stopped, then the STSC will go solid and sand filter backwash will be pumped into the 4-in and 1-in. ventilation exhaust lines and into the 1-in. ventilation inlet line leading to a splash and splatter/pool release.	<ul style="list-style-type: none"> STSC level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 	<ul style="list-style-type: none"> Procedures Training 	

Table C-16. HAZOP Results, Node 4, Sand Filter Backwash							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
4-12.b	Level (Sand Filter at end of backwash)	High	N/A	N/A	N/A	N/A	At the completion of the backwash the sand filter is full, i.e., there is no headspace.
4-13.a	Structural Integrity	Leak/rupture (sand filter)	<ul style="list-style-type: none"> High pressure (see Item 4-7 above) Manufacturing flaw 	<p>Uncontrolled Release:</p> <p>If the sand filter fails, then a spray or splash and splatter/pool release will occur.</p> <p>Hydrogen Deflagration:</p> <p>If the sand filter fails, then sand filter backwash would be spilled into the sand filter enclosure. Hydrogen generated by the backwash could accumulate in the enclosure resulting in a deflagration.</p>	<ul style="list-style-type: none"> Decant line pressure instrumentation (PT-720-201) Decant line flow instrumentation (FE-720-201) Pressure safety valve PSV-01A and -01B (see remarks) Secondary containment with leak detection Sand Filter Enclosure HEPA-filtered confinement ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Quality Assurance Program Modified KW Basin Annex is unmanned during backwash operations Leak detection alarm response 	<p>If Pressure safety valve PSV-01A or -01B opens, then backwash will directed in a controlled manner to the Sand Filter Enclosure sump.</p> <p>As shown on drawing H-1-92301, Sheet 4, the leak detector element in the Sand Filter Enclosure (LDE-720-203) activates interlock I-2. Interlock I-2 does not shut off IXM water for sand filter backwash.</p>
4-13.b	Structural Integrity	Leak/rupture (backwash line – sand filter to STSC)	<ul style="list-style-type: none"> High pressure (see Item 4-7 above) Manufacturing flaw Hose connection decouples 	<p>Uncontrolled Release:</p> <p>If the backwash line fails, then a spray or splash and splatter/pool release will occur.</p> <p>Hydrogen deflagration:</p> <p>If the backwash line leaks or ruptures inside the sand filter enclosure, then sand filter backwash would be spilled into the sand filter enclosure. Hydrogen generated by the backwash could accumulate in the box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Decant line pressure instrumentation (PT-720-201) Decant line flow instrumentation (FE-720-201) Secondary containment with leak detection Decant Pump Box HEPA-filtered confinement Sand Filter Enclosure HEPA-filtered confinement ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Modified KW Basin Annex is unmanned during backwash operations Leak detection alarm response 	<p>As shown on drawing H-1-92301, Sheet 4, the leak detector element in the Sand Filter Enclosure (LDE-720-203) activates interlock I-2. Interlock I-2 does not shut off IXM water for sand filter backwash.</p> <p>As shown on drawing H-1-92301, Sheet 5, the leak detector element in the Decant Pump Box (LDE-720-202) activates interlock I-1. Interlock I-1 does not shut off IXM water for sand filter backwash.</p>

Table C-16. HAZOP Results, Node 4, Sand Filter Backwash							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
4-14	Time Procedure	Too short	Instrumentation and control failure	Operational Upset: If the backwash occurs for too short a time, then the backwash will be incomplete and additional decant/backwash cycles may be required.	STSC level switches LS/LSH/LSHH-740-401	<ul style="list-style-type: none"> Procedures Training 	
4-15	Time Procedure	Too long	See Item 4-12.a above	See Item 4-12.a above	See Item 4-12.a above	See Item 4-12.a above	See Item 4-12.a above
4-16	Time Procedure	Skip action	Operator error	Operational Upset: If the backwash is not performed, then the differential pressure on the sand filter will be higher when the next STSC is processed. Hydrogen Deflagration: If the backwash is not performed, then hydrogen generated by the sludge captured on the sand filter media could accumulate in the headspace of the sand filter resulting in a deflagration.	<ul style="list-style-type: none"> Differential pressure instrumentation (PT-720-205 and -206) Sand Filter Enclosure HEPA filtered ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Modified KW Basin Annex is unmanned during backwash operations Leak detection alarm response 	
4-17	Time Procedure	Wrong action (decant instead of backwash)	Operator error	Operational Upset: If a decant is initiated instead of a backwash, then the floating decant head would be at the same elevation as when the previous decant ended. When the decant pump started in the recirculation mode, the AODD would pump either air or sludge (see remarks)..	Turbidity instrumentation (AE-720-201)	<ul style="list-style-type: none"> Procedures Training 	<p>In testing at MASF, when the floating decant head came to rest on the sludge it pumped sludge to the sand filter.</p> <p>If the AODD pump is allowed to continue operating it will begin to pump air. If air is pumped into the sand filter to the point that it dewateres the media, then the filter may not perform effectively in the future, in which case it would have to be replaced.</p>

Table C-17. Normal Operating Conditions, Node 5, STSC Nitrogen Purge		
Process Parameter	Design Intent	Remarks
Flow	10 cfm	The nitrogen flow rate to the STSC is 10 cfm.
Pressure	65 psi	The STSC is rated at 150 psi. The pressure safety valve is set at 80 psi because that same nitrogen supply system is used to inert the STS cask, which has pressure rating of 80 psi.
Concentration	0.1% oxygen	The STSC will be purged with nitrogen until the oxygen concentration in the STSC reaches 0.1%.
Composition	Nitrogen	The selection of nitrogen as the inerting gas is discussed in PRC-STP-00273, <i>Analysis of Argon and Nitrogen Purging and Inerting of Sludge Transport and Storage Container (STSC) and Sludge Transport System (STS) Cask</i> .
Level	STSC headspace = 0.469 m ³	The liquid level in the STSC at the end of the backwash is established by level switch LSHH-740-401. The headspace above this liquid level is equal to 0.469 m ³ .
	Nitrogen volume >100 scfm	As documented in PRC-STP-00273, at a rate of 10 cfm the STSC is purged for less than 10 minutes to attain 0.1% oxygen. Therefore, in excess of 100 scfm of nitrogen is required to purge the STSC.
Structural Integrity	Maintain integrity under normal operating conditions	None
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The nitrogen bottles are stored outside such that the gas temperature will fluctuate with the ambient air temperature. The typical temperature fluctuations that over the course of several days will have no impact on the operability of the Nitrogen Gas Supply system.
Time Procedure	10 minutes	The purge will be performed until the oxygen concentration in the STSC reaches 0.1% oxygen. The 10 minute value is based calculated in PRC-STP-00273 based on a headspace of 0.469 m ³ and a nitrogen flow rate of 10 cfm.

PRC-STP-00273, 2010, *Analysis of Argon and Nitrogen Purging and Inerting of Sludge Transport and Storage Container (STSC) and Sludge Transport System (STS) Cask*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

Table C-18. HAZOP Results, Node 5, STSC Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
5-1	Flow	No	<ul style="list-style-type: none"> Nitrogen bottles empty A normally-opened valve is closed 	Hydrogen Deflagration: If there is no nitrogen flow, then the STSC will not be inerted. This could result in a hydrogen deflagration.	<ul style="list-style-type: none"> Nitrogen pressure instrumentation (PI-760-604, PI-760-605) Nitrogen flow instrumentation (FI-760-601) Oxygen concentration instrumentation (AE-760-601) STSC active ventilation (see remarks) Valve position indicators Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration 	If there is no nitrogen flow, a hydrogen deflagration can be prevented by re-establishing STSC active ventilation.
5-2	Flow	Low	<ul style="list-style-type: none"> Flow rate set incorrectly A normally-opened valve is partially closed Pressure control valve failure 	Operational Upset: If the nitrogen flow rate is low, then it will take longer to inert the STSC.	<ul style="list-style-type: none"> Nitrogen flow instrumentation (FI-760-601) Oxygen concentration instrumentation (AE-760-601) Valve position indicators 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	
5-3	Flow	High	<ul style="list-style-type: none"> Flow rate set incorrectly Pressure control valve failure 	None: If the nitrogen flow rate is high, then the STSC will be inerted in a shorter period of time.	<ul style="list-style-type: none"> Nitrogen flow instrumentation (FI-760-601) Oxygen concentration instrumentation (AE-760-601) Valve position indicators 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	
5-4	Flow	Reverse	N/A	N/A	N/A	N/A	There are no mechanisms by which a reverse flow could be established.

Table C-18. HAZOP Results, Node 5, STSC Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
5-5.a	Flow	Misdirected (flow into STS cask)	Valve ECRT-V-609 set incorrectly (see remarks)	Hydrogen Deflagration: If the nitrogen flow is misdirected to the STS cask, then the STSC will not be inerted. This could result in a hydrogen deflagration.	<ul style="list-style-type: none"> Nitrogen flow instrumentation (FI-760-601) Oxygen concentration instrumentation (AE-760-601) Valve position indicators STSC active ventilation (see remarks) Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration 	<p>If valve ECRT-V-609 is set incorrectly, then nitrogen will flow into the STS cask instead of into the STSC. From the STS cask, the nitrogen would enter the Loading Bay.</p> <p>The Loading Bay air change rate is 4.2/hr. This represents approximately 3,300 cfm of flow. The 10 cfm of nitrogen associated with a misdirected flow does not result in an oxygen deficient atmosphere.</p> <p>If there is no nitrogen flow to the STSC, a hydrogen deflagration could be prevented by re-establishing STSC active ventilation.</p>
5-5.b	Flow	Misdirected (flow into Annex)	Valve ECRT-V-732 open (see remarks)	Hydrogen Deflagration: If the nitrogen flow is misdirected into the Loading Bay, then the STSC will not be inerted. This could result in a hydrogen deflagration.	<ul style="list-style-type: none"> Nitrogen flow instrumentation (FI-760-601) Oxygen concentration instrumentation (AE-760-601) Valve position indicator STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration 	<p>If valve ECRT-V-732 is open, then nitrogen could flow into the Loading Bay via the STSC ventilation inlet HEPA filter thus bypassing the STSC.</p> <p>The Loading Bay air change rate is 4.2/hr. This represents approximately 3,300 cfm of flow. The 10 cfm of nitrogen associated with a misdirected flow does not result in an oxygen deficient atmosphere.</p> <p>If there is no nitrogen flow to the STSC, a hydrogen deflagration could be prevented by re-establishing STSC active ventilation.</p>
5-6	Pressure	Low	<ul style="list-style-type: none"> Flow rate set incorrectly A normally-opened valve is partially closed Pressure control valve failure 	<p>Operational Upset:</p> <p>If the nitrogen pressure is low, then it will take longer to inert the STSC.</p>	<ul style="list-style-type: none"> Nitrogen pressure instrumentation (PI-760-604, PI-760-605, PI-760-606) Nitrogen flow instrumentation (FI-760-601) Oxygen concentration instrumentation (AE-760-601) Valve position indicators 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	

Table C-18. HAZOP Results, Node 5, STSC Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
5-7.a	Pressure	High (nitrogen supply system)	<ul style="list-style-type: none"> Flow rate set incorrectly Pressure control valve failure 	<p>Industrial Safety:</p> <p>If the pressure is high, then a nitrogen supply hose (ECRT-H-601 or ECRT-H-604) could fail and whip causing a facility worker injury.</p> <p>See also Item 5-13 below.</p>	<ul style="list-style-type: none"> Nitrogen pressure instrumentation (PI-760-604, PI-760-605, PI-760-606) Valve position indicators Pressure safety valve ECRT-PSV-601 Hose tie-downs 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Industrial Safety Program 	High pressure could also result in a leak or rupture of the nitrogen supply line. See Item 5-13 below.
5-7.b	Pressure	High (STSC)	Pressure control valve failure	<p>None:</p> <p>The STSC cannot be isolated from the ventilation system during the nitrogen purge (see remarks)..</p>	N/A	<ul style="list-style-type: none"> N/A 	At the draft preliminary design, it was possible to isolate the STSC by closing valves on the 4 in. and 1 in. ventilation lines. The valve on the 1 in. line has since been removed.
5-8	Concentration	Low (O ₂)	Purge duration too long (see Item 5-15 below)	<p>None:</p> <p>There is no hazard if the oxygen concentration in the STSC is less than 0.1%.</p>	N/A	N/A	
5-9	Concentration	High (O ₂)	<ul style="list-style-type: none"> Purge duration too short (see Item 5-14 below) Insufficient nitrogen supply No nitrogen flow (see Item 5-1 above) Misdirected nitrogen flow (see Item 5-5.a, and .b above) 	<p>Hydrogen Deflagration:</p> <p>If the oxygen concentration in the STSC is high, then the STSC will not be inerted. This could result in a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Oxygen concentration instrumentation (AE-760-601) Nitrogen pressure instrumentation (PI-760-604, PI-760-605, PI-760-606) Nitrogen flow instrumentation (FI-760-601) STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration 	
5-10.a	Composition	Other (oxidant)	Gas bottles containing an oxidant (e.g., air) installed at Inert Bottle Station	<p>Hydrogen Deflagration:</p> <p>If gas bottles containing an oxidant are installed at the Inert Bottle Station, then the STSC will not be inerted. This could result in a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Nitrogen-specific fixtures Oxygen concentration instrumentation (AE-760-601) Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Quality Assurance Program Administrative control requiring verification of O₂ concentration 	

Table C-18. HAZOP Results, Node 5, STSC Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
5-10.b	Composition	Other (helium)	Gas bottles containing helium installed at Inert Bottle Station	Hydrogen Deflagration: If helium gas bottles are installed, then too much counter-current flow will occur and the STSC will not be inerted (see remarks).	<ul style="list-style-type: none"> Nitrogen-specific fixtures Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Quality Assurance Program 	PRC-STP-00273 calculates counter-current flow (of nitrogen out of the STSC and air into the STSC).and establishes the dwell period after nozzle closure and before STS cask closure. If helium gas is used, instead of nitrogen, then there will be greater counter-current flow and the STSC/STS cask will not be inerted.
5-11.a	Level	High (STSC liquid level)	Instrumentation and control failure	None: If the liquid level in the STSC is high, then the STSC will be inerted in a shorter period of time.	<ul style="list-style-type: none"> Oxygen concentration instrumentation (AE-760-601) Level switches LS/LSH/LSHH-740-401 	<ul style="list-style-type: none"> Procedures Training 	
5-11.b	Level	High (nitrogen bottle volume)	N/A	N/A	N/A	N/A	N/A
5-12.a	Level	Low (STSC liquid level)	Instrumentation and control failure	Operational Upset: If the liquid level in the STSC is low, then it will take longer to inert the STSC.	<ul style="list-style-type: none"> Oxygen concentration instrumentation (AE-760-601) Level switches LS/LSH/LSHH-740-401 	<ul style="list-style-type: none"> Procedures Training 	
5-12.b	Level	Low (nitrogen bottle volume)	<ul style="list-style-type: none"> Leak in supply system Operator error (low pressure bottles not replaced as needed) 	Hydrogen Deflagration: If the nitrogen volume is low, then there could be insufficient nitrogen to inert the STSC. This could result in a hydrogen deflagration.	<ul style="list-style-type: none"> Inert gas system pressure indicator PI-760-601 Oxygen concentration instrumentation (AE-760-601) Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration. 	

Table C-18. HAZOP Results, Node 5, STSC Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
5-13	Structural Integrity	Leak/rupture (nitrogen supply system)	<ul style="list-style-type: none"> Overpressurization Hose disconnects 	<p>Hydrogen Deflagration:</p> <p>If a leak or rupture in the nitrogen supply occurs, then the STSC will not be inerted. This could result in a hydrogen deflagration.</p> <p>Oxygen Deficient Atmosphere:</p> <p>If a leak or rupture in the nitrogen supply occurs, then an oxygen deficient atmosphere could form.</p>	<ul style="list-style-type: none"> Oxygen concentration instrumentation (AE-760-601) Nitrogen pressure instrumentation (PI-760-604, PI-760-605, PI-760-606) Nitrogen flow instrumentation (FI-760-601) STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Industrial Safety Program 	<p>If the STS cask cannot be inerted, a hydrogen deflagration could be prevented by re-establishing STSC active ventilation.</p> <p>Depending on the location of the nitrogen supply system leak, the flow rate could be much greater than 10 cfm and thus constitute an oxygen deficient atmosphere hazard.</p>
5-14	Time Procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure (AE-760-601) 	<p>Hydrogen Deflagration:</p> <p>If the purge occurs for too short a period of time (i.e., before the oxygen concentration reaches 0.1%), then a hydrogen deflagration could occur.</p>	<ul style="list-style-type: none"> Oxygen concentration instrumentation (AE-760-601) Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Administrative control requiring verification of O₂ concentration 	
5-15	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Instrumentation failure (AE-760-601) 	<p>None:</p> <p>There is no hazard if the oxygen concentration in the STSC is less than 0.1%.</p>	N/A	N/A	
5-16	Time Procedure	Skip action	Operator error	<p>Hydrogen Deflagration:</p> <p>If the STSC is not inerted, then a hydrogen deflagration could occur.</p>	<ul style="list-style-type: none"> Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Administrative control requiring verification of O₂ concentration 	
5-17	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There is no wrong action associated with this node.

Table C-19. Normal Operating Conditions, Node 6, STS Cask Nitrogen Purge		
Process Parameter	Design Intent	Remarks
Flow	10 cfm (when inerting the cask)	The nitrogen flow rate to the STS Cask is set at 10 cfm when the cask is being inerted.
Pressure	Nitrogen gas supply = 65 psi	The STS cask has is rated at 80 psig. A pressure control valve is set at 65 psi and a pressure safety valve is set at 80 psi.
Concentration	0.1% oxygen	The STS cask will be purged with nitrogen until the oxygen concentration in the cask reaches 0.1%.
Composition	Nitrogen	The selection of nitrogen as the inerting gas is discussed in PRC-STP-00273, <i>Analysis of Argon and Nitrogen Purging and Inerting of Sludge Transport and Storage Container (STSC) and Sludge Transport System (STS) Cask</i> .
Level	Nitrogen volume >240 scfm	As documented in PRC-STP-00273, at a rate of 10 cfm the STS Cask is purged for 24 minutes to attain 0.1% oxygen. Therefore, in excess of 240 scfm of nitrogen is required to purge the STS cask.
Structural Integrity	Maintain integrity under normal operating conditions	None
Temperature	Not applicable	Nitrogen gas temperature is not a process parameter that is monitored or controlled. The nitrogen bottles are stored outside such that the gas temperature will fluctuate with the ambient air temperature. The typical temperature fluctuations that over the course of several days will have no impact on the operability of the Nitrogen Gas Supply system.
Time Procedure	24 minutes	The purge will be performed until the oxygen concentration in the STS Cask reaches 0.1% oxygen. The 24 minute value is calculated in PRC-STP-00273 based on a headspace of 1.236 m ³ and a nitrogen flow rate of 10 cfm.

PRC-STP-00273, 2010, *Analysis of Argon and Nitrogen Purging and Inerting of Sludge Transport and Storage Container (STSC) and Sludge Transport System (STS) Cask*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

Table C-20. HAZOP Results, Node 6, STS Cask Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
6-1	Flow	No	<ul style="list-style-type: none"> Nitrogen bottles empty A normally-opened valve is closed 	Hydrogen Deflagration: If there is no nitrogen flow, then the STS cask will not be inerted. This could result in a hydrogen deflagration.	<ul style="list-style-type: none"> Inert gas system pressure instrumentation (PI-760-601 through -606) Flow indicator FI-760-601 Valve position indicators Oxygen concentration instrumentation (AE-760-601) Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration 	
6-2	Flow	Low	<ul style="list-style-type: none"> Low nitrogen pressure Flow rate set incorrectly A normally-opened valve is partially closed 	Operational Upset: If the nitrogen flow rate is low, then it will take longer to inert the STS cask.	<ul style="list-style-type: none"> Inert gas system pressure instrumentation (PI-760-601 through -606) Flow indicator FI-760-601 Valve position indicators Oxygen concentration instrumentation (AE-760-601) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration 	
6-3	Flow	High	Pressure control valve failure	None: If the nitrogen flow rate is high, then the STS cask will be inerted in a shorter period of time.	<ul style="list-style-type: none"> Inert gas system pressure instrumentation (PI-760-601 through -606) Flow indicator FI-760-601 Valve position indicators Oxygen concentration instrumentation (AE-760-601) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	
6-4	Flow	Reverse	N/A	N/A	N/A	N/A	There are no mechanisms by which a reverse flow could be established.

Table C-20. HAZOP Results, Node 6, STS Cask Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
6-5	Flow	Misdirected (flow into Annex)	Valve ECRT-V-609 set incorrectly	<p>Hydrogen Deflagration:</p> <p>If valve ECRT-V-609 is mispositioned, then the nitrogen flow would be directed to the STSC purge inlet where it would deadhead against the male Staubli connector. The STS cask would not be inerted.</p> <p>Industrial Safety</p> <p>If valve ECRT-V-609 is mispositioned, then the nitrogen flow would deadhead against the male Staubli connector at a pressure of 65 psig. Unmitigated, this could result in failure of piping or hoses which in turn could result in hose whip and the potential for an oxygen deficient atmosphere.</p>	<ul style="list-style-type: none"> • Oxygen concentration instrumentation (AE-760-601) • Flow indicator FI-760-601 • Valve position indicators • Piping and hoses designed to B31.3, "Process Piping" • Hose tie-downs • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration • Administrative control requiring verification of O₂ concentration • Industrial Safety Program 	
6-6	Pressure	Low	<ul style="list-style-type: none"> • A normally-opened valve is partially closed • Pressure control valve failure 	<p>Operational Upset:</p> <p>If the nitrogen pressure is low, then it will take longer to inert the STS cask.</p>	<ul style="list-style-type: none"> • Inert gas system pressure instrumentation (PI-760-601 through -606) • Oxygen concentration instrumentation (AE-760-601) • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration • Administrative control requiring verification of O₂ concentration 	

Table C-20. HAZOP Results, Node 6, STS Cask Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
6-7.a	Pressure	High (nitrogen supply system)	<ul style="list-style-type: none"> A normally-opened valve is partially closed Pressure control valve failure 	<p>Industrial Safety:</p> <p>If the pressure is high, then the piping or hoses could fail. This could result in hose whip and the potential for an oxygen deficient atmosphere.</p> <p>Hydrogen Deflagration:</p> <p>If the pressure is high, then the piping or hoses could fail such that the STS cask is not inerted. This could result in a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Inert gas system pressure instrumentation (PI-760-601 through -606) Pressure safety valve ECRT-PSV-601 Valve position indicators Piping and hoses designed to B31.3, "Process Piping" Oxygen concentration instrumentation (AE-760-601) Hose tie-downs Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Industrial Safety Program Administrative control requiring verification of O₂ concentration 	
6-7.b	Pressure	High (STS cask)	Pressure control valve failure and vent port tool closed	<p>Radiological Control:</p> <p>If the pressure is high, then the STS cask mechanical seal could fail. If the inside of the STS cask was contaminated, then contaminated nitrogen would be discharged into the loading bay.</p> <p>Hydrogen Deflagration:</p> <p>Overpressurizing the STS cask would cause the mechanical seal to fail. This would allow air ingress into the STS cask and, subsequently, into the STSC. This could lead to a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Pressure safety valve ECRT-PSV-601 Valve position indicators Oxygen concentration instrumentation (AE-760-601) STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration 	<p>The STS cask is rated at 80 psig.</p> <p>Pressure control valve ECRT-PCV-602 reduces the pressure from 425 psig to 65 psig.</p> <p>If the STS cask failed, a hydrogen deflagration could be prevented by re-establishing STSC active ventilation.</p>
6-8	Concentration	Low (O ₂)	Purge duration too long (see Item 6-13 below)	<p>None:</p> <p>There is no hazard if the oxygen concentration in the STSC is less than 0.1%.</p>	N/A	N/A	

Table C-20. HAZOP Results, Node 6, STS Cask Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
6-9	Concentration	High (O ₂)	<ul style="list-style-type: none"> Purge duration too short (see Item 6-12 below) Insufficient nitrogen supply No nitrogen flow (see Item 6-1 above) Misdirected nitrogen flow (see Item 6-5 above) 	Hydrogen Deflagration: If the oxygen concentration in the STS cask is high, then the STS cask will not be inerted. This could result in a hydrogen deflagration.	<ul style="list-style-type: none"> Oxygen concentration instrumentation (AE-760-601) Inert gas system pressure instrumentation (PI-760-601 through -606) Flow indicator FI-760-601 Valve position indicators STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration 	If the STS cask cannot be inerted, a hydrogen deflagration could be prevented by re-establishing STSC active ventilation.
6-10.a	Composition	Other (oxidant)	Gas bottles containing an oxidant (e.g., air) installed at Inert Bottle Station	Hydrogen Deflagration: If gas bottles containing an oxidant are installed at the Inert Bottle Station, then the STS cask will not be inerted. This could result in a hydrogen deflagration.	<ul style="list-style-type: none"> Nitrogen-specific fixtures Oxygen concentration instrumentation (AE-760-601) STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Quality Assurance Program 	If the STS cask cannot be inerted, a hydrogen deflagration could be prevented by re-establishing STSC active ventilation.
6-10.b	Composition	Other (helium)	Gas bottles containing helium installed at Inert Bottle Station	Hydrogen Deflagration: If helium gas bottles are installed at the Bottle Station, then too much air ingress will occur and the STS cask will not be inerted (see remarks).	<ul style="list-style-type: none"> Nitrogen-specific fixtures Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Quality Assurance Program 	PRC-STP-00273 calculates counter-current flow (of nitrogen out of the STSC and air into the STSC).and establishes the dwell period after nozzle closure and before STS cask closure. If helium gas is used, instead of nitrogen, then there will be greater counter-current flow and the STSC/STS cask will not be inerted.
6-11	Level	Low (nitrogen bottle volume)	<ul style="list-style-type: none"> Leak in supply system Operator error (low pressure bottles not replaced as needed) 	Hydrogen Deflagration: If the nitrogen volume is low, then there could be insufficient nitrogen to inert the STS cask. This could result in a hydrogen deflagration.	<ul style="list-style-type: none"> Inert gas system pressure indicator PI-760-601 Oxygen concentration instrumentation (AE-760-601) Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of O₂ concentration. 	

Table C-20. HAZOP Results, Node 6, STS Cask Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
6-12	Level	High (nitrogen bottle volume)	N/A	N/A	N/A	N/A	N/A
6-13.a	Structural Integrity	Leak/rupture (nitrogen supply system)	<ul style="list-style-type: none"> • Overpressurization • Hose disconnects 	<p>Hydrogen Deflagration:</p> <p>If a leak or rupture in the nitrogen supply occurs, then the STS cask will not be inerted. This could result in a hydrogen deflagration.</p> <p>Industrial Safety:</p> <p>If the there is leak/rupture in the nitrogen supply system, then nitrogen will be released at the point of failure. This could result hose whip and the potential for an oxygen deficient atmosphere.</p>	<ul style="list-style-type: none"> • Oxygen concentration instrumentation (AE-760-601) • Pressure safety valve ECRT-PSV-601 • Inert gas system pressure instrumentation (PI-760-601 through -606) • Flow indicator FI-760-601 • Piping and hoses designed to B31.3, "Process Piping" • Hose tie-downs • Valve position indicators • STSC active ventilation • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration • Administrative control requiring verification of O₂ concentration. • Industrial Safety Program 	<p>If the STS cask cannot be inerted, a hydrogen deflagration could be prevented by re-establishing STSC active ventilation.</p> <p>Depending on the location of the nitrogen supply system leak, the flow rate could be much greater than 10 cfm and thus constitute an oxygen deficient atmosphere hazard.</p>
6-13.b	Structural Integrity	Leak/rupture (STS cask)	<ul style="list-style-type: none"> • Overpressurization • Mechanical seal failure 	<p>Hydrogen deflagration:</p> <p>If the STS cask leaks, then air will leak into the STS cask and, subsequently, into the STSC. This could lead to a hydrogen deflagration.</p>	<ul style="list-style-type: none"> • STS cask pressure boundary • Oxygen concentration instrumentation (AE-760-601) • Pressure safety valve ECRT-PSV-601 • Inert gas system pressure instrumentation (PI-760-601 through -606) • Valve position indicators • STSC active ventilation • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration • Administrative control requiring verification of O₂ concentration 	<p>If the STS cask failed, a hydrogen deflagration could be prevented by re-establishing STSC active ventilation.</p>

Table C-20. HAZOP Results, Node 6, STS Cask Nitrogen Purge							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
6-14	Time Procedure	Too short	<ul style="list-style-type: none">• Operator error• Instrumentation failure (AE-760-601)	Hydrogen Deflagration: If the purge occurs for too short a period of time (i.e., before the oxygen concentration reaches 0.1%), then a hydrogen deflagration could occur.	<ul style="list-style-type: none">• Oxygen concentration instrumentation (AE-760-601)• Inert gas system pressure instrumentation (PI-760-601 through -606)• STSC active ventilation• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Administrative control requiring verification of O₂ concentration	
6-15	Time Procedure	Too long	<ul style="list-style-type: none">• Operator error• Instrumentation failure (AE-760-601)	None: There is no hazard if the oxygen concentration in the STS cask is less than 0.1%.	N/A	N/A	
6-16	Time Procedure	Skip action	Operator error	Hydrogen Deflagration: If the STS cask is not inerted, then a hydrogen deflagration could occur.	<ul style="list-style-type: none">• Oxygen concentration instrumentation (AE-760-601)• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Administrative control requiring verification of O₂ concentration	
6-17	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There is no wrong action associated with this node.

Table C-21. Normal Operating Conditions, Node 7, STS Cask Pressurization		
Process Parameter	Design Intent	Remarks
Flow	Not applicable	The flow rate is controlled by manually opening needle valve ECRT-V-607. The flow rate is not monitored.
Pressure	3 psig > STC Cask <TBD psig	The 3 psig lower limit on pressure is based on maintaining an inert atmosphere in the STS Cask for the duration of the shipping window given a leak rate of 2×10^{-4} standard cm^3/s air per ANSI N14.5-1997, <i>American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment</i> . The upper bound pressure has not yet been determined. It will be established to prevent overpressurization of the STS Cask during transportation. In the following HAZOP tables, a value of 15 psig has been used. The 15 psig value was previously established for shipping sludge to T Plant in Large Diameter Containers.
Concentration	Not applicable	At the time of STS Cask pressurization, the STS cask has already been purge with nitrogen to yield an oxygen concentration less than 0.1%.
Composition	Nitrogen	The selection of nitrogen as the inerting gas is discussed in PRC-STP-00273, <i>Analysis of Argon and Nitrogen Purging and Inerting of Sludge Transport and Storage Container (STSC) and Sludge Transport System (STS) Cask</i> .
Structural Integrity	Maintain integrity under normal operating conditions	
Level	Nitrogen volume > 8.8 ft^3	The STS Cask has a headspace of 1.236 m^3 . To raise the pressure from atmospheric to the minimum pressure of 3 psig requires the addition of > 8.8 ft^3 of nitrogen.
Temperature	Not applicable	Nitrogen gas temperature is not a process parameter that is monitored or controlled. Transportation safety calculations are performed using conservative values for both the initial nitrogen gas temperature and the ambient daytime temperature during transport.
Time Procedure	Until acceptable pressure is achieved	Operators manually control needle valve ECRT-V-607 and stop the pressurization when the pressure indicated

Table C-22. HAZOP Results Node 7. STS Cask Pressurization							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
7-1.	Flow	No	<ul style="list-style-type: none"> No nitrogen pressure Drain port closed A normally opened valve is closed 	<p>Hydrogen Deflagration:</p> <p>If there is no flow, then the STS cask will not be pressurized. Air leakage could occur eventually leading to a flammable hydrogen concentration.</p>	<ul style="list-style-type: none"> Inert gas system pressure instrumentation (PI-760-601 through -606) Valve position indicators 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of STS cask pressure 	The STS cask is purged with nitrogen via the drain port tool immediately prior to the cask pressurization activity. Thus the drain port would normally be open. If the drain port was inadvertently closed, then a pressure reading in the range of 3 to 15 psig could be obtained on pressure indicator ECRT-PI-606 without pressurizing the STS cask. However, the pressure would be achieved very quickly as the system would be deadheaded against the closed drain port tool.
7-2	Flow	Low	<ul style="list-style-type: none"> Low nitrogen pressure Drain port partially closed A normally opened valve is partially closed 	<p>Operational Upset:</p> <p>If the nitrogen flow is low, then it will take longer to reach the STS cask low pressure limit.</p>	<ul style="list-style-type: none"> Inert gas system pressure instrumentation (PI-760-601 through -606) Valve position indicators 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of STS cask pressure 	
7-3	Flow	High	High nitrogen pressure	<p>Overpressurization:</p> <p>If the flow is high, then operators may exceed the STS cask high pressure limit (see remarks). This could result in cask overpressurization.</p>	<ul style="list-style-type: none"> Pressure control valve ECRT-PCV-602 Inert gas system pressure instrumentation (PI-760-601 through -606) Valve position indicators Pressure safety valve ECRT-PSV-601 Cask vent port tool 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of STS cask pressure 	<p>If the flow rate was high, operators would have less time to stop the flow before exceeding the high pressure limit.</p> <p>If the STS cask high pressure limit is exceeded. The cask vent port tool can be used to reduce the pressure.</p>

Table C-22. HAZOP Results Node 7. STS Cask Pressurization							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
7-4	Flow	Reverse (nitrogen flow out of STS cask)	<ul style="list-style-type: none"> Leak or rupture of nitrogen supply piping or hose Vent port tool leak STS cask mechanical seal leak 	<p>Radiological Control:</p> <p>If nitrogen flows out of the STS cask and the inside of the STS cask was contaminated, then there would be a spread of contamination at the point of the leak.</p> <p>Industrial Safety:</p> <p>If nitrogen flows out of the STS cask, then it creates the potential for an inert atmosphere.</p> <p>Hydrogen Deflagration:</p> <p>If the nitrogen flows out of the cask, then the STS cask will not be pressurized. Air inleakage could occur eventually leading to a flammable hydrogen concentration.</p>	<ul style="list-style-type: none"> Inert gas system pressure instrumentation (PI-760-601 through -606) Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Radiological Control Program Industrial Safety Program Administrative control requiring verification of STS cask pressure STS cask leak test 	
7-5	Flow	Misdirected	Valve ECRT-V-609 mispositioned	<p>Hydrogen Deflagration:</p> <p>If valve ECRT-V-609 is mispositioned, then the nitrogen flow would be directed to the STSC purge inlet where it would deadhead against the male Staubli connector. The STS cask would not be pressurized. Air inleakage could occur eventually leading to a flammable hydrogen concentration.</p> <p>Industrial Safety</p> <p>If valve ECRT-V-609 is mispositioned, then the nitrogen flow would deadhead against the male Staubli connector at a pressure of 65 psig. Unmitigated, this could result in failure of piping or hoses which in turn could result in hose whip and the potential for an oxygen deficient atmosphere.</p>	<ul style="list-style-type: none"> Valve position indicators Piping and hoses designed to B31.3, "Process Piping" Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Administrative control requiring verification of STS cask pressure Industrial Safety Program 	If valve ECRT-V-609 was mispositioned, then a pressure reading in the range of 3 to 15 psig could be obtained on pressure indicator ECRT-PI-606 without pressurizing the STS cask. However, the pressure would be achieved very quickly as the system would be deadheaded

Table C-22. HAZOP Results Node 7. STS Cask Pressurization							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
7-6.a	Pressure	Low (nitrogen supply system)	<ul style="list-style-type: none"> • Drain port partially closed • A normally opened valve is partially closed • Pressure control valve failure 	<p>Operational Upset:</p> <p>If the nitrogen pressure is low, then the flow will be low and it will take longer to reach the STS cask low pressure limit.</p>	<ul style="list-style-type: none"> • Inert gas system pressure instrumentation (PI-760-601 through -606) • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration • Administrative control requiring verification of STS cask pressure 	
7-6.b	Pressure	Low (STS cask pressure < 3 psig)	See remarks	See remarks	See remarks	See remarks	The HAZOP identified multiple ways in which the STS cask pressure could be below the STS cask low pressure limit of 3 psig leading to the inleakage of air and a hydrogen deflagration. See Items 7-1, 7-2, 7-4, 6-5, 7-7.a, 7-7.b, 7-8.b, 7-9, 7-11.a, 7-12, and 7-14.
7-7.a	Pressure	High (nitrogen supply system)	<ul style="list-style-type: none"> • A normally-opened valve is closed or partially closed • Pressure control valve failure 	<p>Overpressurization</p> <p>If the pressure is high then the flow rate will be high and operators may exceed the STS cask high pressure limit. This could result in STS cask overpressurization.</p> <p>Industrial Safety:</p> <p>If the pressure is high, then the piping or hoses could fail. This could result in hose whip and the potential for an oxygen deficient atmosphere.</p> <p>Hydrogen Deflagration:</p> <p>If the pressure is high, then the piping or hoses could fail such that the STS cask would not be pressurized. Air inleakage could occur eventually leading to a flammable hydrogen concentration.</p>	<ul style="list-style-type: none"> • Inert gas system pressure instrumentation (PI-760-601 through -606) • Valve position indicators • Piping and hoses designed to B31.3, "Process Piping" • Pressure safety valve ECRT-PSV-601 • Cask vent port tool • Hose tie-downs • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Radiological Control Program • Conduct of operations verifies proper system configuration • Administrative control requiring verification of STS cask pressure 	<p>If the flow rate was high, operators would have less time to stop the flow before exceeding the high pressure limit.</p> <p>If the STS cask high pressure limit is exceeded. The cask vent port tool can be used to reduce the pressure.</p>

Table C-22. HAZOP Results Node 7. STS Cask Pressurization							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
7-7.b	Pressure	High (STS cask)	Pressure control valve failure	<p>Overpressurization:</p> <p>If the pressure is greater than the STS cask high pressure limit of 15 psig, then the STS cask could overpressurize.</p> <p>Radiological Control:</p> <p>If the pressure is high, then the STS cask mechanical seal could fail. If the inside of the STS cask was contaminated, then contaminated nitrogen would be discharged into the loading bay.</p> <p>Hydrogen Deflagration:</p> <p>If the pressure is high, then the STS cask mechanical seal could fail. This would allow air inleakage once the nitrogen flow was stopped. This could eventually lead to a flammable hydrogen concentration.</p>	<ul style="list-style-type: none"> Pressure safety valve ECRT-PSV-601 Cask vent port tool STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Conduct of operations verifies proper system configuration Administrative control requiring verification of STS cask pressure 	<p>The STS cask is rated at 80 psig.</p> <p>Pressure control valve ECRT-PCV-602 reduces the pressure from 425 psig to 65 psig.</p> <p>If the STS cask high pressure limit is exceeded. The cask vent port tool can be used to reduce the pressure.</p> <p>If the STS cask failed, a hydrogen deflagration could be prevented by re-establishing STSC active ventilation.</p>
7-8.a	Composition	Other (oxidant)	Gas bottles containing an oxidant (e.g., air) installed at Inert Bottle Station	<p>Hydrogen Deflagration:</p> <p>If gas bottles containing an oxidant are installed at the Inert Bottle Station, then an oxidant would be added to the STS cask by the pressurization activity and might not be inerted. This could result in a hydrogen deflagration (see remarks).</p>	<ul style="list-style-type: none"> Nitrogen-specific fixtures STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Quality Assurance Program 	The same gas bottles are used for both STS cask inerting and STS cask pressurization.
7-8.b	Composition	Other (helium)	Gas bottles containing helium installed at Inert Bottle Station	<p>Hydrogen Deflagration:</p> <p>If helium gas bottles are installed at the Bottle Station, then too much air inleakage will occur and the STS cask will not be inerted (see remarks).</p>	<ul style="list-style-type: none"> Nitrogen-specific fixtures Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Quality Assurance Program 	The same gas bottles are used for both STS cask inerting and STS cask pressurization.

Table C-22. HAZOP Results Node 7. STS Cask Pressurization							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
7-9	Level	Low (nitrogen bottle volume)	<ul style="list-style-type: none">Leak in supply systemOperator error (low pressure bottles not replaced as needed)	Hydrogen Deflagration: If the nitrogen volume is low, then there could be insufficient nitrogen to pressurize the STS cask to the low pressure limit. Air inleakage could occur eventually leading to a flammable hydrogen concentration.	<ul style="list-style-type: none">Inert gas system pressure indicator PI-760-601Modified KW Basin Annex confinement ventilationContinuous air monitors	<ul style="list-style-type: none">ProceduresTrainingConduct of operations verifies proper system configurationAdministrative control requiring verification of STS cask pressure	
7-10	Level	High (nitrogen bottle volume)	N/A	N/A	N/A	N/A	
7-11.a	Structural integrity	Leak/rupture (nitrogen supply system)	<ul style="list-style-type: none">OverpressurizationManufacturing flawProcurement errorHose connection decouples	Industrial Safety: If the there is leak/rupture in the nitrogen supply system, then nitrogen will be released at the point of failure. This could potentially result in an oxygen deficient atmosphere. Hydrogen Deflagration: If there is a leak/rupture in the nitrogen supply system, then the STS cask would not be pressurized. Air inleakage could occur eventually leading to a flammable hydrogen concentration.	<ul style="list-style-type: none">Inert gas system pressure instrumentation (PI-760-601 through -606)Valve position indicatorsPiping and hoses designed to B31.3, "Process Piping"Hose tie-downsPressure safety valve ECRT-PSV-601Modified KW Basin Annex confinement ventilationContinuous air monitors	<ul style="list-style-type: none">ProceduresTrainingHydro testingIndustrial Safety ProgramConduct of operations verifies proper system configurationAdministrative control requiring verification of STS cask pressure	

Table C-22. HAZOP Results Node 7. STS Cask Pressurization							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
7-11.b	Structural integrity	Leak/rupture (STS cask)	<ul style="list-style-type: none"> Overpressurization STS cask mechanical seal failure 	Hydrogen deflagration: If the STS cask leaks/ruptures, then air will leak into the STS cask. This could eventually lead to a hydrogen deflagration.	<ul style="list-style-type: none"> STS cask pressure boundary Pressure control valves ECRT-PCV-601, -602 Pressure safety valve ECRT-PSV-601 Inert gas system pressure instrumentation (PI-760-601 through -606) Valve position indicators STSC active ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration STS cask leak test 	
7-12	Time procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure 	Hydrogen deflagration: If the operator pressurizes the STS cask for too short a period of time, then the STS cask will not be pressurized to the low pressure limit. Air inleakage could occur eventually leading to a flammable hydrogen concentration.	STS cask pressure instrumentation (PI-760-606)	<ul style="list-style-type: none"> Procedures Training Administrative control requiring verification of STS cask pressure 	
7-13	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Instrumentation failure 	Overpressurization: If the operator pressurizes the STS cask for too long a period of time, then the STS cask high pressure limit will be exceeded. This could result in cask overpressurization.	<ul style="list-style-type: none"> STS cask pressure instrumentation (PI-760-606) Cask vent port tool 	<ul style="list-style-type: none"> Procedures Training Administrative control requiring verification of STS cask pressure 	If the STS cask high pressure limit is exceeded. The cask vent port tool can be used to reduce the pressure.
7-14	Time Procedure	Skip action	<ul style="list-style-type: none"> Operator error 	Hydrogen deflagration: If the operator does not pressurize the STS cask, then air inleakage could occur eventually leading to a flammable hydrogen concentration.	<ul style="list-style-type: none"> Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Administrative control requiring verification of STS cask pressure 	
7-15	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	

Table C-23. Normal Operating Conditions, Node 8, In-Basin Flocculant Addition System		
Process Parameter	Design Intent	Remarks
Flow	530 ml/min (0.14 gpm)	The motive force is metering pump ECRT-P-203
Pressure	70 - 85 psig	Based on calculations in PRC-STP-CN-CH00229, <i>Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Calculation – Flocculant System</i>
Concentration	1 mg/mL	This is the concentration of the flocculant solution in flocculant tank ECRT-TK-201. Operations personnel will prepare the solution to this concentration.
Composition	Clarifloc N-3300P	The flocculant is a non-ionic water-soluble polymer. The NFPA 704 ratings are : <ul style="list-style-type: none"> • Health 1 (exposure would cause irritation with only minor injury) • Flammability 1 (must be heated before ignition can occur. Flash point over 93 °C) • Reactivity 0 (normally stable, even under fire exposure conditions, and is not reactive with water.
Level	>6 L	Based on calculations in PRC-STP-CN-CH00229, approximately 6 L of flocculant is needed for 1 day of operation.
Structural Integrity	Maintain integrity under normal operating conditions	None
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The flocculant addition tank is located on the deck on the basin deck. The temperature of flocculant will be approximately the same as the air temperature in the basin.
Time Procedure	Flocculant is added at the start of the transfer and continues until the transfer is completed	Flocculant addition is manually started and is terminated by activation of interlock I-5.

PRC-STP-CN-CH00229, 2010, *Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Calculation – Flocculant System*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

Table C-24. HAZOP Results, Node 8, In-Basin Flocculant Addition System							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
8-1	Flow	No	<ul style="list-style-type: none"> • Metering pump ECRT-P-203 is not operating • A normally-opened valve is closed • Tank ECRT-TK-203 is empty 	<p>Operational Upset:</p> <p>If there is no flow, then flocculant will not be added to the sludge transfer. This could result in longer settling times prior to STSC decant.</p>	<ul style="list-style-type: none"> • Pressure instrumentation (PIT-710-203) • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration 	If tank ECRT-TK-201 is empty, there will be no flow of flocculant, but pump ECRT-P-203 would pump air
8-2	Flow	Low	<ul style="list-style-type: none"> • Flow rate set incorrectly • A normally-opened valve is partially closed 	<p>Operational Upset:</p> <p>If the flow rate is low, then less flocculant will be added to the sludge transfer. This could result in longer settling times prior to STSC decant.</p>	<ul style="list-style-type: none"> • Flow controller FC-710-201 • Pressure instrumentation (PIT-710-203) • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration 	The flow rate is set using the calibration column.
8-3	Flow	High	Flow rate set incorrectly	<p>Operation Upset:</p> <p>If the flow rate is high, then more flocculant will be added to the sludge transfer. This could subsequently result in plugging of the sand filters.</p>	<ul style="list-style-type: none"> • Flow controller FC-710-201 • Pressure instrumentation (PIT-710-203) • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration 	<p>The flow rate is set using the calibration column.</p> <p>Based on testing as MASF, it is unlikely that excess flocculant would result in plugging of the sand filter.</p> <p>Amount of flocculant added is limited by the capacity of tank ECRT-TK-201.</p>
8-4.a	Flow	Reverse	Metering pump ECRT-P-203 runs in reverse	<p>Uncontrolled Release:</p> <p>If metering pump ECRT-P-203 runs in reverse, then sludge would be pumped into the flocculant addition system and could result in a spray or splash and splatter/pool release.</p>	Check valves ECRT-207 and -208	<ul style="list-style-type: none"> • Procedures • Training • Pre-operational testing 	Pump ECRT-P-203 is similar to an AODD, except that it has one diaphragm and is mechanically actuated. Regardless of which way the motor is turning, the internal check valves will only allow flow in one direction. Once installed correctly, as verified by pre-operational testing, it cannot pump in the reverse direction.

Table C-24. HAZOP Results, Node 8, In-Basin Flocculant Addition System							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
8-4.b	Flow	Reverse	Booster pump ECRT-P-101 runs in reverse	<p>Uncontrolled Release:</p> <p>If booster pump ECRT-P-101 runs in reverse, then sludge could flow into the flocculant addition system to a point above the basin water.</p> <p>If the flocculant addition system line failed due to the pressure generated by pump ECRT-P-101, then a spray or splash and splatter/pool release could occur.</p>	Check valves ECRT-CV-207 and -208	<ul style="list-style-type: none"> Procedures Training Pre-operational testing 	The design of booster pump ECRT-P-101 is such that it can be operated in the reverse direction. However, there are no plans to operate the pump in reverse.
8-5	Flow	Misdirected	Operator error: metering pump ECRT-P-203 started when Xago Hydrolance™ and booster pump ECRT-P-101 are shut off	<p>Operational Upset:</p> <p>If metering pump ECRT-P-203 operates when the Xago Hydrolance™ and booster pump ECRT-P-101 are shut off, then flocculant will be pumped into the engineered container via the Xago Hydrolance™ Coanda head and into the basin via the basin water flush valve.</p> <p>If flocculant is added to the basin water, then the performance of the IXM Skimmer Water System sand filter could be affected.</p>	None	<ul style="list-style-type: none"> Procedures Training 	The flocculant would be added to the basin at a very low flow rate and concentration. It is unlikely it would affect the IXM Skimmer Water System sand filter performance.
8-6	Pressure	Low	Flow rate set incorrectly	<p>Operational Upset:</p> <p>If the pressure is low, then the flow will be low. Consequences are as stated in Item 8-2 above.</p>	<ul style="list-style-type: none"> Flow controller FC-710-201 Pressure instrumentation (PIT-710-203) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	

Table C-24. HAZOP Results, Node 8, In-Basin Flocculant Addition System							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
8-7	Pressure	High	<ul style="list-style-type: none"> Flow rate set incorrectly Normally opened valve closed or partially closed 	<p>Industrial Safety:</p> <p>If the pressure is high, then the flocculant supply hose could fail above the basin water and whip causing a facility worker injury.</p> <p>Operational Upset:</p> <p>If the pressure is high, then the flocculant supply hose could fail below the basin water and flocculant would be added to the basin water.</p> <p>If flocculant is added to the basin water, then the performance of the IXM Skimmer Water System sand filter could be affected.</p>	<ul style="list-style-type: none"> Pressure instrumentation (PIT-710-203) Piping and hoses designed in accordance with B31.3, "Process Piping." Pressure safety valve ECRT-PSV-201 Valve position indicators 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	The flocculant would be added to the basin at a very low flow rate and concentration. It is unlikely it would affect the IXM Skimmer Water System sand filter performance.
8-8	Concentration	Low	Error in preparing flocculant solution	<p>Operational Upset:</p> <p>If the concentration is low, then less flocculant will be added to the sludge transfer. This could result in longer settling times prior to STSC decant.</p>	None	<ul style="list-style-type: none"> Procedures Training 	
8-9	Concentration	High	Error in preparing flocculant solution	<p>Operation Upset:</p> <p>If the concentration is high, then more flocculant will be added to the sludge transfer. This could subsequently result in plugging of the sand filters.</p>	None	<ul style="list-style-type: none"> Procedures Training 	Based on testing as MASF, it is unlikely that excess flocculant would result in plugging of the sand filter.
8-10.a	Composition	Other (degraded flocculant, see remarks)	Operator error	<p>Operational Upset:</p> <p>If the flocculant is degraded, then settling will not be as efficient. This could result in longer settling times prior to STSC decant.</p>	None	<ul style="list-style-type: none"> Procedures Training 	If the flocculant is not used within 8 days of preparation, it begins to break-down and becomes less effective.

Table C-24. HAZOP Results, Node 8, In-Basin Flocculant Addition System							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
8-10.b	Composition	Other (different flocculant)	Procurement error	Operational Upset: If a flocculant other than Clarifloc N-3300P is used, then settling times prior to STSC decant could be longer. In addition, the different flocculant may result in plugging of the sand filters.	None	<ul style="list-style-type: none"> • Procedures • Training • Quality Assurance Program 	
8-11	Level	High	Operator error	Operational Upset: If the level in flocculant tank ECRT-TK-201 is high, then the tank could overflow and spill flocculant onto the basin deck.	None	<ul style="list-style-type: none"> • Procedures • Training • Visual inspection 	
8-12	Level	Low	Operator error	Operational Upset: If the level in flocculant tank ECRT-TK-201 is low, then there will not be sufficient flocculant for the transfer. This could result in longer settling times prior to STSC decant. If the tank level was sufficiently low, then pump ECRT-P-203 would begin to pump air into the transfer line.	None	<ul style="list-style-type: none"> • Procedures • Training • Visual inspection 	
8-13.a	Structural Integrity	Leak/rupture (above basin water)	<ul style="list-style-type: none"> • Overfill tank ECRT-TK-201 • Overpressurization • Hose disconnects 	Operational Upset: If there is a leak or rupture above the basin water, then the correct amount of flocculant will not be added to the transfer. This could result in longer settling times prior to STSC decant. In addition, the flocculant would run into the basin water such that performance of the IXM Skimmer Water System sand filter could be affected.	<ul style="list-style-type: none"> • Pressure instrumentation (PIT-710-203) • Piping designed in accordance with B31.3, "Process Piping." • Pressure safety valve ECRT-PSV-201 • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration 	The flocculant would be added to the basin at a very low flow rate and concentration. It is unlikely it would affect the IXM Skimmer Water System sand filter performance.

Table C-24. HAZOP Results, Node 8, In-Basin Flocculant Addition System							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
8-13.b	Structural Integrity	Leak/rupture (below basin water)	<ul style="list-style-type: none"> • Overpressurization • Hose disconnects 	<p>Operational Upset:</p> <p>If there is a leak or rupture below the basin water, then the correct amount of flocculant will not be added to the transfer. This could result in longer settling times prior to STSC decant.</p> <p>In addition, if flocculant is added to the basin water, then the performance of the IXM Skimmer Water System sand filter could be affected.</p>	<ul style="list-style-type: none"> • Pressure instrumentation (PIT-710-203) Piping designed in accordance with B31.3, "Process Piping." • Pressure safety valve ECRT-PSV-201 • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration 	The flocculant would be added to the basin at a very low flow rate and concentration. It is unlikely it would affect the IXM Skimmer Water System sand filter performance.
8-14	Time Procedure	Too short	<ul style="list-style-type: none"> • Operator error • Equipment failure 	<p>Operational Upset:</p> <p>If the flocculant is added for too short a period of time, then flocculant will not be added to a portion of the transfer. This could result in longer settling times prior to STSC decant.</p>	Pressure instrumentation (PIT-710-203)	<ul style="list-style-type: none"> • Procedures • Training 	
8-15	Time Procedure	Too long	<ul style="list-style-type: none"> • Operator error • Equipment failure 	<p>Operational Upset:</p> <p>Adding flocculant after the transfer is complete (i.e., after booster pump ECRT-P-101 has been shut off) would result in a misdirected flow of flocculant. The consequences would be as state in Item 8-5 above.</p>	Check valve ECRT-CV-101 (on the basin water check valve)	<ul style="list-style-type: none"> • Procedures • Training 	
8-16	Time Procedure	Skip action	Operator error	<p>Operational Upset:</p> <p>If the action is skipped, then flocculant will not be added to the sludge transfer. This could result in longer settling times prior to STSC decant.</p>	Pressure instrumentation (PIT-710-203)	<ul style="list-style-type: none"> • Procedures • Training 	
8-17	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There is no wrong action associated with this node.

Table C-25. Normal Operating Conditions, Node 9.a, Annex Flocculant Addition System – Flocculant Tank to In-Line Mixer		
Process Parameter	Design Intent	Remarks
Flow	45.4 ml/min (0..12 gpm)	The motive force is metering pump ECRT-P-204. PRC-STP-CN-CH00229, <i>Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Calculation – Flocculant System</i> , shows a range of flocculant addition rates based on a range of flocculant concentrations. Subsequent to issuing PRC-STP-CN-CH00229, Rev. 1, a decision was made to use a single concentration
Pressure	70 to 85 psi	Based on calculations in PRC-STP-CN-CH00229. The pressure is restricted by the pressure rating on AE-720-201.
Concentration	1 mg/mL	This is the concentration of the flocculant solution in flocculant tank ECRT-TK-202. Operations personnel will prepare the solution to this concentration.
Composition	Clarifloc N-3300P	The flocculant is a non-ionic water-soluble polymer. The NFPA 704 ratings are : <ul style="list-style-type: none"> • Health 1 (exposure would cause irritation with only minor injury) • Flammability 1 (must be heated before ignition can occur. Flash point over 93 °C) • Reactivity 0 (normally stable, even under fire exposure conditions, and is not reactive with water.)
Level	>7 L	Based on calculations in PRC-STP-CN-CH00229, approximately 6 L of flocculant is needed for 1 day of operation.
Structural Integrity	Maintain integrity under normal operating conditions	None
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The flocculant addition tank is located on the deck on the basin deck. The temperature of flocculant will be approximately the same as the air temperature in the basin.
Time Procedure	Flocculant is added at the start of the decant recycle and is added until the turbidity decreases to 210 NTUs or until further flocculant addition does not result in a decrease in turbidity	Flocculant addition is manually started and stopped.

PRC-STP-CN-CH00229, 2010, *Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Calculation – Flocculant System*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

Table C-26. HAZOP Results, Node 9.a, Annex Flocculant Addition System – Flocculant Tank to In-Line Mixer							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.a-1	Flow	No	<ul style="list-style-type: none"> • Metering pump ECRT-P-204 is not operating • A normally-opened valve is closed • Tank ECRT-TK-202 is empty 	<p>Operational Upset:</p> <p>If there is no flow, then flocculant will not be added to the recirculated supernate. This could result in longer settling times prior to STSC decant. •</p>	<ul style="list-style-type: none"> • Pressure instrumentation (PIT-710-204) • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration 	If tank ECRT-TK-201 is empty, there will be no flow of flocculant, but pump ECRT-P-203 would pump air
9.a-2	Flow	Low	<ul style="list-style-type: none"> • Flow rate set incorrectly • A normally-opened valve is partially closed 	<p>Operational Upset:</p> <p>If the flow rate is low, then less flocculant will be added to the recirculated supernate. This could result in longer settling times prior to STSC decant.</p>	<ul style="list-style-type: none"> • Flow controller FC-710-202 • Pressure instrumentation (PIT-710-204) • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration 	The flow rate is set using the calibration column.
9.a-3	Flow	High	Flow rate set incorrectly	<p>Operation Upset:</p> <p>If the flow rate is high, then more flocculant will be added to the recirculated supernate. This could subsequently result in plugging of the sand filters.</p>	<ul style="list-style-type: none"> • Flow controller FC-710-202 • Pressure instrumentation (PIT-710-204) • Valve position indicators 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration 	<p>The flow rate is set using the calibration column.</p> <p>Based on testing as MASF, it is unlikely that excess flocculant would result in plugging of the sand filter.</p>
9.a-4	Flow	Reverse	<ul style="list-style-type: none"> • Metering pump ECRT-P-204 runs in reverse • Metering pump ECRT-P-204 not operating • Low pressure in flocculant addition line 	<p>Uncontrolled Release:</p> <p>If metering pump ECRT-P-204 runs in reverse, then recirculated supernate would be pumped into the flocculant addition system and could result in a spray or and splatter/pool release.</p> <p>If metering pump ECRT-P-204 does not operate, or if the pressure in the flocculant addition line is low, then recirculated supernate would be pumped into the flocculant addition system (due to the 80 psi generated by decant pump ECRT-P-201) and could result in a spray or splash and splatter/pool release.</p>	<ul style="list-style-type: none"> • Check valve ECRT-CV-202 • Pressure instrumentation (PIT-710-204) • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Pre-operational testing • Modified KW Basin Annex is unmanned during decant operations 	Pump ECRT-P-204 is similar to an AODD, except that it has one diaphragm and is mechanically actuated. Regardless of which way the motor is turning, the internal check valves will only allow flow in one direction. Once installed correctly, as verified by pre-operational testing, it cannot pump in the reverse direction.
9.a-5	Flow	Misdirected	N/A	N/A	N/A	N/A	This Node cannot be misdirected.

Table C-26. HAZOP Results, Node 9.a, Annex Flocculant Addition System – Flocculant Tank to In-Line Mixer							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.a-6	Pressure	Low	Flow rate set incorrectly	<p>Uncontrolled Release:</p> <p>If the pressure is low, then recirculated supernate would be pumped into the flocculant addition system (due to the 80 psi generated by decant pump ECRT-P-201) and could result in a spray or splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Flow controller FC-710-201 Pressure instrumentation (PIT-710-204) 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations 	
9.a-7	Pressure	High	<ul style="list-style-type: none"> Flow rate set incorrectly Normally opened valve closed or partially closed 	<p>Operational Upset:</p> <p>If the pressure is high, then the flow rate will be high. The consequences are as shown in Item 8-3.</p> <p>Uncontrolled Release:</p> <p>If the pressure is high, then the decant/flocculant recirculation line could fail resulting in a spray or splash and splatter/pool release</p> <p>Hydrogen Deflagration:</p> <p>If the pressure is high, then the decant/flocculant recirculation line could fail. Hydrogen generated by the supernate could accumulate in the Decant Pump Box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Flow controller FC-710-202 Pressure instrumentation (PIT-710-204) Piping and hoses designed in accordance with B31.3, "Process Piping." Pressure safety valve ECRT-PSV-202 Valve position indicators Secondary containment with leak detection Leak detection interlocked to shut off Decant pump ECRT-P-201 Decant Pump Box HEPA-filtered confinement ventilation Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations Leak detection alarm response 	
9.a-8	Concentration	Low	Error in preparing flocculant solution	<p>Operational Upset:</p> <p>If the concentration is low, then less flocculant will be added to the recirculated decant . This could result in longer settling times prior to STSC decant.</p>	None	<ul style="list-style-type: none"> Procedures Training 	

Table C-26. HAZOP Results, Node 9.a, Annex Flocculant Addition System – Flocculant Tank to In-Line Mixer							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.a-9	Concentration	High	Error in preparing flocculant solution	Operation Upset: If the concentration is high, then more flocculant will be added to the recirculated decant. This could subsequently result in plugging of the sand filters.	None	<ul style="list-style-type: none"> Procedures Training 	Based on testing as MASF, it is unlikely that excess flocculant would result in plugging of the sand filter.
9.a-10.a	Composition	Other (degraded flocculant, see remarks)	Operator error	Operational Upset: If the flocculant is degraded, then settling will not be as efficient. This could result in longer settling times prior to STSC decant.	None	<ul style="list-style-type: none"> Procedures Training 	If the flocculant is not used within 8 days of preparation, it begins to break-down and becomes less effective.
9.a-10.b	Composition	Other (different flocculant)	Procurement error	Operational Upset: If a flocculant other than Clarifloc N-3300P is used, then settling times prior to STSC decant could be longer. In addition, the different flocculant may result in plugging of the sand filters.	None	<ul style="list-style-type: none"> Procedures Training Quality Assurance Program 	
9.a-11	Level	High	Operator error	Operational Upset: If the level in flocculant tank ECRT-TK-202 is high, then the tank could overflow and spill flocculant in the Annex.	None	<ul style="list-style-type: none"> Procedures Training Visual inspection 	
9.a-12	Level	Low	Operator error	Operational Upset: If the level in flocculant tank ECRT-TK-202 is low, then there will not be sufficient flocculant for the transfer. This could result in longer settling times prior to STSC decant. If the tank level was sufficiently low, then pump ECRT-P-204 would begin to pump air into the decant/flocculant recirculation line.	None	<ul style="list-style-type: none"> Procedures Training Visual inspection 	

Table C-26. HAZOP Results, Node 9.a, Annex Flocculant Addition System – Flocculant Tank to In-Line Mixer							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.a-13.a	Structural Integrity	Leak/rupture (inside Decant Pump Box)	<ul style="list-style-type: none">• Overpressurization• Hose disconnects	Operational Upset: If the leak is small, then flocculant will spill into the Decant Pump Box. Uncontrolled Release: If the leak is large, then the pressure could drop to the point that recirculated supernate would be pumped into the flocculant addition system (due to the 80 psi generated by decant pump ECRT-P-201) which would result in a spray or splash and splatter/pool release. Hydrogen Deflagration: If the leak is large, and recirculated supernate is pumped into the Decant Pump Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.	<ul style="list-style-type: none">• Pressure instrumentation (PIT-710-204)• Check valve ECRT-CV-202• Piping and hoses designed in accordance with B31.3, “Process Piping.”• Pressure safety valve ECRT-PSV-202• Valve position indicators• Secondary confinement with leak detection• Leak detection interlocked to shut off decant pump ECRT-P-201Decant Pump BoxHEPA-filtered active ventilation	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration• Modified KW Basin Annex is unmanned during decant operations• Leak detection alarm response	
9.a-13.b	Structural Integrity	Leak/rupture (outside Decant Pump Box)	<ul style="list-style-type: none">• Overpressurization• Hose disconnects	Operational Upset: If the leak is small, then flocculant will spill into the Modified KW Basin Annex Uncontrolled Release: If the leak is large, then the pressure could drop to the point that recirculated supernate would be pumped into the flocculant addition system (due to the 80 psi generated by decant pump ECRT-P-201) which would result in a spray or splash and splatter/pool release.	<ul style="list-style-type: none">• Pressure instrumentation (PIT-710-204)• Piping and hoses designed in accordance with B31.3, “Process Piping.”• Valve position indicators• Check valve ECRT-CV-202• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration• Modified KW Basin Annex is unmanned during decant operations	
9.a-14	Time Procedure	Too short	<ul style="list-style-type: none">• Operator error• Equipment failure	Operational Upset: If the flocculant is added for too short a period of time, then an insufficient amount of flocculant will be added. This could result in longer settling times prior to STSC decant.	% solids instrumentation (AE-720-201)	<ul style="list-style-type: none">• Procedures• Training	

Table C-26. HAZOP Results, Node 9.a, Annex Flocculant Addition System – Flocculant Tank to In-Line Mixer							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.a-15	Time Procedure	Too long	<ul style="list-style-type: none">• Operator error• Equipment failure	Operational Upset: If flocculant is added for too long a period of time, then too much flocculant will be added. This could subsequently result in plugging of the sand filters.	% solids instrumentation (AE-720-201)	<ul style="list-style-type: none">• Procedures• Training	The volume of flocculant tank ECRT-TK-202 is too small to result in overfilling the STSC.
9.a-16	Time Procedure	Skip action	Operator error	Operational Upset: If the action is skipped, then flocculant will not be added to the recirculated decant. This could result in longer settling times prior to STSC decant.	% solids instrumentation (AE-720-201)	<ul style="list-style-type: none">• Procedures• Training	
9.a-17	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There is no wrong action associated with this node.

Table C-27. Normal Operating Conditions, Node 9.b, Annex Flocculant Addition System – Decant Recirculation		
Process Parameter	Design Intent	Remarks
Flow	20 gpm	Motive force is decant pump ECRT-P-201. Decant pump ECRT-P-201 is an air-operated, double-diaphragm (AODD) pump.
Pressure	80 psig	Pressure is controlled by the air pressure supplied to decant pump ECRT-P-201. The instrument air system produces 212 scfm of dry air at 100 psig. Pressure control valves are used to regulate the pressure to the pump.
Concentration (solids in recirculated decant)	<u>Prior to flocculant addition:</u> KE sludge = 11.9 g/L KW sludge = 16.8 g/L Settler tank sludge = 39.3 g/L	The concentrations shown are maximums as documented in HNF-40151 for STSC decant.
	After flocculant addition < 1,000 mg/L	
Composition	STSC supernate and Clarifloc N-3300P	None
Level	<u>STSC level at start/finish of decant recycle:</u> KE/KW sludge ~ 925 gal Settler tank sludge ~ 765 gal	Flocculant addition increases the STSC volume by approximately 2 gallons. The volume of flocculant tank ECRT-TK-202 is too small to overfill the STSC.
Structural Integrity	Maintain integrity under normal operating conditions	None
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. When initially transferred to the STSC, the slurry temperature will be approximately 10-15 °C (i.e., the same as basin water). Once transferred, the slurry temperature will slowly increase based on two factors: (1) the ambient temperature in the Modified KW Basin Annex, and (2) the quantity of uranium metal in the slurry and rate of uranium metal oxidation. The annex HVAC system is design to maintain a minimum temperature of 65 °F (18 °C) given an outside temperature of 0 °F, and a maximum temperature of 80 °F (27 °C) given an outside temperature of 105 °F.
Time Procedure	The decant recycle continues until the turbidity decreases to 210 NTUs or until further flocculant addition does not result in a decrease in turbidity	None

Table C-28. HAZOP Results, Node 9.b, Annex Flocculant Addition System – Decant Recirculation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.b-1	Flow	No	<ul style="list-style-type: none"> Decant pump ECRT-P-201 not operating A normally-opened valve is closed 	<p>Operational Upset:</p> <p>If there is no flow, then the STSC supernate will not be recirculated.</p> <p>If there is no flow because a normally-opened valve is closed, then decant pump ECRT-P-201 will deadhead resulting in a high pressure. See item 9-7 below.</p>	<ul style="list-style-type: none"> Decant line pressure instrumentation (PT-720-201 and -202) Decant line flow instrumentation (FE-720-201) Manual valve position indicators 	<ul style="list-style-type: none"> Procedures Training 	
9.b-2	Flow	Low	<ul style="list-style-type: none"> Low air pressure to decant pump ECRT-P-201 A normally-opened valve is partially closed 	<p>Operational Upset:</p> <p>If the flow rate is low, then it will take longer to recirculate the STSC supernate.</p>	<ul style="list-style-type: none"> Decant line pressure instrumentation (PT-720-201 and -202) Decant line flow instrumentation (FE-720-201) Manual valve position indicators 	<ul style="list-style-type: none"> Procedures Training 	
9.b-3	Flow	High	High air pressure to decant pump ECRT-P-201	<p>Operational Upset:</p> <p>If the flow rate is high, then the STSC supernate will be recirculated faster.</p>	<ul style="list-style-type: none"> Pressure control valve ECRT-PCV-760 Pressure control valve ECRT-PCV-765 Decant line pressure instrumentation (PT-720-201 and -202) Decant line flow instrumentation (FE-720-201) 	<ul style="list-style-type: none"> Procedures Training 	
9.b-4	Flow	Reverse	Decant pump ECRT-P-201 runs in reverse	<p>Operational Upset:</p> <p>If the pump operated in reverse, then the recirculation would occur in the reverse direction.</p>	<ul style="list-style-type: none"> Decant line pressure instrumentation (PT-720-201 and -202) Decant line flow instrumentation (FE-720-201) 	<ul style="list-style-type: none"> Procedures Training Pre-operational testing 	The only way to get reverse flow during decant recirculation would be install decant pump ECRT-P-201 backwards. Such an error would be discovered in pre-operational testing.

Table C-28. HAZOP Results, Node 9.b, Annex Flocculant Addition System – Decant Recirculation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.b-5.a	Flow	Misdirected (into Decant Pump Box)	<ul style="list-style-type: none"> Valving error such that supernate enters box via IXM water spray nozzles Valving error such that supernate enters box via siphon break 	<p>Uncontrolled Release:</p> <p>If supernate is misdirected into the Decant Pump Box, then a splash and splatter/pool release will occur.</p> <p>Hydrogen Deflagration:</p> <p>If supernate is misdirected into the Decant Pump Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Valve position indicators Secondary confinement with leak detection Leak detection interlocked to shut off Decant pump ECRT-P-201 Decant Pump Box HEPA-filtered active ventilation 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations Leak detection alarm response 	
9.b-5.b	Flow	Misdirected (into Transfer Line Service Box)	<ul style="list-style-type: none"> Valving error such that supernate enters box via IXM water spray nozzles Valving error such that supernate enters box via siphon break 	<p>Uncontrolled Release:</p> <p>If supernate is misdirected into the Transfer Line Service Box, then a splash and splatter/pool release will occur.</p> <p>Hydrogen Deflagration:</p> <p>If supernate is misdirected into the Transfer Line Service Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Valve position indicators Secondary confinement with leak detection Leak detection interlocked to shut off Decant pump ECRT-P-201 Transfer Line Service Box HEPA-filtered active ventilation 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations Leak detection alarm response 	
9.b-5.c	Flow	Misdirected (to sand filters)	Valve ECRT-V-201 misaligned	<p>Uncontrolled Release:</p> <p>If supernate is misdirected into the sand filter, then decant pump ECRT-P-201 will deadhead resulting in a high pressure. See Item 9-7 below.</p>	Valve position indicators	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	
9.b-5.d	Flow	Misdirected (into Decant Pump Box IXM water supply)	Valving error	<p>Uncontrolled Release:</p> <p>If supernate is misdirected into the Decant Pump Box IXM water supply, then a splash and splatter/pool release could occur.</p>	<ul style="list-style-type: none"> Valve position indicators Check valve ECRT-CV-201 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations 	

Table C-28. HAZOP Results, Node 9.b, Annex Flocculant Addition System – Decant Recirculation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.b-5.e	Flow	Misdirected (into Transfer Line Service Box IXM water supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the Transfer Line Service Box IXM water supply, then a splash and splatter/pool release could occur.	<ul style="list-style-type: none"> Valve position indicators Check valve ECRT-CV-301 and -302 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations 	
9.b-5.f	Flow	Misdirected (into flocculant addition supply)	<ul style="list-style-type: none"> Valving error Low pressure in flocculant addition line High pressure in the decant/flocculant recirculation line 	Uncontrolled Release: If supernate is misdirected into the flocculant addition supply, then a splash and splatter/pool release could occur.	<ul style="list-style-type: none"> Valve position indicators Check valve ECRT-CV-202 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations 	
9.b-6	Pressure	Low	Low air pressure to decant pump ECRT-P-201	Operational Upset: If the pressure is low, then the flow rate will be low and it will take longer to recirculate the STSC supernate.	<ul style="list-style-type: none"> Decant line pressure instrumentation (PT-720-201 and -202) Decant line flow instrumentation (FE-720-201) 	<ul style="list-style-type: none"> Procedures Training 	

Table C-28. HAZOP Results, Node 9.b, Annex Flocculant Addition System – Decant Recirculation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.b-7	Pressure	High	<ul style="list-style-type: none"> High air pressure to decant pump ECRT-P-201 A normally-opened valve is closed 	<p>Uncontrolled Release:</p> <p>If the pressure is high, then the decant/flocculant recirculation line or flocculant addition line could fail resulting in an airborne spray release or splash and splatter/pool release.</p> <p>Hydrogen Deflagration:</p> <p>If the pressure is high, then the decant/flocculant recirculation line could fail. Hydrogen generated by the supernate could accumulate in the Decant Pump Box or Transfer Line Service Box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Piping designed in accordance with B31.3, "Process Piping" Valve position indicators Pressure control valve ECRT-PCV-760 and -765 Decant line pressure instrumentation (PT-720-201 and -202) Secondary containment with leak detection Leak detection interlocked to shut off Decant pump ECRT-P-201 Decant Pump Box HEPA-filtered active ventilation Transfer Line Service Box HEPA-filtered active ventilation 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Modified KW Basin Annex is unmanned during decant operations Leak detection alarm response 	
9.b-8	Concentration (solids in recirculating supernate)	Low	N/A	N/A	N/A	N/A	A low turbidity in the decanted supernate is desirable.
9.b-9	Concentration (solids in recirculated supernate)	High	<ul style="list-style-type: none"> Settling time too short No flocculant addition 	<p>Operational Upset:</p> <p>If the turbidity is high, then the supernate cannot be decanted to the sand filter. See Table C-14, Item 3-9.a for the consequences of transferring a high concentration supernate to the sand filters.</p>	Turbidity instrumentation (AE-720-201)	<ul style="list-style-type: none"> Procedures Training 	

Table C-28. HAZOP Results, Node 9.b, Annex Flocculant Addition System – Decant Recirculation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.b-10	Composition	Other (degraded flocculant, different flocculant)	Operator error	See Table C-26, Items 8.a-10.a and -10.b	See Table C-26, Items 8.a-10.a and -10.b	See Table C-26, Items 8.a-10.a and -10.b	
9.b-11	Level (STSC)	Low	STSC not filled to proper level (see Table C-10, Items 2.c-9.a and -b)	None	Level switches LS/LSH/LSHH-740-401	<ul style="list-style-type: none">• Procedures• Training	
9.b-12	Level (STSC)	High	STSC not filled to proper level (see Table C-10, Items 2.c-10.a and -b)	None	Level switches LS/LSH/LSHH-740-401	<ul style="list-style-type: none">• Procedures• Training	
9.b-13.a	Structural Integrity	Leak/rupture	Decant pump ECRT-P-201 diaphragm failure	Uncontrolled Release: If the decant pump diaphragm failed, then supernate could enter the pump exhaust resulting in a spray or splash and splatter/pool release.	<ul style="list-style-type: none">• Decant line pressure instrumentation (PT-720-201 and -202)• Decant line flow instrumentation (FE-720-201)• HEPA filtration of decant pump exhaust	<ul style="list-style-type: none">• Procedures• Training• Modified KW Basin Annex is unmanned during decant operations	

Table C-28. HAZOP Results, Node 9.b, Annex Flocculant Addition System – Decant Recirculation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.b-13.b	Structural Integrity	Leak/rupture (decant/flocculant recirculation line, see remarks)	<ul style="list-style-type: none"> High pressure (see Item 9.b-7 above) Manufacturing flaw Hose connection decouples 	<p>Uncontrolled Release:</p> <p>If the decant/flocculant recirculation line fails, then a spray or splash and splatter/pool release of STSC supernate will occur.</p> <p>Hydrogen Deflagration:</p> <p>If the leak is large, and recirculated supernate is pumped into the Decant Pump Box or Transfer Line Service Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.</p>	<ul style="list-style-type: none"> Piping designed in accordance with B31.3, "Process Piping" Decant line pressure instrumentation (PT-720-201 and -202) Decant line flow instrumentation (FE-720-201) Secondary containment with leak detection Leak detection interlocked to shut off Decant pump ECRT-P-201 Decant Pump Box HEPA-filtered confinement Transfer Line Service Box HEPA-filtered confinement ventilation 	<ul style="list-style-type: none"> Procedures Training Modified KW Basin Annex is unmanned during decant operations Leak detection alarm response 	The decant/flocculant recirculation line is comprised of a combination of hose-in-hose transfer lines and hard piping. The hard piping is located within the Decant Pump Box and the Transfer Line Service Box.
9.b-14	Time Procedure	Too soon	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Operational Upset:</p> <p>If the recirculation occurs for too short a time, then an insufficient amount of flocculant would be added. An additional decant/flocculant recirculation step would be required.</p>	Turbidity instrumentation (AE-720-201)	<ul style="list-style-type: none"> Procedures Training 	
9.b-15	Time Procedure	Too late	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Operational Upset:</p> <p>If the recirculation occurs for too long a time, then too much flocculant would be added. This could subsequently result in plugging of the sand filters.</p>	Turbidity instrumentation (AE-720-201)	<ul style="list-style-type: none"> Procedures Training 	

Table C-28. HAZOP Results, Node 9.b, Annex Flocculant Addition System – Decant Recirculation							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
9.b-16	Time Procedure	Skip action	Operator error	Uncontrolled Release: If the decant/flocculant recirculation is not performed, then flocculant will not be added such that the decant transferred to the sand filters will have a high solids concentration. See Table C-14, Item 3.9.a.	See Table C-14, Item 3.9a.	<ul style="list-style-type: none">• Procedures• Training	
9.b-17	Time Procedure	Wrong action (decant instead of recirculate)	Operator error	Uncontrolled Release: If the supernate is decanted instead of recirculated, then decant pump ECRT-P-201 will deadhead resulting in a high pressure. See Item 9-7 above.	See Item 9-7 above.	<ul style="list-style-type: none">• Procedures• Training	

Table C-29. Normal Operating Conditions, Node 10, Transfer Line Automatic Flush		
Process Parameter	Design Intent	Remarks
Flow	70 gpm	As calculated in PRC-STP-00021, <i>Preliminary Hydraulic Analysis for Direct Loading of Sludge Transport and Storage Containers</i> , a flow rate of 70 gpm at 96 psi is required to provide enough motive force to flush the transfer line and deter the settling of solids.
Pressure	Flush tank initial charge = 140 psi Transfer line pressure 96 psi	As calculated in PRC-STP-CN-P-00196, <i>Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Equipment Sizing Calculation – Flush Tank</i> , 29 gallons of water in the flush tank at an initial charge pressure of 135 psi will discharge 20 gallons (one line volume) at a minimum flow rate of 70 gpm at a minimum pressure of 96 psi.
Concentration	Not applicable	The autoflush is performed using IXM water in flush tank ECRT-TK-101. The Skimmer Water Cleanup System takes basin water and pumps it first through a sand filter (for water clarity) and then through an IXM (to remove ionic species). The IXM water composition/concentration is not a critical attribute of the autoflush.
Composition	Not applicable	There are no other process fluids at the KW Basin that could be inadvertently connected or directed to the autoflush skid.
Level	Tank working volume = 50 gallons Flush volume = 29 gallons	The tank level is not monitored. Fifty gallons of IXM water are added to the tank as indicated by flow totalizer FQI-710-101. Per PRC-STP-CN-P-00196, the line is to be flushed by 1.5 line volumes of water, which is equal to ~29 gallons. As stated above, 29 gallons of water in the flush tank at an initial pressure of 135 psi will discharge 20 gallons (one line volume) at a minimum flow rate of 70 gpm at a minimum pressure of 96 psi.
Structural Integrity	Maintain integrity under normal operating conditions	The autoflush system consists of a tank and a combination of piping and hoses.
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The flush tank is located on the deck on the basin deck. The temperature of water in the flush tank will be approximately the same as the air temperature in the basin.
Time Procedure	Upon activation of interlock I-1 or I-3	Upon activation of interlock I-1 or I-3, valves ECRT-AOV-102 and ECRT-AOV-103 open. The flush continues until the pressure in flush tank ECRT-TK-101 normalizes to the transfer line pressure.

Table C-30. HAZOP Results, Node 10, Transfer Line Automatic Flush							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
10-1	Flow	No	<ul style="list-style-type: none"> Flush tank ECRT-TK-101 not pressurized No water in flush tank ECRT-TK-101 Valve ECRT-AOV-102 or ECRT-AOV-113 fails to open Bladder flush disabled 	<p>Operational Upset:</p> <p>If there is no flow, then the transfer line will not be flushed. This could result in a plugged transfer line. See Table C-6, Item 2.a-1.</p> <p>Radiological Control:</p> <p>If the autoflush is not performed, then there is a higher probability of significant contamination and higher dose rate during STSC process disconnects.</p>	<ul style="list-style-type: none"> Pressure instrumentation (PIT-710-103) IXM water flow totalizer FQI-710-101 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Radiological Control Program Perform manual flush 	Testing at MASF has demonstrated that a manual flush is capable of suspending and transferring settled solids.
10-2	Flow	Low	<ul style="list-style-type: none"> Low pressure in flush tank ECRT-TK-101 A normally-opened valve is partially closed 	<p>Operational Upset:</p> <p>If the flow rate is less than 70 gpm, then solids will not be flushed efficiently. This could result in a plugged transfer line. See Table C-6, Item 2.a-1.</p> <p>Radiological Control:</p> <p>If the autoflush is not performed, then there is a higher probability of significant contamination and higher dose rate during STSC process disconnects.</p>	Pressure instrumentation (PIT-710-103)	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Perform manual flush 	Testing at MASF has demonstrated that a manual flush is capable of suspending and transferring settled solids.
10-3	Flow	High	High pressure in flush tank ECRT-TK-101	<p>None:</p> <p>There are no consequences associated with a high flow rate.</p>	Pressure instrumentation (PIT-710-103)	<ul style="list-style-type: none"> Procedures Training 	

Table C-30. HAZOP Results, Node 10, Transfer Line Automatic Flush							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
10-4	Flow	Reverse	Valves ECRT-AOV-102 and open during a slurry transfer	<p>Uncontrolled Release:</p> <p>If there is reverse flow, then sludge could be pumped into the autoflush line resulting in a spray or splash and splatter/pool release (see remarks).</p>	<ul style="list-style-type: none"> Piping designed in accordance with B31.3, "Process Piping" Check valves ECRT-CV-102, -103, and -104 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration 	<p>Valve ECRT-AOV-102 is normally closed which would prevent backflow into the autoflush line.</p> <p>If valve ECRT-AOV-102 opened during a transfer, there would be a small amount of flow into the autoflush line because the pressure in the transfer line (100 psi at the booster pump discharge) is approximately equal to the autoflush line pressure at its connection point.</p> <p>For a spray or splash and splatter/pool release to occur, the reverse flow would either need to overpressurize and fail the autoflush system or the system would need to be open to atmosphere.</p> <p>The autoflush system is designed to the same operating pressure as the transfer line.</p>
10-5	Flow	Misdirected	N/A	N/A	N/A	N/A	This Node cannot be misdirected.
10-6	Pressure	Low	<ul style="list-style-type: none"> Operator error Pressure indication reads incorrectly Air fitting leakage 	<p>Operational Upset:</p> <p>If the pressure is low, then the flow rate will be low. The consequences are as stated in Item 10-1 above.</p>	Pressure instrumentation (PIT-710-103)	<ul style="list-style-type: none"> Procedures Training 	
10-7	Pressure	High	<ul style="list-style-type: none"> Operator error Pressure indication reads incorrectly 	<p>Uncontrolled Release/Industrial Safety:</p> <p>If the pressure is high, then the flush tank or flush line could fail resulting in a release of IXM water (see remarks).</p> <p>Overpressurization of the tank or line could potentially injure a facility worker.</p>	<ul style="list-style-type: none"> Pressure instrumentation (PIT-710-204) Pressure safety valve ECRT-PSV-101 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program 	Spills of IXM water do not constitute a radiological hazard to facility workers based on operational experience at the KW Basin.
10-8	Level	High	<ul style="list-style-type: none"> Operator error Flow indication reads incorrectly 	<p>None:</p> <p>There are no consequences associated with a high IXM water level in the flush tank (see remarks).</p>	Flow instrumentation (FQI-710-101)	<ul style="list-style-type: none"> Procedures Training 	The volume of the flush tank is sufficiently small that the STSC cannot be overfilled by the autoflush system.

Table C-30. HAZOP Results, Node 10, Transfer Line Automatic Flush							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
10-9	Level	Low	<ul style="list-style-type: none"> Operator error Flow indication reads incorrectly 	<p>Operational Upset:</p> <p>If the level in flush tank ECRT-TK-101 is low, then there will not be sufficient water to perform the flush. This could result in a plugged transfer line. See Table C-6, Item 2.a-1.</p>	Flow instrumentation (FQI-710-101)	<ul style="list-style-type: none"> Procedures Training Perform manual flush 	Testing at MASF has demonstrated that a manual flush is capable of suspending and transferring settled solids.
10-10.a	Structural Integrity	Leak/rupture (flush tank, air side)	<ul style="list-style-type: none"> Overpressurization Air fitting leakage 	<p>Operational Upset/Radiological Control:</p> <p>If the flush tank fails on the air side of the bladder, then the pressure will bleed off. When valve ECRT-AOV-102 opens, there will be no flow. Consequences are as stated in Item 10-1 above.</p>	<ul style="list-style-type: none"> Pressure instrumentation (PIT-710-204) Pressure safety valve ECRT-PSV-101 	<ul style="list-style-type: none"> Procedures Training Perform manual flush 	Testing at MASF has demonstrated that a manual flush is capable of suspending and transferring settled solids.
10-10.b	Structural Integrity	Leak/rupture (flush tank, water side; autoflush line to valve ECRT-V-102)	<ul style="list-style-type: none"> Overpressurization Valve ECRT-V-112 leaks 	<p>Uncontrolled Release:</p> <p>If the tank fails on the water side, or the autoflush line to valve ECRT-V-102 fails, then a spray or splash and splatter/pool release of IXM water will occur (see remarks).</p> <p>Operational Upset/Radiological Control:</p> <p>If the water leaks from the tank, then when valve ECRT-AOV-102 opens, there will be no flow. Consequences are as stated in Item 10-1 above.</p>	<ul style="list-style-type: none"> Piping designed in accordance with B31.3, "Process Piping" Pressure instrumentation (PIT-710-204) Pressure safety valve ECRT-PSV-101 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Perform manual flush 	<p>Spills of IXM water do not constitute a radiological hazard to facility workers based on operational experience at the KW Basin.</p> <p>Testing at MASF has demonstrated that a manual flush is capable of suspending and transferring settled solids.</p>

Table C-30. HAZOP Results, Node 10, Transfer Line Automatic Flush							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
10-10.c	Structural Integrity	Leak/rupture (autoflush line from valve ECRT-V-102 to booster pump skid)	<ul style="list-style-type: none"> • Overpressurization • Hose disconnects 	<p>Uncontrolled Release:</p> <p>If the autoflush fails between ECRT-V-102 and the booster pump skid, then when valve ECRT-AOV-102 opens, a spray or splash and splatter/pool release of IXM water will occur (see remarks).</p> <p>Operational Upset:</p> <p>Depending on the amount of IXM water released via the leak/rupture, there may be insufficient water to effectively flush the transfer line. This could result in a plugged transfer line. See Table C-6, Item 2.a-1.</p>	Piping designed in accordance with B31.3, "Process Piping"	<ul style="list-style-type: none"> • Procedures • Training • Radiological Control Program 	Spills of IXM water do not constitute a radiological hazard to facility workers based on operational experience at the KW Basin.
10-11.a	Time Procedure	Too soon (inadvertent activation during a transfer)	<ul style="list-style-type: none"> • Failure in interlock sequence • Loss of power 	<p>Operational Upset:</p> <p>If valve ECRT-AOV-102 opened during a transfer, then only be a small amount of sludge would flow into the autoflush line because the pressure in the transfer line (100 psi at the booster pump discharge) is approximately equal to the autoflush line pressure at its connection point (96 psi).</p>	<ul style="list-style-type: none"> • Pressure instrumentation (PIT-710-204) • Valve position indication for valves ECRT-AOV-102 • Interlock activation indication (ECRT-IL-120, ECRT-IL-13) 	<ul style="list-style-type: none"> • Procedures • Training 	Pressure instrumentation and valve position indication could be used by operators to ascertain that the autoflush was inadvertently activated.

Table C-30. HAZOP Results, Node 10, Transfer Line Automatic Flush							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
10-11.b	Time Procedure	Too soon (inadvertent activation after a transfer)	<ul style="list-style-type: none"> Failure in interlock sequence Loss of power 	<p>Uncontrolled Release:</p> <p>If the autoflush activated after a transfer was complete and the transfer line was disconnected from the STSC and was not isolated, then a splash and splatter/pool release could occur (see remarks).</p> <p>Operational Upset:</p> <p>If the autoflush activated after a transfer was complete and the transfer line was disconnected from the STSC and was isolated, then the transfer line between booster pump ECRT-P-101 and the isolation valve would be pressurized (see remarks).</p>	<ul style="list-style-type: none"> Isolation valves Valve position indicators Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration Autoflush disable 	<p>After a transfer is complete, the autoflush system is disabled via bladder flush enable/disable handswitch ECRT-HS-113 which closes valve ECRT-AOV-113.</p> <p>After a transfer is complete and the transfer line is disconnected from the STSC, isolation valve ECRT-V-101 in the transfer line service box is closed.</p> <p>If the transfer line between booster pump ECRT-P-101 and the isolation valve was pressurized, then the line would depressurize when a new STSC was put into place and a slurry transfer initiated. Consequently, the autoflush system would not be functional. The consequences are as stated in Item 10-1 above.</p>
10-12	Time Procedure	Too late (activation of autoflush delayed)	Failure in interlock sequence	<p>None:</p> <p>See remarks.</p>	None	<ul style="list-style-type: none"> Procedures Training 	If the autoflush is delayed, then solids will settle in the transfer line. Testing at MASF has demonstrated that the autoflush system is capable of suspending and transferring settled solids.
10-13	Time Procedure	Skip action (autoflush not performed)	Failure in interlock sequence	<p>Operational Upset:</p> <p>If the autoflush is not performed, then the transfer line could plug. See Table C-6, Item 2.a-1.</p> <p>Radiological Control:</p> <p>If the autoflush is not performed, then there is a higher probability of significant contamination and higher dose rates during STSC process disconnects.</p>	<ul style="list-style-type: none"> Pressure instrumentation (PI-710-204) Valve position indication for valve ECRT-AOV-102 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Perform manual flush 	<p>Pressure instrumentation and valve position indication could be used by operators to ascertain that the autoflush was not performed.</p> <p>Testing at MASF has demonstrated that a manual flush is capable of suspending and transferring settled solids.</p>
10-14	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There is no wrong action associated with this node.

Table C-31. Normal Operating Conditions, Node 11.a, Overfill Recovery – IXM Water to Recovery Tool Fluidizing Jets		
Process Parameter	Design Intent	Remarks
Flow	42 gpm	Motive force is fluidizing pump ECRT-P-302. The 42 gpm is the flow rate when the fluidizing jets are on. When the jets are not on, 10 gpm flows to the fluidizing jets via bypass flow orifice ECRT-FO-301.
Pressure	Upstream of pump ECRT-P-302 = 100-130 psi Downstream of pump ECRT-P-302 = 385 psi	When the operators turn on the fluidizing jets, valve ECRT-AOV-304 opens and high pressure water is directed to the jets.
Concentration	Not applicable	The Skimmer Water Cleanup System takes basin water and pumps it first through a sand filter (for water clarity) and then through an IXM (to remove ionic species). The IXM water concentration is not a critical attribute of recovery tool operability.
Composition	Not applicable	There are no other process fluids at the KW Basin that could be inadvertently connected or directed to the overfill recovery pump skid.
Structural Integrity	Maintain integrity under normal operating conditions	The IXM water lines are a combination of piping and hoses.
Level	Maintain liquid level in STSC below LE-740-401 setting	If the liquid level in the STSC reached the setting of LSH-740-402, then interlock I-3 would terminate IXM water flow.
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin is maintained at a temperature of 10-15 °C. The IXM water is approximately the same temperature as the basin water, i.e., the pumps of the Skimmer Water Cleanup System do not impart significant thermal energy to the water. Fluctuations in basin water temperature occur very slowly. The IXM water temperature is not a critical attribute of recovery tool operability,
Time Procedure	Variable	In contrast to the sludge retrieval using the Xago Hydrolance™ where the fluidizing jets are periodically pulsed for 3-5 seconds to achieve a target vol % solids, the recovery tool fluidizing jets are operated on an as-needed basis to recovery the necessary amount of sludge. Operators determine the need to operate the jets based on differential weight indication (DWI-740-401) and STSC liquid level (LIT-740-401). Fluidizing jet pump ECRT-P-301 is manually stopped when the target recovery has been achieved.

Table C-32. HAZOP Results, Node 11.a. Overfill Recovery – IXM Water to Recovery Tool Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.a-1	Flow	No	<ul style="list-style-type: none">• No IXM water supply from the Skimmer Water Cleanup System• A normally-open valve is closed• Fluidizing jets are plugged	<p>Overpressurization/Hydrogen Deflagration:</p> <p>If there is no flow because there is no IXM water supply, then there will be no flow to the fluidizing jets and there will be no dilution water. Overfill recovery pump ECRT-P-301 would continue to operate which could plug the overfill recovery tool. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p> <p>If there is no flow because valve ECRT-V-704, ECRT-AOV-701, or ECRT-V-303 is closed, then there will be no flow to the fluidizing jets and there will be no dilution water. Consequences are as stated above.</p> <p>If there is no flow because the fluidizing jets are plugged, then the sludge will not be fluidized. Dilution water alone might be sufficient to achieve the targeted recovery. If dilution water alone cannot achieve the targeted recovery, then the sludge limits would be exceeded. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration</p>	<ul style="list-style-type: none">• Valve position indicators• Fluidizing water pump ECRT-P-302 inlet and outlet pressure instrumentation (PIT-730-303, -304)• Fluidizing water flow rate instrumentation (FQIT-730-301)• Fluidizing jet O-rings (to prevent plugging)• Differential sludge weight instrumentation (DWI-740-704)• STSC active ventilation• Auxiliary ventilation system• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration• STSC sludge limit verification• Recovery Plan• Modified KW Basin Annex is unmanned during overfill recovery operations	<p>It would be readily apparent to operators at the start-up of overfill recovery operations if there was no IXM water supply as prior to overfill recovery IXM water is used to fill the overfill recovery tool discharge line with water.</p> <p>Valve ECRT-AOV-701 is an air-operated valve. The valve closes on loss of air. The valve also closes on loss of power to solenoid-operated valve ECRT-SOV-701.</p> <p>If the overfill recovery tool becomes plugged, it can be backflushed with IXM water.</p> <p>Operation of fluidizing water pump ECRT-P-302 is not required for fluidizing water flow. If the pump is not operating IXM water will flow through the centrifugal pump at the flow rate and pressure provided by the IXM water supply.</p> <p>The STSC sludge limit verification control will prevent disconnecting the STSC active ventilation and the auxiliary ventilation system from the STSC until the applicable sludge limit is met.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed.</p>

Table C-32. HAZOP Results, Node 11.a. Overfill Recovery – IXM Water to Recovery Tool Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.a-2	Flow	Low	<ul style="list-style-type: none"> Low IXM water supply flow rate from the Skimmer Water Cleanup System Fluidizing pump ECRT-P-302 not operating Fluidizing pump ECRT-P-302 speed low Valve ECRT-AOV-304 is closed Fluidizing jets are partially plugged A normally open valve is partially closed 	<p>Operational Upset:</p> <p>If the flow is low, then it could take longer to achieve the targeted recovery.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the flow is low, then sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration</p>	<ul style="list-style-type: none"> Valve position indicators Fluidizing water pump ECRT-P-302 inlet and outlet pressure instrumentation (PIT-730-303, -304) Fluidizing water flow rate instrumentation (FQIT-730-301) Fluidizing jet O-rings (to prevent plugging) Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The fluidizing pump speed is controlled by variable frequency drive ECRT-VFD-302. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p> <p>The STSC sludge limit verification control will prevent disconnecting the STSC active ventilation system and the auxiliary ventilation system from the STSC until the applicable sludge limit is met.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed.</p>
11.a-3	Flow	High	Fluidizing pump ECRT-P-302 speed high	<p>Uncontrolled Release:</p> <p>If the flow rate is sufficiently high, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Fluidizing water flow rate instrumentation (FQIT-730-301) Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>Under normal operating conditions 62 gpm is added to the STSC (42 gpm from the fluidizing jets and 20 gpm dilution water) and 70 gpm is withdrawn by the overfill recovery pump.</p> <p>The fluidizing pump speed is controlled by variable frequency drive ECRT-VFD-302. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p>

Table C-32. HAZOP Results, Node 11.a. Overfill Recovery – IXM Water to Recovery Tool Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.a-4	Flow	Reverse	Siphon from STSC (see remarks)	<p>Uncontrolled Release:</p> <p>If a siphon is created, then liquid would be drawn out of the STSC through the fluidizing jets and discharged at the location of system breach leading to splash and splatter/pool release.</p>	<ul style="list-style-type: none"> • Check valve ECRT-CV-302 • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Radiological Control Program • Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>If fluidizing pump ECRT-P-302 is not operating and there is a system breach below STSC liquid level, then a siphon could be created.</p> <p>There are eight fluidizing jet nozzles, each approximately 3 mm in diameter. The nozzles could plug with solids and either limit or stop the siphon flow.</p>
11.a-5	Flow	Misdirected (to overfill recovery tool dilution water connection)	Operator error in making hose connections	<p>Overpressurization/Hydrogen Deflagration:</p> <p>If the fluidizing and dilution water hoses are cross-connected, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration</p>	<ul style="list-style-type: none"> • Unique process connections • STSC active ventilation • Auxiliary ventilation system • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration • STSC sludge limit verification • Recovery Plan • Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed.</p>
11.a-6	Pressure	Low	<ul style="list-style-type: none"> • Fluidizing pump ECRT-P-302 not operating • Fluidizing pump ECRT-P-302 speed low 	<p>Operational Upset:</p> <p>If the pressure is low, then it could take longer to achieve the targeted recovery.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the pressure is low, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration</p>	<ul style="list-style-type: none"> • Fluidizing water pump ECRT-P-302 inlet and outlet pressure instrumentation (PIT-730-303, -304) • Fluidizing water flow rate instrumentation (FQIT-730-301) • Differential sludge weight instrumentation (DWI-740-704) • STSC active ventilation • Auxiliary ventilation system • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Conduct of operations verifies proper system configuration • STSC sludge limit verification • Recovery Plan • Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The fluidizing pump speed is controlled by variable frequency drive ECRT-VFD-302. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed.</p>

Table C-32. HAZOP Results, Node 11.a. Overfill Recovery – IXM Water to Recovery Tool Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.a-7	Pressure	High	<ul style="list-style-type: none"> Fluidizing pump ECRT-P-302 speed high Fluidizing jets are plugged 	<p>Uncontrolled Release/Industrial Safety:</p> <p>If the fluidizing pump speed is high then the flow rate will be high. If sufficiently high, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>If the pressure is high, then the fluidizing water line could fail. This would result in a spill of IXM water.</p> <p>If hose ECRT-H-302 failed completely or became disconnected, then hose whip could potentially whip and injure a facility worker or damage other equipment.</p> <p>If hose ECRT-H-302 failed completely or became disconnected, then liquid could be siphoned from the STSC leading to splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Fluidizing jet O-rings (to prevent plugging) Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Piping designed to B31.3, "Process Piping" Check valve ECRT-CV-302 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Industrial Safety Program Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The fluidizing pump speed is controlled by variable frequency drive ECRT-VFD-302. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p> <p>Relative to B31.3, the piping and hoses are designed to withstand the deadhead pressure of fluidizing water pump ECRT-P-302.</p> <p>Spills of IXM water constitute a minor radiological hazard to facility workers based on operational experience at the KW Basin.</p>
11.a-8	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure (see Item 11.a-7 above) Manufacturing flaw Procurement error Hose connection decouples 	<p>Uncontrolled Release/Industrial Safety:</p> <p>If the fluidizing water line failed, then there would be a spill of IXM water.</p> <p>If hose ECRT-H-302 failed completely or became disconnected, then hose whip could potentially whip and injure a facility worker or damage other equipment.</p> <p>If hose ECRT-H-302 failed completely or became disconnected, then liquid could be siphoned from the STSC leading to splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Piping designed to B31.3, "Process Piping" Check valve ECRT-CV-302 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Hydro testing Radiological Control Program Industrial Safety Program Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>Relative to B31.3, the piping and hoses are designed to withstand the deadhead pressure of fluidizing water pump ECRT-P-302.</p> <p>Spills of IXM water constitute a minor radiological hazard to facility workers based on operational experience at the KW Basin.</p>

Table C-32. HAZOP Results, Node 11.a. Overfill Recovery – IXM Water to Recovery Tool Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.a-9	Time Procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Operational Upset:</p> <p>If the fluidizing flow valve is open for too short a period of time, then it could take longer to achieve the targeted recovery.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the fluidizing jets are operated for too short a period of time, sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>
11.a-10	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Operational Upset:</p> <p>If the fluidizing flow valve is opened for too long a period of time, then too much sludge could be recovered such that an STSC is sent to T Plant with a low as-settled sludge level.</p> <p>Uncontrolled Release:</p> <p>If the fluidizing water flow is not terminated and overfill recovery pump ECRT-P-301 is stopped, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Differential sludge weight instrumentation (DWI-740-401) Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Modified KW Basin Annex is unmanned during overfill recovery operations 	

Table C-32. HAZOP Results, Node 11.a. Overfill Recovery – IXM Water to Recovery Tool Fluidizing Jets							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.a-11	Time Procedure	Skip action (fluidizing water valve not opened)	<ul style="list-style-type: none">• Operator error• Instrumentation failure	<p>Operational Upset:</p> <p>If operators do not open fluidizing water valve ECRT-AOV-304, then IXM water will flow to the fluidizing jets via bypass orifice ECRT-FO-301 at a reduced pressure and flow rate such that it could take longer to achieve the targeted recovery.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If operators do not open fluidizing water valve ECRT-AOV-304, then IXM water will flow to the fluidizing jets via bypass orifice ECRT-FO-301 at a reduced pressure and flow rate. The pressure and flow rate might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration</p>	<ul style="list-style-type: none">• Differential sludge weight instrumentation (DWI-740-704)• STSC active ventilation• Auxiliary ventilation system• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• STSC sludge limit verification• Recovery Plan• Modified KW Basin Annex is unmanned during overfill recovery operations	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>
11.a-12	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There are no wrong actions associated with this node.

Table C-33. Normal Operating Conditions, Node 11.b, Overfill Recovery – IXM Water to Recovery Tool Dilution Head		
Process Parameter	Design Intent	Remarks
Flow	20 gpm	The 20 gpm is established by the dilution water line pressure and the number and size of dilution water orifices.
Pressure	100 psi	The pressure is the based on the IXM water supply pressure.
Concentration	Not applicable	The Skimmer Water Cleanup System takes basin water and pumps it first through a sand filter (for water clarity) and then through an IXM (to remove ionic species). The IXM water concentration is not a critical attribute of recovery tool operability.
Composition	Not applicable	There are no other process fluids at the KW Basin that could be inadvertently connected or directed to the overfill recovery pump skid.
Structural Integrity	Maintain integrity under normal operating conditions	The IXM water lines are a combination of piping and hoses.
Level	Maintain liquid level in STSC below LE-740-401 setting	If the liquid level in the STSC reached the setting of LSH-740-402, then interlock I-3 would terminate IXM water flow.
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin is maintained at a temperature of 10-15 °C. The IXM water is approximately the same temperature as the basin water, i.e., the pumps of the Skimmer Water Cleanup System do not impart significant thermal energy to the water. Fluctuations in basin water temperature occur very slowly. The IXM water temperature is not a critical attribute of recovery tool operability,
Time Procedure	For the duration of the overfill recovery	Dilution water flow is initiated prior to operation of the fluidizing jets and is terminated when the target recovery has been achieved. This is a manual operation.

Table C-34. HAZOP Results, Node 11.b. Overfill Recovery – IXM Water to Recovery Tool Dilution Water							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.b-1.	Flow	No	<ul style="list-style-type: none"> No IXM water supply from the Skimmer Water Cleanup System A normally-open valve is closed 	<p>Overpressurization/Hydrogen Deflagration:</p> <p>If there is no flow because there is no IXM water supply, then there will be no dilution water flow and there will be no flow to the fluidizing jets. Overfill recovery pump ECRT-P-301 would continue to operate which could plug the overfill recovery tool. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p> <p>If there is no flow to because valve ECRT-V-704, ECRT-AOV-701, or ECRT-V-303 is closed, then there will be no dilution water flow and there will be no flow to the fluidizing jets. Consequences are as stated above.</p> <p>If there is no flow because valve ECRT-AOV-706 is closed then there will be no dilution water. Fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. Consequences are as stated above.</p>	<ul style="list-style-type: none"> Valve position indicators Fluidizing water pump ECRT-P-302 inlet and outlet pressure instrumentation (PIT-730-303, -304) Fluidizing water flow rate instrumentation (FQIT-730-301) Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>There is no flow or pressure monitoring instrumentation on the dilution water line.</p> <p>It would be readily apparent to operators at the start-up of overfill recovery operations if there was no IXM water supply as prior to overfill recovery IXM water is used to fill the overfill recovery tool discharge line with water.</p> <p>Valve ECRT-AOV-701 is an air-operated valve. The valve closes on loss of air. The valve also closes on loss of power to solenoid-operated valve ECRT-SOV-701.</p> <p>If the overfill recovery tool becomes plugged, it can be backflushed with IXM water.</p> <p>The STSC sludge limit verification control will prevent disconnecting the STSC active ventilation and the auxiliary ventilation system from the STSC until the applicable sludge limit is met.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed.</p>

Table C-34. HAZOP Results, Node 11.b. Overfill Recovery – IXM Water to Recovery Tool Dilution Water							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.b-2	Flow	Low	<ul style="list-style-type: none"> Low IXM water supply flow rate from the Skimmer Water Cleanup System A normally open valve is partially closed 	<p>Overpressurization/Hydrogen Deflagration:</p> <p>If there is low dilution water flow, fluidizing jet water alone could be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Valve position indicators Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>There is no flow or pressure monitoring instrumentation on the dilution water line.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>
11.b-3	Flow	High	High IXM water supply flow rate from the Skimmer Water Cleanup System	<p>Uncontrolled Release:</p> <p>If the flow rate is sufficiently high, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>Under normal operating conditions 62 gpm is added to the STSC (42 gpm from the fluidizing jets and 20 gpm dilution water) and 70 gpm is withdrawn by the overfill recovery pump.</p> <p>The dilution water flow rate is a function of the Skimmer Water Cleanup System pressure and the number and diameter of the overfill recovery tool dilution water orifices</p>
11.b-4	Flow	Reverse	Siphon from STSC (see remarks)	<p>Uncontrolled Release:</p> <p>If a siphon is created, then liquid would be drawn out of the STSC through the dilution water orifices and discharged at the location of system breach leading to splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Check valve ECRT-CV-301 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>If valve ECRT-AOC-706 is closed and there is a system breach below STSC liquid level, then a siphon could be created.</p> <p>There are three dilution water orifices, each approximately 3 mm in diameter. The orifices could plug with solids and either limit or stop the siphon flow.</p>

Table C-34. HAZOP Results, Node 11.b. Overfill Recovery – IXM Water to Recovery Tool Dilution Water							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.b-5	Flow	Misdirected (to overfill recovery tool fluidizing jet connection)	Operator error in making hose connections	Overpressurization/Hydrogen Deflagration: If the dilution water and fluidizing water hoses are cross-connected, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration	<ul style="list-style-type: none"> Unique process connections STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>
11.b-6	Pressure	Low	<ul style="list-style-type: none"> Low IXM water supply pressure from the Skimmer Water Cleanup System 	Overpressurization/Hydrogen Deflagration: If there is dilution water pressure is low then the flow will be low. Fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.	<ul style="list-style-type: none"> Valve position indicators Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of operations verifies proper system configuration STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>There is no flow or pressure monitoring instrumentation on the dilution water line.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>

Table C-34. HAZOP Results, Node 11.b. Overfill Recovery – IXM Water to Recovery Tool Dilution Water							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.b-7	Pressure	High	<ul style="list-style-type: none"> High IXM water supply pressure from the Skimmer Water Cleanup System 	<p>Uncontrolled Release/Industrial Safety:</p> <p>If the pressure is high then the flow rate will be high. If sufficiently high, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>If the pressure is high, then the dilution water line could fail. This would result in a spill of IXM water.</p> <p>If hose ECRT-H-301 failed completely or became disconnected, then hose whip could potentially whip and injure a facility worker or damage other equipment.</p> <p>If hose ECRT-H-301 failed completely or became disconnected, then liquid could be siphoned from the STSC leading to splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Piping designed to B31.3, "Process Piping" Check valve ECRT-CV-301 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Industrial Safety Program Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The fluidizing pump speed is controlled by variable frequency drive ECRT-VFD-302. The pump speed will be set during pre-operational testing. There will be no procedural steps directing operators to adjust the pump speed.</p> <p>Relative to B31.3, the piping and hoses are designed to withstand the deadhead pressure of Skimmer Water Cleanup System</p> <p>Spills of IXM water constitute a minor radiological hazard to facility workers based on operational experience at the KW Basin.</p>
11.b-8	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure (see Item 11.b-7 above) Manufacturing flaw Procurement error 	<p>Uncontrolled Release/Industrial Safety:</p> <p>If the pressure is high, then the dilution water line could fail. This would result in a spill of IXM water.</p> <p>If hose ECRT-H-301 failed completely or became disconnected, then hose whip could potentially whip and injure a facility worker or damage other equipment.</p> <p>If hose ECRT-H-301 failed completely or became disconnected, then liquid could be siphoned from the STSC leading to splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Piping designed to B31.3, "Process Piping" Check valve ECRT-CV-301 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Hydro testing Radiological Control Program Industrial Safety Program Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>Relative to B31.3, the piping and hoses are designed to withstand the deadhead pressure of fluidizing water pump ECRT-P-302.</p> <p>Spills of IXM water constitute a minor radiological hazard to facility workers based on operational experience at the KW Basin.</p>

Table C-34. HAZOP Results, Node 11.b. Overfill Recovery – IXM Water to Recovery Tool Dilution Water							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.b-9	Time Procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Operational Upset:</p> <p>If the dilution water flow is terminated early, then it could take longer to achieve the targeted recovery.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the dilution water flow is terminated early, fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>
11.b-10	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Uncontrolled Release:</p> <p>If the dilution water flow is not terminated and overfill recovery pump ECRT-P-301 is stopped, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Modified KW Basin Annex is unmanned during overfill recovery operations 	

Table C-34. HAZOP Results, Node 11.b. Overfill Recovery – IXM Water to Recovery Tool Dilution Water							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.b-11	Time Procedure	Skip action (dilution water valve not opened)	Operator error	Overpressurization/Hydrogen Deflagration: If operators do not open dilution water valve ECRT AOV-706, then there will be no dilution water. Fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.	<ul style="list-style-type: none">• Valve position indicators• Differential sludge weight instrumentation (DWI-740-704)• STSC active ventilation• Auxiliary ventilation system• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Conduct of operations verifies proper system configuration• STSC sludge limit verification• Recovery Plan• Modified KW Basin Annex is unmanned during overfill recovery operations	The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met. In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed
11.b-12	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There are no wrong actions associated with this node.

Table C-35. Normal Operating Conditions, Node 11.c, Overfill Recovery – STSC to Pump ECRT-P-301		
Process Parameter	Design Intent	Remarks
Flow	Nominally 70 gpm	Motive force is overfill recovery pump ECRT-P-301 located in the transfer line service box. Overfill recovery pump ECRT-P-301 is an air-operated, double-diaphragm (AODD) pump
Pressure	Full vacuum to 0 psi	This segment of the overfill recovery tool discharge line is under suction during overfill recovery.
Concentration	Not applicable	The vol % solids in the recovered sludge is not monitored or controlled.
Composition	Not applicable	The composition of the recovered sludge (i.e., KE, KW, or settler tank sludge) depends on the engineered container from which the sludge was originally retrieved.
Structural Integrity	Maintain integrity under normal operating conditions	The overfill recovery tool discharge line is a combination of hose and piping.
Level	Maintain liquid level in STSC below LE-740-401 setting	If the liquid level in the STSC reached the setting of LSH-740-402, then interlock I-3 would terminate IXM water flow.
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin is maintained at a temperature of 10-15 °C. The IXM water is approximately the same temperature as the basin water, i.e., the pumps of the Skimmer Water Cleanup System do not impart significant thermal energy to the water. Fluctuations in basin water temperature occur very slowly. The IXM water temperature is not a critical attribute of recovery tool operability,
Time Procedure	For the duration of the overfill recovery	The overfill recovery pump is manually stopped when the target recovery has been achieved.

Table C-36. HAZOP Results, Node 11.c. Overfill Recovery – STSC to Pump ECRT-P-301							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.c-1	Flow	No	<ul style="list-style-type: none">• Overfill recovery pump ECRT-P-301 not operating• A normally opened valve is closed• Overfill recovery tool rupture disk fails to rupture• Overfill recovery tool or discharge line plugged	<p>Uncontrolled Release:</p> <p>If there is no flow, then the STSC will eventually be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If there was no flow, then there would be no overfill recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none">• Overfill recovery pump ECRT-P-301 inlet and outlet pressure instrumentation (PIT-730-301, -302)• Valve position indicators• Level switches LS/LSH/LSHH-740-401• High level switch LSH-740-402• Emergency stop switch ECRT-ES-1• Differential sludge weight instrumentation (DWI-740-704)• STSC active ventilation• Auxiliary ventilation system• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Radiological Control Program• STSC sludge limit verification• Recovery Plan• Modified KW Basin Annex is unmanned during overfill recovery operations	<p>Under normal operating conditions 62 gpm is added to the STSC (42 gpm from the fluidizing jets and 20 gpm dilution water) and 70 gpm is withdrawn by the overfill recovery pump.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>

Table C-36. HAZOP Results, Node 11.c. Overfill Recovery – STSC to Pump ECRT-P-301							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.c-2	Flow	Low	<ul style="list-style-type: none">• Low air pressure to Overfill recovery pump ECRT-P-301• A normally open valve is partially closed	<p>Operational Upset:</p> <p>If the flow is low, then it could take longer to achieve the targeted recovery.</p> <p>Uncontrolled Release:</p> <p>If the flow rate is sufficiently low, then eventually the STSC will be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the flow rate is low, then sludge could settle out and plug the line. If the line plugs, then there would be no overfill recovery. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none">• Instrument air pressure control valve ECRT-PCV-761• Level switches LS/LSH/LSHH-740-401• High level switch LSH-740-402• Emergency stop switch ECRT-ES-1• Differential sludge weight instrumentation (DWI-740-704)• STSC active ventilation• Auxiliary ventilation system• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Radiological Control Program• Modified KW Basin Annex is unmanned during overfill recovery operations	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>

Table C-36. HAZOP Results, Node 11.c. Overfill Recovery – STSC to Pump ECRT-P-301							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.c-3	Flow	High	High air pressure to Overfill recovery pump ECRT-P-301	<p>Overpressurization/Hydrogen Deflagration:</p> <p>If the flow was high, then the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Instrument air pressure control valve ECRT-PCV-761 Overfill recovery pump air supply pressure indication (PI-270-767) Overfill recovery pump ECRT-P-301 inlet and outlet pressure instrumentation (PIT-730-301, -302) Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>If the high flow did not result in a line plug, then the target recovery would be achieved in a shorter period of time.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p>
11.c-4	Flow	Reverse	Overfill recovery flush valve open	<p>Uncontrolled Release:</p> <p>If overfill recovery flush valve ECRT-AOV-103 is open, then 100 gpm of IXM water at 100 psi will enter the overfill recovery discharge line upstream of overfill recovery pump ECRT-P-301. As ECRT-P-301 pumps 70 gpm, approximately 30 gpm of IXM water would reverse flow to the STSC. Eventually the STSC would be overfilled and slurry would overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Valve position indicators Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>Overfill recovery pump ECRT-P-301 cannot run in reverse. The only way it could pump in the reverse direction would be if it was installed backwards. Such an error would be discovered during pre-operation testing.</p>
11.c-5	Flow	Misdirected	N/A	N/A	N/A	N/A	<p>The flow from the STSC to overfill recovery pump ECRT-P-301 cannot be misdirected.</p>

Table C-36. HAZOP Results, Node 11.c. Overfill Recovery – STSC to Pump ECRT-P-301							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.c-6	Pressure	Low	N/A	N/A	N/A	N/A	This portion of the overfill recovery discharge line is on the suction side of overfill recovery pump ECRT-P-301. The hose is rate to full vacuum.
11.c-7	Pressure	High	Line or valve closed plug during flushing (see remarks)	<p>Uncontrolled Release:</p> <p>If the pressure is high, then the overfill recovery tool discharge line could fail resulting in an airborne spray or splash and splatter/pool release..</p>	<ul style="list-style-type: none"> Piping designed to B31.3, "Process Piping" Secondary containment with leak detection (if failure occurs within transfer line service box. Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Modified KW Basin Annex is unmanned during overfill recovery operations 	This portion of the overfill recovery discharge line is on the suction side of overfill recovery pump ECRT-P-301. However, after the overfill recovery operation is complete the line is flushed with IXM water. If the overfill recovery tool or a portion of the line was plugged, or if isolation valve ECRT-V-301 was not opened, then the IXM water supply would be deadhead.
11.c-8	Structural integrity	Leak/rupture	<ul style="list-style-type: none"> Manufacturing flaw Procurement error Hose connection decouples 	<p>Radiological Control:</p> <p>If there is a leak in the overfill recovery discharge line, then air will be drawn into the flow stream. This would result in air bubbles in the KW Basin (see remarks)</p> <p>Uncontrolled Release:</p> <p>If overfill recovery discharge hose ECRT-H-306 decouples at the transfer line service box and drops below the liquid level in the STSC, then a siphon would be created. Liquid would be drawn out of the STSC</p>	<ul style="list-style-type: none"> Sump with leak detection Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Hydro testing Radiological Control Program Modified KW Basin Annex is unmanned during overfill recovery operations Quality Assurance Program 	Historically, air bubbles in the KW Basin have not resulted in a high airborne radioactivity or a spread of contamination.
11.c-9	Time procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure Overfill recovery pump failure 	<p>Overpressurization/Hydrogen Deflagration:</p> <p>If the recovery operation occurs for too short a period of time, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	

Table C-36. HAZOP Results, Node 11.c. Overfill Recovery – STSC to Pump ECRT-P-301							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.c-10	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Operational Upset:</p> <p>If the recovery operation occurs for too long a period of time, then too much sludge could be recovered such that an STSC is sent to T Plant with a low as-settled sludge level.</p>	<ul style="list-style-type: none"> Differential sludge weight instrumentation (DWI-740-704) 	<ul style="list-style-type: none"> Procedures Training 	
11.c-11	Time Procedure	Skip action (Overfill recovery pump not started)	Operator error	<p>Uncontrolled Release:</p> <p>If operators do not start overfill recovery pump ECRT-P-301, then there will be no flow. If there is no flow then the STSC will eventually be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the operators do not start overfill recovery pump ECRT-P-301, then there would be no overfill recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.
11.c-12	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There are no wrong actions associated with this node.

Table C-37. Normal Operating Conditions, Node 11.d, Overfill Recovery – Pump ECRT-P-301 to Engineered Container		
Process Parameter	Design Intent	Remarks
Flow	Nominally 70 gpm	Motive force is overfill recovery pump ECRT-P-301 located in the transfer line service box. Overfill recovery pump ECRT-P-301 is an air-operated, double-diaphragm (AODD) pump
Pressure	Nominally 60 psig	Pressure is controlled by the air pressure supplied to overfill recovery pump ECRT-P-301. The instrument air system produces 212 scfm of dry air at 120 psig. Pressure control valves are used to regulate the pressure to the pump.
Concentration	Not applicable	The vol % solids in the recovered sludge is not monitored or controlled.
Composition	Not applicable	The composition of the recovered sludge (i.e., KE, KW, or settler tank sludge) depends on the engineered container from which the sludge was originally retrieved.
Structural Integrity	Maintain integrity under normal operating conditions	The overfill recovery tool discharge line is a combination of hose and piping.
Level	Maintain liquid level in STSC below LE-740-401 setting	If the liquid level in the STSC reached the setting of LSH-740-402, then interlock I-3 would terminate IXM water flow.
Temperature	Not applicable	Temperature is not a process parameter that is monitored or controlled. The 1.3 million gallons of water in the KW Basin is maintained at a temperature of 10-15 °C. The IXM water is approximately the same temperature as the basin water, i.e., the pumps of the Skimmer Water Cleanup System do not impart significant thermal energy to the water. Fluctuations in basin water temperature occur very slowly. The IXM water temperature is not a critical attribute of recovery tool operability,
Time Procedure	For the duration of the overfill recovery	The overfill recovery pump is manually stopped when the target recovery has been achieved.

Table C-38. HAZOP Results, Node 11.d. Overfill Recovery – Pump ECRT-P-301 to Engineered Container							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.d-1	Flow	No	<ul style="list-style-type: none"> • Overfill recovery pump ECRT-P-301 not operating • A normally opened valve is closed • Overfill recovery tool rupture disk fails to rupture • Overfill recovery tool or discharge line plugged 	<p>Uncontrolled Release:</p> <p>If there is no flow, then the STSC will eventually be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If there was no flow, then there would be no overfill recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> • Overfill recovery pump ECRT-P-301 inlet and outlet pressure instrumentation (PIT-730-301, -302) • Valve position indicators • Level switches LS/LSH/LSHH-740-401 • High level switch LSH-740-402 • Emergency stop switch ECRT-ES-1 • Differential sludge weight instrumentation (DWI-740-704) • STSC active ventilation • Auxiliary ventilation system • Modified KW Basin Annex confinement ventilation • Continuous air monitors 	<ul style="list-style-type: none"> • Procedures • Training • Radiological Control Program • STSC sludge limit verification • Recovery Plan • Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>Under normal operating conditions 62 gpm is added to the STSC (42 gpm from the fluidizing jets and 20 gpm dilution water) and 70 gpm is withdrawn by the overfill recovery pump.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>

Table C-38. HAZOP Results, Node 11.d. Overfill Recovery – Pump ECRT-P-301 to Engineered Container							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.d-2	Flow	Low	<ul style="list-style-type: none">• Low air pressure to Overfill recovery pump ECRT-P-301• A normally open valve is partially closed	<p>Operational Upset:</p> <p>If the flow is low, then it could take longer to achieve the targeted recovery.</p> <p>Uncontrolled Release:</p> <p>If the flow rate is sufficiently low, then eventually the STSC will be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the flow rate is low, then sludge could settle out and plug the line. If the line plugs, then there would be no overfill recovery. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none">• Instrument air pressure control valve ECRT-PCV-761• Level switches LS/LSH/LSHH-740-401• High level switch LSH-740-402• Emergency stop switch ECRT-ES-1• Differential sludge weight instrumentation (DWI-740-704)• STSC active ventilation• Auxiliary ventilation system• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Radiological Control Program• Recovery Plan• Modified KW Basin Annex is unmanned during overfill recovery operations	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>

Table C-38. HAZOP Results, Node 11.d. Overfill Recovery – Pump ECRT-P-301 to Engineered Container							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.d-3	Flow	High	High air pressure to Overfill recovery pump ECRT-P-301	<p>Overpressurization/Hydrogen Deflagration:</p> <p>If the flow was high, then the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none">• Instrument air pressure control valve ECRT-PCV-761• Overfill recovery pump air supply pressure indication (PI-270-767)• Overfill recovery pump ECRT-P-301 inlet and outlet pressure instrumentation (PIT-730-301, -302)• Differential sludge weight instrumentation (DWI-740-704)• STSC active ventilation• Auxiliary ventilation system• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• STSC sludge limit verification• Recovery Plan• Modified KW Basin Annex is unmanned during overfill recovery operations	<p>If the high flow did not result in a line plug, then the target recovery would be achieved in a shorter period of time.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>
11.d-4	Flow	Reverse	N/A	N/A	N/A	N/A	<p>Overfill recovery pump ECRT-P-301 cannot run in reverse. The only way it could pump in the reverse direction would be if it was installed backwards. Such an error would be discovered during pre-operation testing.</p> <p>During a slurry transfer, slurry could be misdirected to the overfill recovery pump is valve ECRT-V-102 is misaligned. Such an event is addressed in Node 2.b, "Sludge Transfer – Ingress/Egress Pipe to STSC." See Table C-8, Item 2.b-5.d.</p>

Table C-38. HAZOP Results, Node 11.d. Overfill Recovery – Pump ECRT-P-301 to Engineered Container							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.d-5.a	Flow	Misdirected (to booster pump)	Operator error (see remarks)	Uncontrolled Release: If the flow is misdirected to booster pump ECRT-P-101, then overfill recovery pump ECRT-P-301 will deadhead resulting in high pressure in the transfer line. The high pressure could result in a transfer line failure resulting in an airborne spray or splash and splatter/pool release.	<ul style="list-style-type: none"> Piping designed to B31.3, "Process Piping" Overfill recovery pump ECRT-P-301 inlet and outlet pressure instrumentation (PIT-730-301, -302) Secondary containment with leak detection Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Conduct of Operations verifies proper system configuration Radiological Control Program Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>For overfill recovery, hose ECRT-H-102 is disconnected and a routing to the engineering container is established. If hose ECRT-H-102 is not disconnected, then overfill recovery pump ECRT-P-301 would deadhead against booster pump ECRT-P-101.</p> <p>Relative to B31.3, the piping and hoses are designed to withstand the deadhead pressure of overfill recovery pump ECRT-P-301.</p>
11.d-5.b	Flow	Misdirected (into basin)	<ul style="list-style-type: none"> Operator error Hose connection decouples (see remarks)	Operational Upset: If the flow is misdirected into the basin, then the recovered sludge would be deposited on the basin floor.	None	<ul style="list-style-type: none"> Procedures Training Conduct of Operations verifies proper system configuration 	<p>For overfill recovery, hose ECRT-H-102 is disconnected and a routing to the engineering container is established. If the hose was not connected to an engineered container, or is the hose connected decoupled at either the ingress/egress pipe or engineered container, then sludge would be deposited on the basin floor.</p>
11.d-5.c	Flow	Misdirected (to incorrect engineered container)	Operator error (see remarks)	Operational Upset: If the flow is misdirected into the wrong container, then sludge streams could be mixed (e.g., settler tank sludge could be mixed with KE sludge).	None	<ul style="list-style-type: none"> Procedures Training Conduct of Operations verifies proper system configuration Recovery Plan 	<p>CHPRC has been directed to maintained the sludge streams separate. If the streams were mixed, a recovery plan would be developed to determine the disposition of the mixed stream.</p>

Table C-38. HAZOP Results, Node 11.d. Overfill Recovery – Pump ECRT-P-301 to Engineered Container							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.d-5.d	Flow	Misdirected (into STSC)	Valve ECRT-V-102 positioned incorrectly	Uncontrolled Release: If valve ECRT-V-102 is positioned incorrectly, then the recovered sludge would be directed back to the STSC. Eventually the STSC will be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	<ul style="list-style-type: none">• Valve position indicators• Differential sludge weight instrumentation (DWI-740-704) Level switches LS/LSH/LSHH-740-401• High level switch LSH-740-402• Emergency stop switch ECRT-ES-1• STSC active ventilation• Auxiliary ventilation system• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Radiological Control Program• Modified KW Basin Annex is unmanned during overfill recovery operations	

Table C-38. HAZOP Results, Node 11.d. Overfill Recovery – Pump ECRT-P-301 to Engineered Container							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.d-6	Pressure	Low	Low air pressure to overfill recovery pump ECRT-P-301	<p>Operational Upset:</p> <p>If the pressure is low, then the flow rate will be low. If the flow rate is low, then it could take longer to achieve the targeted recovery.</p> <p>Uncontrolled Release:</p> <p>If the pressure is low, then the flow rate will be low. If the flow rate is sufficiently low, then eventually the STSC will be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the pressure is low, then the flow rate will be low. Sludge could settle out and plug the line. If the line plugs, then there would be no overfill recovery. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none">• Instrument air pressure control valve ECRT-PCV-761• Level switches LS/LSH/LSHH-740-401• High level switch LSH-740-402• Emergency stop switch ECRT-ES-1• Differential sludge weight instrumentation (DWI-740-704)• STSC active ventilation• Auxiliary ventilation system• Modified KW Basin Annex confinement ventilation• Continuous air monitors	<ul style="list-style-type: none">• Procedures• Training• Radiological Control Program• Recovery Plan• Modified KW Basin Annex is unmanned during overfill recovery operations	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>

Table C-38. HAZOP Results, Node 11.d. Overfill Recovery – Pump ECRT-P-301 to Engineered Container							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.d-7	Pressure	High	<ul style="list-style-type: none"> High air pressure to overfill recovery pump ECRT-P-301 A normally-opened valve is closed Transfer line plugged 	<p>Uncontrolled Release:</p> <p>If the pressure is high, then transfer line could fail resulting in an airborne spray or splash and splatter/pool release.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the pressure high, then the flow rate will be high. If the flow rate is high, then the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Piping designed to B31.3, "Process Piping" Instrument air pressure control valve ECRT-PCV-761 Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Emergency stop switch ECRT-ES-1 Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>
11.d-8	Structural integrity	Leak/rupture (transfer line)	<ul style="list-style-type: none"> High pressure (see Item 7 above) Pulsation damper failure Manufacturing flaw Procurement error External event 	<p>Uncontrolled Release:</p> <p>If the overfill recovery tool discharge line fails, then there will be an airborne spray or splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Piping designed to B31.3, "Process Piping" Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Hydro testing Quality Assurance Program Leak detection alarm response. 	Relative to B31.3, the piping and hoses are designed to withstand the deadhead pressure of overfill recovery pump ECRT-P-301.
11.d-9	Structural Integrity	Leak/rupture (pump diaphragm)	<ul style="list-style-type: none"> Erosion Manufacturing flaw Procurement error 	<p>Uncontrolled Release:</p> <p>If the pump diaphragm fails, then sludge could enter the overfill recovery pump exhaust resulting in a spray or splash and splatter/pool release.</p>	<ul style="list-style-type: none"> Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training Radiological Control Program Modified KW Basin Annex is unmanned during overfill recovery operations 	

Table C-38. HAZOP Results, Node 11.d. Overfill Recovery – Pump ECRT-P-301 to Engineered Container							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.d-10	Time procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure Overfill recovery pump failure 	<p>Overpressurization/Hydrogen Deflagration:</p> <p>If the recovery operation occurs for too short a period of time, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>If the overfill recovery was stopped before the targeted recovery was achieved it might be possible to restart the tool and complete the recovery. However, it is also possible that the fluidizing jets would plug.</p> <p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>
11.d-11	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Operational Upset:</p> <p>If the recovery operation occurs for too long a period of time, then too much sludge could be recovered such that an STSC is sent to T Plant with a low as-settled sludge level.</p>	<ul style="list-style-type: none"> Differential sludge weight instrumentation (DWI-740-704) 	<ul style="list-style-type: none"> Procedures Training 	

Table C-38. HAZOP Results, Node 11.d. Overfill Recovery – Pump ECRT-P-301 to Engineered Container							
Item	Process Parameter	Deviation	Cause	Consequences	Candidate Controls		Remarks
					Engineered	Administrative	
11.d-12	Time Procedure	Skip action (overfill recovery pump not started)	Operator error	<p>Uncontrolled Release:</p> <p>If operators do not start overfill recovery pump ECRT-P-301, then there will be no flow. If there is no flow then the STSC will eventually be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>Overpressurization/Hydrogen Deflagration:</p> <p>If the operators do not start overfill recovery pump ECRT-P-301, then there would be no overfill recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization or a hydrogen deflagration.</p>	<ul style="list-style-type: none"> Level switches LS/LSH/LSHH-740-401 High level switch LSH-740-402 Differential sludge weight instrumentation (DWI-740-704) STSC active ventilation Auxiliary ventilation system Modified KW Basin Annex confinement ventilation Continuous air monitors 	<ul style="list-style-type: none"> Procedures Training STSC sludge limit verification Recovery Plan Modified KW Basin Annex is unmanned during overfill recovery operations 	<p>The overpressurization hazard does not exist until the STS Cask lid is bolted onto the cask. The STSC sludge limit verification administrative control will prevent this activity if the sludge limits are not met.</p> <p>In the event that the targeted recovery could not be achieved by the installed overfill recovery tool, a Recovery Plan would be developed</p>
11.d-13	Time Procedure	Wrong action	N/A	N/A	N/A	N/A	There are no wrong actions associated with this node.

APPENDIX D
FREQUENCY AND CONSEQUENCE LEVELS

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
1.a-4	Flow	Reverse	Booster pump ECRT-P-101 runs in reverse	<p>Uncontrolled Release:</p> <p>If booster pump ECRT-P-101 runs in reverse, then sludge/basin water could flow into the fluidizing jet IXM water supply line to a point above the basin water. If the fluidizing jet IXM water supply line failed due to the pressure generated by pump ECRT-P-101, then a spray or splash and splatter/pool release could occur.</p>	EU	H	H	L
				<p>Radiological Control:</p> <p>If air is pumped into an Engineered Container, then it will bubble to the surface of basin water and could result in elevated airborne radioactivity levels.</p>	EU	L	N/A	N/A
1.a-8	Pressure	High	<ul style="list-style-type: none"> Fluidizing pump speed high A normally-open valve is closed Fluidizing jets are plugged 	<p>Uncontrolled Release:</p> <p>If the pressure is high, then the fluidizing jet IXM water supply line could fail at a location above the basin water. This would result in a spill of IXM water.</p>	A	L	L	L
1.a-9	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure Manufacturing flaw Procurement error 	<p>Uncontrolled Release:</p> <p>If the fluidizing jet IXM water supply line failed at a location above the basin water, then IXM water would be spilled.</p>	A	L	L	L
1.b-4	Flow	Reverse	Booster pump ECRT-P-101 runs in reverse	<p>Uncontrolled Release:</p> <p>If booster pump ECRT-P-101 runs in reverse, then sludge/basin water could flow into the motive IXM water supply line to a point above the basin water. If the motive water IXM water supply line failed due to the pressure generated by pump ECRT-P-101, then a spray or splash and splatter/pool release could occur.</p>	EU	H	H	L
				<p>Radiological Control:</p> <p>If air is pumped into an Engineered Container, then it will bubble to the surface of basin water and could result in elevated airborne radioactivity levels.</p>	EU	L	N/A	N/A

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
1.b-7	Pressure	High	<ul style="list-style-type: none"> A normally-open valve is closed Booster pump ECRT-P-101 not operating 	<p>Uncontrolled Release:</p> <p>If the pressure is high, then the motive water IXM water supply line could fail at a location above the basin water. This would result in a spill of IXM water.</p>	A	L	L	L
1.b-8	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure Manufacturing flaw Procurement error 	<p>Uncontrolled Release:</p> <p>If the motive water IXM water supply line failed at a location above the basin water, then IXM water would be spilled.</p>	A	L	L	L
2.a-4	Flow	Reverse	<p>Booster pump ECRT-P-101 runs in reverse</p> <p>See also Table C-8, Item 2.b-4</p>	<p>Uncontrolled Release:</p> <p>If booster pump ECRT-P-101 runs in reverse, then sludge/basin water could flow into the motive IXM water supply line to a point above the basin water.</p> <p>If the motive water IXM water supply line failed due to the pressure generated by pump ECRT-P-101, then a spray or splash and splatter/pool release could occur.</p>	EU	H	H	L
				<p>Radiological Control:</p> <p>If air is pumped into an Engineered Container, then it will bubble to the surface of basin water and could result in elevated airborne radioactivity levels.</p>	EU	L	N/A	N/A
2.b-3	Flow	High	Booster pump ECRT-P-101 speed high	<p>Uncontrolled Release:</p> <p>If the flow rate is high because booster pump ECRT-P-101 speed is high, then the booster pump will become suction-starved. This could cause rupture disk ECRT-PSE-101 or -102 downstream of the booster pump to rupture and sludge would be released under the basin water surface.</p> <p>In an unmitigated scenario where no credit is taken for the rupture disks, then the transfer line downstream of the booster pump could fail. This could result in an airborne spray or splash and splatter/pool release of sludge.</p>	A	H	H	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
2.b-4.a	Flow	Reverse	Booster pump ECRT-P-101 runs in reverse	<p>Uncontrolled Release:</p> <p>If booster pump ECRT-P-101 runs in reverse, then sludge/basin water could flow into the motive IXM water supply line to a point above the basin water.</p> <p>If the motive water IXM water supply line failed due to the pressure generated by pump ECRT-P-101, then a spray or splash and splatter/pool release could occur.</p>	EU	H	H	L
				<p>Radiological Control:</p> <p>If air is pumped into an Engineered Container, then it will bubble to the surface of basin water and could result in elevated airborne radioactivity levels.</p>	EU	L	N/A	N/A
2.b-4.b	Flow	Reverse	Siphon from STSC	<p>Uncontrolled Release:</p> <p>If sludge was siphoned from the STSC due to a breach in the transfer line, then a splash and splatter/pool release could occur.</p>	A	H	H	L
				<p>Hydrogen Deflagration:</p> <p>If the release was into the Transfer Line Service Box, then hydrogen generated by the sludge could accumulate in the box resulting in a deflagration.</p>	A	H	L	L
2.b-5.a	Flow	Misdirected (into Transfer Line Service Box)	<ul style="list-style-type: none"> Valving error such that sludge enters box via IXM water spray nozzles Valving error such that sludge enters box via siphon break Valving error such that sludge enters box via sump pump 	<p>Uncontrolled Release:</p> <p>If sludge is misdirected into the Transfer Line Service Box, then a splash and splatter/pool release would occur.</p>	A	H	H	L
				<p>Hydrogen Deflagration:</p> <p>If sludge is misdirected into the Transfer Line Service Box, then hydrogen generated by the sludge could accumulate in the box resulting in a deflagration.</p>	A	H	L	L
2.b-5.b	Flow	Misdirected (into Transfer Line Service Box IXM water supply)	Valving error	<p>Uncontrolled Release:</p> <p>If sludge is misdirected into the Transfer Line Service Box IXM water supply, then a spray or splash and splatter/pool release could occur.</p>	A	H	H	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
2.b-5.c	Flow	Misdirected (into decant/flocculant recirculation line)	Valving error	Uncontrolled Release: If sludge is misdirected into the decant/flocculant recirculation line, then the line could be overpressurized and fail resulting in as spray or splash and splatter/pool release.	A	H	H	L
2.b-5.d	Flow	Misdirected (to overfill recovery pump)	Valving error	Uncontrolled Release: If the slurry flow is misdirect to the overfill recovery pump, then booster pump ECRT-P-101 will deadhead resulting in high pressure in the transfer line. In an unmitigated scenario where no credit is taken for the rupture disks, then high pressure could result in a transfer line failure resulting in an airborne spray or splash and splatter/pool release.	A	H	H	L
2.b-7	Pressure	High	<ul style="list-style-type: none"> Booster pump ECRT-P-101 speed high A normally-open valve is closed Transfer line plugged 	Uncontrolled Release: In an unmitigated scenario where no credit is taken for the rupture disks, then high pressure could result in a transfer line failure resulting in an airborne spray or splash and splatter/pool release.	A	H	H	L
2.b-10	Concentration	High	<ul style="list-style-type: none"> Xago Hydrolance™ lowered into sludge too fast Fluidizing jets pulsed too frequently 	Uncontrolled Release: If the vol% solids is too high, then sludge may settle out in the transfer line and form a plug. If a plug forms and booster pump ECRT-P-101 continues to operate, then rupture disk ECRT-PSE-101 would fail and sludge would be released under the surface of the basin water. In an unmitigated scenario where no credit is taken for the rupture disk, then high pressure could result in a transfer line failure resulting in an airborne spray or splash and splatter/pool release.	A	H	H	L
2.b-12	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure (see Item 2.b-6 above) Pulsation damper failure Manufacturing flaw Procurement error External event 	Uncontrolled Release: If the transfer line leaks or ruptures, then there will be an airborne spray or splash and splatter/pool release.	A	H	H	L
				Hydrogen Deflagration: If the transfer line leaks or ruptures inside the transfer line service box, then sludge would be spilled into the box. Hydrogen generated by the sludge could accumulate in the box resulting in a deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
2.c-7.a	Composition	Other (settler tank sludge retrieved instead of KE/KW sludge)	Xago Hydrolance™ lowered into incorrect Engineered Container due to operator error	Overpressurization: The STSC sludge limits have been established, in part, to prevent the sludge from reaching a temperature of approximately 100 °C in order to prevent excessive headspace pressures. If the Xago Hydrolance™ is erroneously lowered into SCS-CON-230, then settler tank sludge would be retrieved into an STSC without an annulus. Placing settler tank sludge in an STSC without an annulus could result in the sludge temperature reaching 100 °C and overpressurizing the STS cask.	A	L	L	L
				Hydrogen Deflagration: The STSC sludge limits have been established, in part, to control the hydrogen concentration in the headspace of the STSC. Placing settler tank sludge in an STSC without an annulus could result in a hydrogen deflagration.	A	H	L	L
2.c-7.b	Composition	Other (KE/KW sludge retrieved instead of settler tank sludge)	Xago Hydrolance™ lowered into incorrect Engineered Container due to operator error	Radiological Control: If the Xago Hydrolance™ is erroneously lowered into a container other than SCS-CON-230, then KE or KW Basin sludge would be retrieved into an STSC with an inner core. This could result in higher than expected dose rates at the top of the STSC. In addition, If the sludge were to subsequently expand at the safety basis expansion rate, then sludge could escape the STSC during long-term storage at T Plant.	A	L	L	L
2.c-7.d	Composition	Other (KW sludge retrieved instead of KE sludge)	Xago Hydrolance™ lowered into incorrect Engineered Container due to operator error	Radiological Control (T Plant): If the Xago Hydrolance™ is erroneously lowered into SCS-CON-210 or 220 instead of SCS-CON-240, -250, or -260, then KW sludge would be retrieved instead of KE sludge. Consequently, the STSC volume limit for KW sludge would be exceeded. If the sludge were to subsequently expand at the safety basis expansion rate, then sludge could escape the STSC during long-term storage at T Plant.	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
2.c-8	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure (see Table 2-12, Item 2.d-6.b) Manufacturing flaw Corrosion 	<p>Uncontrolled Release:</p> <p>For non-pressurized scenarios, if the breach occurred above the liquid level, then contaminated air could exit the STSC.</p> <p>For non-pressurized scenarios, if the breach occurred below the liquid level, then sludge would leak into the STS cask.</p> <p>The consequences of a leak due to high pressure are as stated in Table 2-12, Item 2.d-6b.</p>	A	H	H	L
2.c-10.a	Level (KE/KW slurry)	High	Instrumentation and control failure	<p>Uncontrolled Release:</p> <p>If the KE/KW slurry transfer is not stopped, then the STSC will be overfilled and slurry will be pumped into the 4-in and 1-in. ventilation exhaust lines and into the 1-in. ventilation inlet line leading to a splash and splatter/pool release.</p>	A	L	L	L
2.c-10.b	Level (settler tank slurry)	High	Instrumentation and control failure	<p>Uncontrolled Release:</p> <p>If the settler tank slurry transfer is not stopped, then the STSC will be overfilled and slurry will be pumped into the 4-in and 1-in. ventilation exhaust lines and into the 1-in. ventilation inlet line leading to a splash and splatter/pool release.</p>	A	L	L	L
				<p>Overpressurization:</p> <p>Thermal modeling of settler tank sludge in an STSC with an annulus assumes that the core region is filled with water. If the settler sludge level is high, then a small amount of sludge could enter the core region. If a large amount of sludge was present in the core region, then the sludge temperature could eventually reach 100 °C and overpressurize the STS cask.</p>	A	L	L	L
				<p>Hydrogen Deflagration:</p> <p>Gas generation analyses of settler sludge in an STSC with an annulus assume that the core region if filled with water. If the settler sludge level is high, then a small amount of sludge could enter the core region. If a large amount of sludge was present in the core region, a hydrogen deflagration could occur.</p>	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
2.c-10.c	Level (KE/KW as-settle sludge)	High	<ul style="list-style-type: none"> Instrumentation and control failure Operator error 	Radiological Control (T Plant) If the as-settled sludge level is high and the sludge was to subsequently expand at the safety basis expansion rate, then sludge could escape the STSC during long-term storage at T Plant.	A	L	L	L
2.c-10.d	Level (settler tank as-settled sludge)	High	<ul style="list-style-type: none"> Instrumentation and control failure Operator error 	Overpressurization: Settler tank sludge limits have been established, in part, to prevent the sludge from reaching a temperature of 100 °C in order to prevent excessive headspace pressures. If the as-settled sludge level is high, then the sludge temperature could reach 100 °C and overpressurize the STS cask.	A	L	L	L
				Hydrogen Deflagration: The settler tank sludge limits have been established, in part, to control the hydrogen concentration in the headspace of the STSC. If the as-settled sludge level is high, then a hydrogen deflagration could occur.	A	H	L	L
2.d-1	Flow	No	<ul style="list-style-type: none"> Air inlet valve ECRT-V-732 closed STSC inlet HEPA filter plugged Exhaust fan ECRT-EF-502 or -503 not operating 	Hydrogen Deflagration: If there is no ventilation system flow, then a hydrogen deflagration could occur.	A	H	L	L
				Radiological Control: If there is no ventilation system flow, then the pressure in the STSC will be slightly greater than atmospheric during a transfer. See Item 2.d-6.a below.	A	L	L	L
2.d-2	Flow	Low	<ul style="list-style-type: none"> Inlet HEPA filter partially plugged Air Inlet and outlet valves set incorrectly Exhaust fan ECRT-EF-502 or -503 speed low 	Hydrogen Deflagration: If the flow rate falls below 1 cfm, then a hydrogen deflagration could occur.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
2.d-3	Flow	High	<ul style="list-style-type: none"> Air inlet and outlet valves set incorrectly Exhaust fan ECRT-EF-502 or -503 speed high 	Radiological Control: If the flow rate is high, then more aerosol may be swept out of the STSC. This could result in increased deposition in the vent line resulting in an increased dose rate and an increased potential for contamination. See also Item 2.d-8.a below.	A	L	L	L
2.d-5	Pressure (absolute)	Low (less than -1.0 in. wg)	<ul style="list-style-type: none"> Air inlet and outlet valves set incorrectly Exhaust fan ECRT-EF-502 or -503 speed high 	Radiological Control: If the pressure is low (i.e., less than -1.0 in. wg), then the flow rate will increase. If the flow rate is high, then more aerosol may be swept out of the STSC. Consequences are as stated in Item 2.d-3 above.	A	L	L	L
2.d-6	Pressure (absolute)	High (greater than -1.0 in. wg)	<ul style="list-style-type: none"> No flow (see Item 2.d-1, above) Low flow (see Item 2.d-2, above) 	Radiological Control: If the pressure in the STSC is greater than atmospheric, then the potential exists for a spread of contamination.	A	L	L	L
2.d-8.a	Concentration (moisture in STSC exhaust)	High	High flow rate, see Item 2.d-3 above	Radiological Control: If there is too much moisture in the exhaust air, then the HEPA filters could be damaged.	A	L	L	L
2.d-8.b	Concentration (radionuclide in STSC exhaust))	High	High flow rate, see Item 2.d-3	Radiological Control: If the flow rate is high, then more aerosol may be swept out of the STSC. This could result in increased deposition in the vent line resulting in an increased dose rate and an increased potential for contamination.	A	L	L	L
2.d-10.b	Structural Integrity (STSC outlet line)	Leak/rupture	<ul style="list-style-type: none"> Physical damage to outlet line(s) Hose ECRT-H-501 disconnects from STSC at nozzle F1 Hose ECRT-H-659 disconnects from STSC at nozzle F2 	Hydrogen Deflagration: If there is a leak/rupture in the outlet line, then the flow rate through the STSC will decrease. If the flow rate drops below 1 cfm, a hydrogen deflagration could occur.	A	H	L	L
				Radiological Control: The interior of the outlet lines will be contaminated. Although the lines are under negative pressure, if there is a leak/rupture then a spread of contamination could occur.	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
2.d.-10.c	Structural Integrity (exhaust HEPA filters)	Leak/rupture	<ul style="list-style-type: none"> High differential pressure (e.g., moisture build-up, particulate loading) Incorrect installation Manufacturing flaw Mechanical insult 	Radiological Control: If the HEPA filters leak/rupture, then the exhaust air from the STSC would not be filtered, or would not be filtered as efficiently.	A	L	L	L
2.d-12	Level (demisters)	High	High moisture content of STSC exhaust air (see Item 2.d-8.a) or other inlet stream coupled with closed isolation valve ECRT-V-501)	Radiological Control: If the liquid level in the demisters is high, then moisture will not be removed from the airstream. This could result in moisture build-up on the HEPA filters resulting in their failure.	A	L	L	L
2.d-13	Level (condensate tank)	Low	<ul style="list-style-type: none"> Instrumentation failure Operator error (failure to add water to tank) 	Radiological Control: If the liquid level in condensate tank ECRT-TK-502 drops below the diplegs, then the ventilation system will draw a room air through the tank via the condensate tank vent. This will unbalance the confinement ventilation system airflows with the result that negative air pressure differentials may not be properly maintained leading to a spread of contamination.	A	L	L	L
				Hydrogen Deflagration: If the airflows are unbalanced to the point that less than 1 cfm is exhausted from the STSC, then a hydrogen deflagration could occur.	A	H	L	L
2.d-14	Level (condensate tank)	High	<ul style="list-style-type: none"> High moisture content of STSC exhaust air (see Item 2.d-8.a) or other inlet air stream STSC overflow Sand filter valving error (see Table C-14, Item 3-5.c and Table C-16, Item 4-5.c) 	Uncontrolled Release: If the liquid level in condensate tank ECRT-TK-502 is high, then the liquid can overflow the tank resulting in a splash and splatter/pool release.	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
3-5.a	Flow	Misdirected (into Decant Pump Box)	<ul style="list-style-type: none"> Valving error such that supernate enters box via IXM water spray nozzles Valving error such that supernate enters box via siphon break 	Uncontrolled Release: If supernate is misdirected into the Decant Pump Box, then a splash and splatter/pool release will occur.	A	L	L	L
				Hydrogen deflagration: If supernate is misdirected into the Decant Pump Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.	A	H	L	L
3-5.b	Flow	Misdirected (into Sand Filter Enclosure)	<ul style="list-style-type: none"> Pressure safety valve PSV-1A or -01B open Drain valve HV-03A/3B open Valving error such that supernate enters enclosure via siphon break 	Uncontrolled Release: If supernate is misdirected into the Sand Filter Enclosure, then a splash and splatter/pool release will occur.	A	L	L	L
				Hydrogen Deflagration: If supernate is misdirected into the Sand Filter Enclosure, then hydrogen generated by the supernate could accumulate in the enclosure resulting in a deflagration.	A	H	L	L
3-5.c	Flow	Misdirected (into sand filter sparge exhaust)	Valving error (FV-06A/B)	Uncontrolled Release: If supernate is misdirected into the sand filter sparge exhaust, then catch tank ECRT-TK-502 will overflow and a splash and splatter/pool release will occur.	A	L	L	L
3-5.d	Flow	Misdirected (into Decant Pump Box IXM water supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the Decant Pump Box IXM water supply, then a splash and splatter/pool release could occur.	A	L	L	L
3-5.e	Flow	Misdirected (into Sand Filter Enclosure IXM water supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the Sand Filter Enclosure IXM water supply, then a splash and splatter/pool release could occur.	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
3-5.f	Flow	Misdirected (into Sand Filter Enclosure instrument air supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the Sand Filter Enclosure instrument air supply, then a splash and splatter/pool release could occur.	A	L	L	L
3-5.g	Flow	Misdirected (into flocculant addition supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the flocculant addition supply, then a splash and splatter/pool release could occur.	A	L	L	L
3-7	Pressure	High	<ul style="list-style-type: none"> High air pressure to decant pump ECRT-P-201 A normally-opened valve is closed Sand filter media plugged 	Uncontrolled Release: If the pressure is high, then the decant line or sand filter could fail resulting in an airborne spray or splash and splatter/pool release.	A	L	L	L
3-9.a	Concentration (decanted supernate)	High	<ul style="list-style-type: none"> Settling time too short Operator error 	Uncontrolled Release: If the high turbidity results in plugging the sand filter, then decant pump ECRT-P-201 will deadhead resulting in a high pressure. The consequences are as stated in Item 3-7 above.	A	L	L	L
3-13.a	Structural Integrity	Leak/rupture (diaphragm pump)	Decant pump ECRT-P-201 diaphragm failure	Uncontrolled Release: If the decant pump diaphragm failed, then supernate could enter the pump exhaust resulting in a spray or splash and splatter/pool release.	A	L	L	L
3-13.b	Structural Integrity	Leak/rupture (sand filter)	<ul style="list-style-type: none"> High pressure (see Item 3-7 above) Manufacturing flaw 	Uncontrolled Release: If the sand filter fails, then a spray or splash and splatter/pool release will occur inside the sand filter enclosure.	A	L	L	L
				Hydrogen Deflagration: If the sand filter fails, then decanted supernate would be spilled into the sand filter enclosure. Hydrogen generated by the supernate could accumulate in the enclosure resulting in a deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
3-13.c	Structural Integrity	Leak/rupture (decant line – STSC to sand filter)	<ul style="list-style-type: none"> High pressure (see Item 3-7 above) Manufacturing flaw Hose connection decouples 	<p>Uncontrolled Release:</p> <p>If the decant line fails, then a spray or splash and splatter/pool release of STSC supernate will occur.</p>	A	L	L	L
				<p>Hydrogen deflagration:</p> <p>If the decant line leaks or ruptures inside the decant pump box, then decanted supernate would be spilled into the box. Hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.</p>	A	H	L	L
3-13.d	Structural Integrity	Leak/rupture (decant line – sand filter to basin)	<ul style="list-style-type: none"> Manufacturing flaw Hose connection decouples External event 	<p>Uncontrolled Release:</p> <p>If the decant line fails, then a spray or splash and splatter/pool release of filtered STSC supernate will occur.</p>	A	L	L	L
3-16	Time Procedure	Skip action	Operator error	<p>Uncontrolled Release:</p> <p>If the decant is not performed, the next process step is to backwash the sand filters. This would result in pumping 20-45 gpm of IXM water into the STSC. The STSC would go solid and liquid would be pumped into the 4-in and 1-in. ventilation exhaust lines and into the 1-in. ventilation inlet line leading to a splash and splatter/pool release.</p>	A	L	L	L
3-17.b	Time Procedure	Wrong action (recirculate instead of decant)	Operator error	<p>Uncontrolled Release:</p> <p>If the supernate is recirculated instead of decanted, then decant pump *-P-201 will deadhead resulting in high pressure. See Item 3-7 above.</p>	A	L	L	L
4-4	Flow	Reverse	<p>Breach in the IXM water supply line results in siphoning of supernate from the STSC</p> <p>See also Table C-14, Item 3-5.3</p>	<p>Uncontrolled Release:</p> <p>If the IXM water supply line is breached, then STSC supernate could be siphoned from the STSC. The supernate would be filtered by a portion of the sand filter bed.</p>	A	L	L	L
4-5.a	Flow	Misdirected (into Sand Filter Enclosure)	<ul style="list-style-type: none"> Pressure safety valve PSV-1A or -01B open Valving error such that supernate enters enclosure via siphon break 	<p>Uncontrolled Release:</p> <p>If the release is via pressure safety valve PSV-1A or -01B, then sand filter backwash will be misdirected into the Sand Filter Enclosure and a splash and splatter/pool release will occur</p>	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
4-5.b	Flow	Misdirected (into Decant Pump Box)	<ul style="list-style-type: none"> Valving error such that sand filter backwash enters box via IXM water spray nozzles Valving error such that supernate enters box via siphon break 	<p>Uncontrolled Release:</p> <p>If sand filter backwash is misdirected into the Decant Pump Box, then a splash and splatter/pool release will occur.</p>	A	L	L	L
4-5.c	Flow	Misdirected (into sand filter sparge exhaust)	Valving error (FV-06A/B)	<p>Uncontrolled Release:</p> <p>If backwash is misdirected into the sand filter sparge exhaust, then catch tank ECRT-TK-502 will overflow and a splash and splatter/pool release will occur.</p>	A	L	L	L
4-5.d	Flow	Misdirected (into Decant Pump Box IXM water supply)	Valving error	<p>Uncontrolled Release:</p> <p>If sand filter backwash is misdirected into the Decant Pump Box IXM water supply, then a splash and splatter/pool release could occur.</p>	A	L	L	L
4-5.e	Flow	Misdirected (into Sand Filter Enclosure instrument air supply)	Valving error	<p>Uncontrolled Release:</p> <p>If misdirected into the Sand Filter Enclosure instrument air supply, then a splash and splatter/pool release could occur. The release would be primarily IXM water.</p>	A	L	L	L
4-5.f	Flow	Misdirected (into flocculant addition supply)	Valving error	<p>Uncontrolled Release:</p> <p>If sand filter backwash is misdirected into the flocculant addition supply, then a splash and splatter/pool release could occur.</p>	A	L	L	L
4-7	Pressure	High	<ul style="list-style-type: none"> High water pressure from the Skimmer Water Cleanup System Throttle valve HCV-511 set incorrectly A normally-opened valve is closed 	<p>Uncontrolled Release:</p> <p>If a normally-opened valve is closed, then high pressure could result in a failure in the filter backwash system resulting in a spray or splash and splatter/pool release.</p>	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
4-12.a	Level (STSC at end of backwash)	High	Instrumentation and control failure	Uncontrolled Release: If the backwash is not stopped, then the STSC will go solid and sand filter backwash will be pumped into the 4-in and 1-in. ventilation exhaust lines and into the 1-in. ventilation inlet line leading to a splash and splatter/pool release.	A	L	L	L
4-13.a	Structural Integrity	Leak/rupture (sand filter)	<ul style="list-style-type: none"> High pressure (see Item 4-7 above) Manufacturing flaw 	Uncontrolled Release: If the sand filter fails, then a spray or splash and splatter/pool release will occur.	A	L	L	L
				Hydrogen Deflagration: If the sand filter fails, then sand filter backwash would be spilled into the sand filter enclosure. Hydrogen generated by the backwash could accumulate in the enclosure resulting in a deflagration.	A	H	L	L
4-13.b	Structural Integrity	Leak/rupture (backwash line – sand filter to STSC)	<ul style="list-style-type: none"> High pressure (see Item 4-7 above) Manufacturing flaw Hose connection decouples 	Uncontrolled Release: If the backwash line fails, then a spray or splash and splatter/pool release will occur.	A	H	H	L
				Hydrogen deflagration: If the backwash line leaks or ruptures inside the sand filter enclosure, then sand filter backwash would be spilled into the sand filter enclosure. Hydrogen generated by the backwash could accumulate in the box resulting in a deflagration.	A	H	L	L
4-16	Time Procedure	Skip action	Operator error	Hydrogen Deflagration: If the backwash is not performed, then hydrogen generated by the sludge captured on the sand filter media could accumulate in the headspace of the sand filter resulting in a deflagration.	A	H	L	L
5-1	Flow	No	<ul style="list-style-type: none"> Nitrogen bottles empty A normally-opened valve is closed 	Hydrogen Deflagration: If there is no nitrogen flow, then the STSC will not be inerted. This could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
5-5.a	Flow	Misdirected (flow into STS cask)	Valve ECRT-V-609 set incorrectly	Hydrogen Deflagration: If the nitrogen flow is misdirected to the STS cask, then the STSC will not be inerted. This could result in a hydrogen deflagration.	A	H	L	L
5-5.b	Flow	Misdirected (flow into Annex)	Valve ECRT-V-732 open	Hydrogen Deflagration: If the nitrogen flow is misdirected into the Loading Bay, then the STSC will not be inerted. This could result in a hydrogen deflagration.	A	H	L	L
5-9	Concentration	High (O ₂)	<ul style="list-style-type: none"> Purge duration too short (see Item 5-14 below) Insufficient nitrogen supply No nitrogen flow (see Item 5-1 above) Misdirected nitrogen flow (see Item 5-5.a, and .b above) 	Hydrogen Deflagration: If the oxygen concentration in the STSC is high, then the STSC will not be inerted. This could result in a hydrogen deflagration.	A	H	L	L
5-10.a	Composition	Other (oxidant)	Gas bottles containing an oxidant (e.g., air) installed at Inert Bottle Station	Hydrogen Deflagration: If gas bottles containing an oxidant are installed at the Inert Bottle Station, then the STSC will not be inerted. This could result in a hydrogen deflagration.	A	H	L	L
5-10.b	Composition	Other (helium)	Gas bottles containing helium installed at Inert Bottle Station	Hydrogen Deflagration: If helium gas bottles are installed, then too much counter-current flow will occur and the STSC will not be inerted.	A	H	L	L
5-12.b	Level	Low (nitrogen bottle volume)	<ul style="list-style-type: none"> Leak in supply system Operator error (low pressure bottles not replaced as needed) 	Hydrogen Deflagration: If the nitrogen volume is low, then there could be insufficient nitrogen to inert the STSC. This could result in a hydrogen deflagration.	A	H	L	L
5-13	Structural Integrity	Leak/rupture (nitrogen supply system)	<ul style="list-style-type: none"> Overpressurization Hose disconnects 	Hydrogen Deflagration: If a leak or rupture in the nitrogen supply occurs, then the STSC will not be inerted. This could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
5-14	Time Procedure	Too short	<ul style="list-style-type: none">• Operator error• Instrumentation failure (AE-760-601)	Hydrogen Deflagration: If the purge occurs for too short a period of time (i.e., before the oxygen concentration reaches 0.1%), then a hydrogen deflagration could occur.	A	H	L	L
5-16	Time Procedure	Skip action	Operator error	Hydrogen Deflagration: If the STSC is not inerted, then a hydrogen deflagration could occur.	A	H	L	L
6-1	Flow	No	<ul style="list-style-type: none">• Nitrogen bottles empty• A normally-opened valve is closed	Hydrogen Deflagration: If there is no nitrogen flow, then the STS cask will not be inerted. This could result in a hydrogen deflagration.	A	H	L	L
6-5	Flow	Misdirected (flow into Annex)	Valve ECRT-V-609 set incorrectly	Hydrogen Deflagration: If valve ECRT-V-609 is mispositioned, then the nitrogen flow would be directed to the STSC purge inlet where it would deadhead against the male Staubli connector. The STS cask would not be inerted.	A	H	L	L
6-7.a	Pressure	High (nitrogen supply system)	<ul style="list-style-type: none">• A normally-opened valve is partially closed• Pressure control valve failure	Hydrogen Deflagration: If the pressure is high, then the piping or hoses could fail such that the STS cask is not inerted. This could result in a hydrogen deflagration.	A	H	L	L
6-7.b	Pressure	High (STS cask)	Pressure control valve failure and vent port tool closed	Radiological Control: If the pressure is high, then the STS cask mechanical seal could fail. If the inside of the STS cask was contaminated, then contaminated nitrogen would be discharged into the loading bay.	A	L	L	L
				Hydrogen Deflagration: Overpressurizing the STS cask would cause the mechanical seal to fail. This would allow air ingress into the STS cask and, subsequently, into the STSC. This could lead to a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
6-9	Concentration	High (O ₂)	<ul style="list-style-type: none"> Purge duration too short (see Item 6-12 below) Insufficient nitrogen supply No nitrogen flow (see Item 6-1 above) Misdirected nitrogen flow (see Item 6-5 above) 	<p>Hydrogen Deflagration:</p> <p>If the oxygen concentration in the STS cask is high, then the STS cask will not be inerted. This could result in a hydrogen deflagration.</p>	A	H	L	L
6-10.a	Composition	Other (oxidant)	Gas bottles containing an oxidant (e.g., air) installed at Inert Bottle Station	<p>Hydrogen Deflagration:</p> <p>If gas bottles containing an oxidant are installed at the Inert Bottle Station, then the STS cask will not be inerted. This could result in a hydrogen deflagration.</p>	A	H	L	L
6-10.b	Composition	Other (helium)	Gas bottles containing helium installed at Inert Bottle Station	<p>Hydrogen Deflagration:</p> <p>If helium gas bottles are installed at the Bottle Station, then too much air ingress will occur and the STS cask will not be inerted.</p>	A	H	L	L
6-11	Level	Low (nitrogen bottle volume)	<ul style="list-style-type: none"> Leak in supply system Operator error (low pressure bottles not replaced as needed) 	<p>Hydrogen Deflagration:</p> <p>If the nitrogen volume is low, then there could be insufficient nitrogen to inert the STS cask. This could result in a hydrogen deflagration.</p>	A	H	L	L
6-13.a	Structural Integrity	Leak/rupture (nitrogen supply system)	<ul style="list-style-type: none"> Overpressurization Hose disconnects 	<p>Hydrogen Deflagration:</p> <p>If a leak or rupture in the nitrogen supply occurs, then the STS cask will not be inerted. This could result in a hydrogen deflagration.</p>	A	H	L	L
6-13.b	Structural Integrity	Leak/rupture (STS cask)	<ul style="list-style-type: none"> Overpressurization Mechanical seal failure 	<p>Hydrogen deflagration:</p> <p>If the STS cask leaks, then air will leak into the STS cask and, subsequently, into the STSC. This could lead to a hydrogen deflagration.</p>	A	H	L	L
6-14	Time Procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure (AE-760-601) 	<p>Hydrogen Deflagration:</p> <p>If the purge occurs for too short a period of time (i.e., before the oxygen concentration reaches 0.1%), then a hydrogen deflagration could occur.</p>	A	H	L	L
6-16	Time Procedure	Skip action	Operator error	<p>Hydrogen Deflagration:</p> <p>If the STS cask is not inerted, then a hydrogen deflagration could occur.</p>	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
7-1.	Flow	No	<ul style="list-style-type: none"> No nitrogen pressure Drain port closed A normally opened valve is closed 	<p>Hydrogen Deflagration:</p> <p>If there is no flow, then the STS cask will not be pressurized. Air inleakage could occur eventually leading to a flammable hydrogen concentration.</p>	A	H	L	L
7-3	Flow	High	High nitrogen pressure	<p>Overpressurization:</p> <p>If the flow is high, then operators may exceed the STS cask high pressure limit. This could result in cask overpressurization.</p>	A	L	L	L
7-4	Flow	Reverse (nitrogen flow out of STS cask)	<ul style="list-style-type: none"> Leak or rupture of nitrogen supply piping or hose Vent port tool leak STS cask mechanical seal leak 	<p>Radiological Control:</p> <p>If nitrogen flows out of the STS cask and the inside of the STS cask was contaminated, then there would be a spread of contamination at the point of the leak.</p>	A	L	L	L
				<p>Hydrogen Deflagration:</p> <p>If the nitrogen flows out of the cask, then the STS cask will not be pressurized. Air inleakage could occur eventually leading to a flammable hydrogen concentration.</p>	A	H	L	L
7-5	Flow	Misdirected	Valve ECRT-V-609 mispositioned	<p>Hydrogen Deflagration:</p> <p>If valve ECRT-V-609 is mispositioned, then the nitrogen flow would be directed to the STSC purge inlet where it would deadhead against the male Staubli connector. The STS cask would not be pressurized. Air inleakage could occur eventually leading to a flammable hydrogen concentration.</p>	A	H	L	L
7-7.a	Pressure	High (nitrogen supply system)	<ul style="list-style-type: none"> A normally-opened valve is closed or partially closed Pressure control valve failure 	<p>Overpressurization</p> <p>If the pressure is high then the flow rate will be high and operators may exceed the STS cask high pressure limit. This could result in STS cask overpressurization.</p>	A	L	L	L
				<p>Hydrogen Deflagration:</p> <p>If the pressure is high, then the piping or hoses could fail such that the STS cask would not be pressurized. Air inleakage could occur eventually leading to a flammable hydrogen concentration.</p>	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
7-7.b	Pressure	High (STS cask)	Pressure control valve failure	Overpressurization: If the pressure is greater than the STS cask high pressure limit of 15 psig, then the STS cask could overpressurize.	A	L	L	L
				Hydrogen Deflagration: If the pressure is high, then the STS cask mechanical seal could fail. This would allow air inleakage once the nitrogen flow was stopped. This could eventually lead to a flammable hydrogen concentration.	A	H	L	L
7-8.a	Composition	Other (oxidant)	Gas bottles containing an oxidant (e.g., air) installed at Inert Bottle Station	Hydrogen Deflagration: If gas bottles containing an oxidant are installed at the Inert Bottle Station, then an oxidant would be added to the STS cask by the pressurization activity and might not be inerted. This could result in a hydrogen deflagration.	A	H	L	L
7-8.b	Composition	Other (helium)	Gas bottles containing helium installed at Inert Bottle Station	Hydrogen Deflagration: If helium gas bottles are installed at the Bottle Station, then too much air inleakage will occur and the STS cask will not be inerted.	A	H	L	L
7-9	Level	Low (nitrogen bottle volume)	<ul style="list-style-type: none"> Leak in supply system Operator error (low pressure bottles not replaced as needed) 	Hydrogen Deflagration: If the nitrogen volume is low, then there could be insufficient nitrogen to pressurize the STS cask to the low pressure limit. Air inleakage could occur eventually leading to a flammable hydrogen concentration.	A	H	L	L
7-11.a	Structural integrity	Leak/rupture (nitrogen supply system)	<ul style="list-style-type: none"> Overpressurization Manufacturing flaw Procurement error Hose connection decouples 	Hydrogen Deflagration: If there is a leak/rupture in the nitrogen supply system, then the STS cask would not be pressurized. Air inleakage could occur eventually leading to a flammable hydrogen concentration.	A	H	L	L
7-11.b	Structural integrity	Leak/rupture (STS cask)	<ul style="list-style-type: none"> Overpressurization STS cask mechanical seal failure 	Hydrogen deflagration: If the STS cask leaks/ruptures, then air will leak into the STS cask. This could eventually lead to a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
7-12	Time procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Hydrogen deflagration:</p> <p>If the operator pressurizes the STS cask for too short a period of time, then the STS cask will not be pressurized to the low pressure limit. Air inleakage could occur eventually leading to a flammable hydrogen concentration.</p>	A	H	L	L
7-13	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Overpressurization:</p> <p>If the operator pressurizes the STS cask for too long a period of time, then the STS cask high pressure limit will be exceeded. This could result in cask overpressurization.</p>	A	L	L	L
7-14	Time Procedure	Skip action	<ul style="list-style-type: none"> Operator error 	<p>Hydrogen deflagration:</p> <p>If the operator does not pressurize the STS cask, then air inleakage could occur eventually leading to a flammable hydrogen concentration.</p>	A	H	L	L
8-4.a	Flow	Reverse	Metering pump ECRT-P-203 runs in reverse	<p>Uncontrolled Release:</p> <p>If metering pump ECRT-P-203 runs in reverse, then sludge would be pumped into the flocculant addition system and could result in a spray or splash and splatter/pool release.</p>	A	L	L	L
8-4.b	Flow	Reverse	Booster pump ECRT-P-101 runs in reverse	<p>Uncontrolled Release:</p> <p>If booster pump ECRT-P-101 runs in reverse, then sludge could flow into the flocculant addition system to a point above the basin water.</p> <p>If the flocculant addition system line failed due to the pressure generated by pump ECRT-P-101, then a spray or splash and splatter/pool release could occur.</p>	A	H	H	L
9.a-4	Flow	Reverse	<ul style="list-style-type: none"> Metering pump ECRT-P-204 runs in reverse Metering pump ECRT-P-204 not operating Low pressure in flocculant addition line 	<p>Uncontrolled Release:</p> <p>If metering pump ECRT-P-204 runs in reverse, then recirculated supernate would be pumped into the flocculant addition system and could result in a spray or and splatter/pool release.</p> <p>If metering pump ECRT-P-204 does not operate, or if the pressure in the flocculant addition line is low, then recirculated supernate would be pumped into the flocculant addition system (due to the 80 psi generated by decant pump ECRT-P-201) and could result in a spray or splash and splatter/pool release.</p>	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
9.a-6	Pressure	Low	<ul style="list-style-type: none">Flow rate set incorrectly	Uncontrolled Release: If the pressure is low, then recirculated supernate would be pumped into the flocculant addition system (due to the 80 psi generated by decant pump ECRT-P-201) and could result in a spray or splash and splatter/pool release.	A	L	L	L
9.a-7	Pressure	High	<ul style="list-style-type: none">Flow rate set incorrectlyNormally opened valve closed or partially closed	Uncontrolled Release: If the pressure is high, then the decant/flocculant recirculation line could fail resulting in a spray or splash and splatter/pool release	A	L	L	L
				Hydrogen Deflagration: If the pressure is high, then the decant/flocculant recirculation line could fail. Hydrogen generated by the supernate could accumulate in the Decant Pump Box resulting in a deflagration.	A	H	L	L
9.a-13.a	Structural Integrity	Leak/rupture (inside Decant Pump Box)	<ul style="list-style-type: none">OverpressurizationHose disconnects	Uncontrolled Release: If the leak is large, then the pressure could drop to the point that recirculated supernate would be pumped into the flocculant addition system (due to the 80 psi generated by decant pump ECRT-P-201) which would result in a spray or splash and splatter/pool release.	A	L	L	L
				Hydrogen Deflagration: If the leak is large, and recirculated supernate is pumped into the Decant Pump Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.	A	H	L	L
9.a-13.b	Structural Integrity	Leak/rupture (outside Decant Pump Box)	<ul style="list-style-type: none">OverpressurizationHose disconnects	Uncontrolled Release: If the leak is large, then the pressure could drop to the point that recirculated supernate would be pumped into the flocculant addition system (due to the 80 psi generated by decant pump ECRT-P-201) which would result in a spray or splash and splatter/pool release.	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
9.b-5.a	Flow	Misdirected (into Decant Pump Box)	<ul style="list-style-type: none"> Valving error such that supernate enters box via IXM water spray nozzles Valving error such that supernate enters box via siphon break 	Uncontrolled Release: If supernate is misdirected into the Decant Pump Box, then a splash and splatter/pool release will occur.	A	L	L	L
				Hydrogen Deflagration: If supernate is misdirected into the Decant Pump Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.	A	H	L	L
9.b-5.b	Flow	Misdirected (into Transfer Line Service Box)	<ul style="list-style-type: none"> Valving error such that supernate enters box via IXM water spray nozzles Valving error such that supernate enters box via siphon break 	Uncontrolled Release: If supernate is misdirected into the Transfer Line Service Box, then a splash and splatter/pool release will occur.	A	L	L	L
				Hydrogen Deflagration: If supernate is misdirected into the Transfer Line Service Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.	A	H	L	L
9.b-5.c	Flow	Misdirected (to sand filters)	Valve ECRT-V-201 misaligned	Uncontrolled Release: If supernate is misdirected into the sand filter, then decant pump ECRT-P-201 will deadhead resulting in a high pressure. See Item 9-7 below.	A	L	L	L
9.b-5.d	Flow	Misdirected (into Decant Pump Box IXM water supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the Decant Pump Box IXM water supply, then a splash and splatter/pool release could occur.	A	L	L	L
9.b-5.e	Flow	Misdirected (into Transfer Line Service Box IXM water supply)	Valving error	Uncontrolled Release: If supernate is misdirected into the Transfer Line Service Box IXM water supply, then a splash and splatter/pool release could occur.	LA	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
9.b-5.f	Flow	Misdirected (into flocculant addition supply)	<ul style="list-style-type: none"> Valving error Low pressure in flocculant addition line High pressure in the decant/flocculant recirculation line 	<p>Uncontrolled Release:</p> <p>If supernate is misdirected into the flocculant addition supply, then a splash and splatter/pool release could occur.</p>	A	L	L	L
9.b-7	Pressure	High	<ul style="list-style-type: none"> High air pressure to decant pump ECRT-P-201 A normally-opened valve is closed 	<p>Uncontrolled Release:</p> <p>If the pressure is high, then the decant/flocculant recirculation line or flocculant addition line could fail resulting in an airborne spray release or splash and splatter/pool release.</p>	A	L	L	L
				<p>Hydrogen Deflagration:</p> <p>If the pressure is high, then the decant/flocculant recirculation line could fail. Hydrogen generated by the supernate could accumulate in the Decant Pump Box or Transfer Line Service Box resulting in a deflagration.</p>	A	H	L	L
9.b-13.a	Structural Integrity	Leak/rupture	Decant pump ECRT-P-201 diaphragm failure	<p>Uncontrolled Release:</p> <p>If the decant pump diaphragm failed, then supernate could enter the pump exhaust resulting in a spray or splash and splatter/pool release.</p>	A	L	L	L
9.b-13.b	Structural Integrity	Leak/rupture (decant/flocculant recirculation line)	<ul style="list-style-type: none"> High pressure (see Item 9.b-7 above) Manufacturing flaw Hose connection decouples 	<p>Uncontrolled Release:</p> <p>If the decant/flocculant recirculation line fails, then a spray or splash and splatter/pool release of STSC supernate will occur.</p>	A	L	L	L
				<p>Hydrogen Deflagration:</p> <p>If the leak is large, and recirculated supernate is pumped into the Decant Pump Box or Transfer Line Service Box, then hydrogen generated by the supernate could accumulate in the box resulting in a deflagration.</p>	A	H	L	L
9.b-16	Time Procedure	Skip action	Operator error	<p>Uncontrolled Release:</p> <p>If the decant/flocculant recirculation is not performed, then flocculant will not be added such that the decant transferred to the sand filters will have a high solids concentration. See Item 3.9.a above.</p>	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
9.b-17	Time Procedure	Wrong action (decant instead of recirculate)	Operator error	Uncontrolled Release: If the supernate is decanted instead of recirculated, then decant pump ECRT-P-201 will deadhead resulting in a high pressure. See Item 9.b-7 above.	A	L	L	L
				Hydrogen Deflagration: If the supernate is decanted instead of recirculated, then decant pump ECRT-P-201 will deadhead resulting in a high pressure. See Item 9.b-7 above.	A	H	L	L
10-1	Flow	No	<ul style="list-style-type: none"> Flush tank ECRT-TK-101 not pressurized No water in flush tank ECRT-TK-101 Valve ECRT-AOV-102 or ECRT-AOV-113 fails to open Bladder flush disabled 	Radiological Control: If the autoflush is not performed, then there is a higher probability of significant contamination and higher dose rate during STSC process disconnects.	A	L	L	L
10-2	Flow	Low	<ul style="list-style-type: none"> Low pressure in flush tank ECRT-TK-101 A normally-opened valve is partially closed 	Radiological Control: If the autoflush is not performed, then there is a higher probability of significant contamination and higher dose rate during STSC process disconnects.	A	L	L	L
10-4	Flow	Reverse	Valves ECRT-AOV-102 and open during a slurry transfer	Uncontrolled Release: If there is reverse flow, then sludge could be pumped into the autoflush line resulting in a spray or splash and splatter/pool release.	A	H	L	L
10-7	Pressure	High	<ul style="list-style-type: none"> Operator error Pressure indication reads incorrectly 	Uncontrolled Release: If the pressure is high, then the flush tank or flush line could fail resulting in a release of IXM water will occur.	A	L	L	L
10-10.a	Structural Integrity	Leak/rupture (flush tank, air side)	<ul style="list-style-type: none"> Overpressurization Air fitting leakage 	Radiological Control: If the autoflush is not performed, then there is a higher probability of significant contamination and higher dose rate during STSC process disconnects.	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
10-10.b	Structural Integrity	Leak/rupture (flush tank, water side; autoflush line to valve ECRT-V-102)	<ul style="list-style-type: none"> Overpressurization Valve ECRT-V-112 leaks 	Uncontrolled Release: If the tank fails on the water side, or the autoflush line to valve ECRT-V-102 fails, then a spray or splash and splatter/pool release of IXM water will occur.	A	L	L	L
				Radiological Control: If the autoflush is not performed, then there is a higher probability of significant contamination and higher dose rate during STSC process disconnects.	A	L	L	L
10-10.c	Structural Integrity	Leak/rupture (autoflush line from valve ECRT-V-102 to booster pump skid)	<ul style="list-style-type: none"> Overpressurization Hose disconnects 	Uncontrolled Release: If the autoflush fails between ECRT-V-102 and the booster pump skid, then when valve ECRT-AOV-102 opens, a spray or splash and splatter/pool release of IXM water will occur.	A	L	L	L
10-11.b	Time Procedure	Too soon (inadvertent activation after a transfer)	<ul style="list-style-type: none"> Failure in interlock sequence Loss of power 	Uncontrolled Release: If the autoflush activated after a transfer was complete and the transfer line was disconnected from the STSC and was not isolated, then a splash and splatter/pool release could occur.	A	L	L	L
10-13	Time Procedure	Skip action (autoflush not performed)	Failure in interlock sequence	Radiological Control: If the autoflush is not performed, then there is a higher probability of significant contamination and higher dose rates during STSC process disconnects.	A	L	L	L
11.a-1	Flow	No	<ul style="list-style-type: none"> No IXM water supply from the Skimmer Water Cleanup System A normally-open valve is closed Fluidizing jets are plugged 	Overpressurization: If there is no flow, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If there is no flow, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.a-2	Flow	Low	<ul style="list-style-type: none"> Low IXM water supply flow rate from the Skimmer Water Cleanup System Fluidizing pump ECRT-P-302 not operating Fluidizing pump ECRT-P-302 speed low Valve ECRT-AOV-304 is closed Fluidizing jets are partially plugged A normally open valve is partially closed 	Overpressurization: If the flow is low, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the flow is low, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.a-3	Flow	High	Fluidizing pump ECRT-P-302 speed high	Uncontrolled Release: If the flow rate is sufficiently high, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	A	L	L	L
11.a-4	Flow	Reverse	Siphon from STSC	Uncontrolled Release: If a siphon is created, then liquid would be drawn out of the STSC through the fluidizing jets and discharged at the location of system breach leading to splash and splatter/pool release.	A	L	L	L
11.a-5	Flow	Misdirected (to overfill recovery tool dilution water connection)	Operator error in making hose connections	Overpressurization: If the fluidizing and dilution water hoses are cross-connected, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the fluidizing and dilution water hoses are cross-connected, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.a-6	Pressure	Low	<ul style="list-style-type: none"> Fluidizing pump ECRT-P-302 not operating Fluidizing pump ECRT-P-302 speed low 	Overpressurization: If the pressure is low, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the pressure is low, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.a-7	Pressure	High	<ul style="list-style-type: none"> Fluidizing pump ECRT-P-302 speed high Fluidizing jets are plugged 	Uncontrolled Release: If the fluidizing pump speed is high then the flow rate will be high. If sufficiently high, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release. If the pressure is high, then the fluidizing water line could fail. This would result in a spill of IXM water. If hose ECRT-H-302 failed completely or became disconnected, then liquid could be siphoned from the STSC leading to splash and splatter/pool release.	A	L	L	L
11.a-8	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure (see Item 11.a-7 above) Manufacturing flaw Procurement error Hose connection decouples 	Uncontrolled Release: If the fluidizing water line failed, then there would be a spill of IXM water. If hose ECRT-H-302 failed completely or became disconnected, then liquid could be siphoned from the STSC leading to splash and splatter/pool release.	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.a-9	Time Procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure 	Overpressurization: If the fluidizing jets are operated for too short a period of time, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the fluidizing jets are operated for too short a period of time, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.a-10	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Instrumentation failure 	Uncontrolled Release: If the fluidizing water flow is not terminated and overfill recovery pump ECRT-P-301 is stopped, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	A	L	L	L
11.a-11	Time Procedure	Skip action (fluidizing water valve not opened)	<ul style="list-style-type: none"> Operator error Instrumentation failure 	Overpressurization: If operators do not open fluidizing water valve ECRT-AOV-304, then IXM water will flow to the fluidizing jets via bypass orifice ECRT-FO-301 at a reduced pressure and flow rate. The pressure and flow rate might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If operators do not open fluidizing water valve ECRT-AOV-304, then IXM water will flow to the fluidizing jets via bypass orifice ECRT-FO-301 at a reduced pressure and flow rate. The pressure and flow rate might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.b-1.	Flow	No	<ul style="list-style-type: none"> No IXM water supply from the Skimmer Water Cleanup System A normally-open valve is closed 	Overpressurization: If there is no flow, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization	A	L	L	L
				Hydrogen Deflagration: If there is no flow, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.b-2	Flow	Low	<ul style="list-style-type: none"> Low IXM water supply flow rate from the Skimmer Water Cleanup System A normally open valve is partially closed 	Overpressurization: If the flow is low, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the flow is low, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.b-3	Flow	High	High IXM water supply flow rate from the Skimmer Water Cleanup System	Uncontrolled Release: If the flow rate is sufficiently high, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	A	L	L	L
11.b-4	Flow	Reverse	Siphon from STSC	Uncontrolled Release: If a siphon is created, then liquid would be drawn out of the STSC through the dilution water orifices and discharged at the location of system breach leading to splash and splatter/pool release.	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.b-5	Flow	Misdirected (to overfill recovery tool fluidizing jet connection)	Operator error in making hose connections	Overpressurization: If the fluidizing and dilution water hoses are cross-connected, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the fluidizing and dilution water hoses are cross-connected, then the sludge might not be sufficiently fluidized to achieve the targeted recovery. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.b-6	Pressure	Low	• Low IXM water supply pressure from the Skimmer Water Cleanup System	Overpressurization: If there is dilution water pressure is low then the flow will be low. Fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If there is dilution water pressure is low then the flow will be low. Fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.b-7	Pressure	High	<ul style="list-style-type: none"> High IXM water supply pressure from the Skimmer Water Cleanup System 	<p>Uncontrolled Release:</p> <p>If the pressure is high then the flow rate will be high. If sufficiently high, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p> <p>If the pressure is high, then the dilution water line could fail. This would result in a spill of IXM water.</p> <p>If hose ECRT-H-301 failed completely or became disconnected, then liquid could be siphoned from the STSC leading to splash and splatter/pool release.</p>	A	L	L	L
11.b-8	Structural Integrity	Leak/rupture	<ul style="list-style-type: none"> High pressure (see Item 11.b-7 above) Manufacturing flaw Procurement error 	<p>Uncontrolled Release:</p> <p>If the dilution water line failed, then there would be a spill of IXM water.</p> <p>If hose ECRT-H-301 failed completely or became disconnected, then liquid could be siphoned from the STSC leading to splash and splatter/pool release.</p>	A	L	L	L
11.b-9	Time Procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Overpressurization:</p> <p>If the dilution water flow is terminated early, fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.</p>	A	L	L	L
				<p>Hydrogen Deflagration:</p> <p>If the dilution water flow is terminated early, fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.</p>	A	H	L	L
11.b-10	Time Procedure	Too long	<ul style="list-style-type: none"> Operator error Instrumentation failure 	<p>Uncontrolled Release:</p> <p>If the dilution water flow is not terminated and overfill recovery pump ECRT-P-301 is stopped, then eventually the STSC will be overfilled and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p>	A	L	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.b-11	Time Procedure	Skip action (dilution water valve not opened)	• Operator error	Overpressurization: If operators do not open dilution water valve ECRT AOV-706, then there will be no dilution water. Fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If operators do not open dilution water valve ECRT AOV-706, then there will be no dilution water. Fluidizing jet water alone might be sufficient to achieve the targeted recovery. However, the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.c-1	Flow	No	<ul style="list-style-type: none">• Overfill recovery pump ECRT-P-301 not operating• A normally opened valve is closed• Overfill recovery tool rupture disk fails to rupture• Overfill recovery tool or discharge line plugged	Uncontrolled Release: If there is no flow, then the STSC will eventually be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	A	L	L	L
				Overpressurization: If there was no flow, then there would be no overfill recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If there was no flow, then there would be no overfill recovery. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.c-2	Flow	Low	<ul style="list-style-type: none">• Low air pressure to overfill recovery pump ECRT-P-301• A normally open valve is partially closed	Uncontrolled Release: If the flow rate is sufficiently low, then eventually the STSC will be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	A	L	L	L
				Overpressurization: If the flow rate is low, then sludge could settle out and plug the line. If the line plugs, then there would be no overfill recovery. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the flow rate is low, then sludge could settle out and plug the line. If the line plugs, then there would be no overfill recovery. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.c-3	Flow	High	High air pressure to overfill recovery pump ECRT-P-301	Overpressurization: If the flow was high, then the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the flow was high, then the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.c-4	Flow	Reverse	Overfill recovery flush valve open	<p>Uncontrolled Release:</p> <p>If overfill recovery flush valve ECRT-AOV-103 is open, then 100 gpm of IXM water at 100 psi will enter the overfill recovery discharge line upstream of overfill recovery pump ECRT-P-301. As ECRT-P-301 pumps 70 gpm, approximately 30 gpm of IXM water would reverse flow to the STSC. Eventually the STSC would be overfilled and slurry would overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p>	A	L	L	L
11.c-7	Pressure	High	Line or valve closed plug during flushing	<p>Uncontrolled Release:</p> <p>If the pressure is high, then the overfill recovery tool discharge line could fail resulting in an airborne spray or splash and splatter/pool release.</p> <p>(Note: the consequences are qualitatively judged to be low based on the limited volume of slurry and relatively low pressure (i.e., 130 psi) at which a spray release would occur.</p>	A	L	L	L
11.c-8	Structural integrity	Leak/rupture	<ul style="list-style-type: none"> • Manufacturing flaw • Procurement error • Hose connection decouples 	<p>Radiological Control:</p> <p>If there is a leak in the overfill recovery discharge line, then air will be drawn into the flow stream. This would result in air bubbles in the KW Basin.</p>	A	L	L	L
				<p>Uncontrolled Release:</p> <p>If overfill recovery discharge hose ECRT-H-306 decouples at the transfer line service box and drops below the liquid level in the STSC, then a siphon would be created. Liquid would be drawn out of the STSC.</p>	A	L	L	L
11.c-9	Time procedure	Too short	<ul style="list-style-type: none"> • Operator error • Instrumentation failure • Overfill recovery pump failure 	<p>Overpressurization:</p> <p>If the recovery operation occurs for too short a period of time, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.</p>	A	L	L	L
				<p>Hydrogen Deflagration:</p> <p>If the recovery operation occurs for too short a period of time, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.</p>	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.c-11	Time Procedure	Skip action (overflow recovery pump not started)	Operator error	Uncontrolled Release: If operators do not start overflow recovery pump ECRT-P-301, then there will be no flow. If there is no flow then the STSC will eventually be overfilled with IXM water from the overflow recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	A	L	L	L
				Overpressurization: If the operators do not start overflow recovery pump ECRT-P-301, then there would be no overflow recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the operators do not start overflow recovery pump ECRT-P-301, then there would be no overflow recovery. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.d-1	Flow	No	<ul style="list-style-type: none"> • Overflow recovery pump ECRT-P-301 not operating • A normally opened valve is closed • Overflow recovery tool rupture disk fails to rupture • Overflow recovery tool or discharge line plugged 	Uncontrolled Release: If there is no flow, then the STSC will eventually be overfilled with IXM water from the overflow recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	A	L	L	L
				Overpressurization: If there was no flow, then there would be no overflow recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If there was no flow, then there would be no overflow recovery. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.d-2	Flow	Low	<ul style="list-style-type: none"> Low air pressure to overfill recovery pump ECRT-P-301 A normally open valve is partially closed 	Uncontrolled Release: If the flow rate is sufficiently low, then eventually the STSC will be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	A	L	L	L
				Overpressurization: If the flow rate is low, then sludge could settle out and plug the line. If the line plugs, then there would be no overfill recovery. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the flow rate is low, then sludge could settle out and plug the line. If the line plugs, then there would be no overfill recovery. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.d-3	Flow	High	High air pressure to overfill recovery pump ECRT-P-301	Overpressurization: If the flow was high, then the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the flow was high, then the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.d-5.a	Flow	Misdirected (to booster pump)	Operator error	Uncontrolled Release: If the flow is misdirected to booster pump ECRT-P-101, then overfill recovery pump ECRT-P-301 will deadhead resulting in high pressure in the transfer line. The high pressure could result in a transfer line failure resulting in an airborne spray or splash and splatter/pool release.	A	H	H	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.d-5.d	Flow	Misdirected (into STSC)	Valve ECRT-V-102 positioned incorrectly	<p>Uncontrolled Release:</p> <p>If valve ECRT-V-102 is positioned incorrectly, then the recovered sludge would be directed back to the STSC. Eventually the STSC will be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p>	A	L	L	L
11.d-6	Pressure	Low	Low air pressure to overfill recovery pump ECRT-P-301	<p>Uncontrolled Release:</p> <p>If the pressure is low, then the flow rate will be low. If the flow rate is sufficiently low, then eventually the STSC will be overfilled with IXM water from the overfill recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.</p>	A	L	L	L
				<p>Overpressurization:</p> <p>If the pressure is low, then the flow rate will be low. Sludge could settle out and plug the line. If the line plugs, then there would be no overfill recovery. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.</p>	A	L	L	L
				<p>Hydrogen Deflagration:</p> <p>If the pressure is low, then the flow rate will be low. Sludge could settle out and plug the line. If the line plugs, then there would be no overfill recovery. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.</p>	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.d-7	Pressure	High	<ul style="list-style-type: none"> High air pressure to overfill recovery pump ECRT-P-301 A normally-opened valve is closed Transfer line plugged 	Uncontrolled Release: If the pressure is high, then transfer line could fail resulting in an airborne spray or splash and splatter/pool release	A	H	H	H
				Overpressurization: If the pressure high, then the flow rate will be high. If the flow rate is high, then the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the pressure high, then the flow rate will be high. If the flow rate is high, then the overfill recovery tool could plug. If the plug could not be cleared, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L
11.d-8	Structural integrity	Leak/rupture (transfer line)	<ul style="list-style-type: none"> High pressure (see Item 7 above) Pulsation damper failure Manufacturing flaw Procurement error External event 	Uncontrolled Release: If the overfill recovery tool discharge line fails, then there will be an airborne spray or splash and splatter/pool release.	A	H	H	L
11.d-9	Structural Integrity	Leak/rupture (pump diaphragm)	<ul style="list-style-type: none"> Erosion Manufacturing flaw Procurement error 	Uncontrolled Release: If the pump diaphragm fails, then sludge could enter the overfill recovery pump exhaust resulting in a spray or splash and splatter/pool release.	A	L	L	L
11.d-10	Time procedure	Too short	<ul style="list-style-type: none"> Operator error Instrumentation failure Overfill recovery pump failure 	Overpressurization: If the recovery operation occurs for too short a period of time, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the recovery operation occurs for too short a period of time, then the targeted recovery would not be achieved. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L

Table D-1. Frequency and Consequence Levels

Item	Process Parameter	Deviation	Cause	Hazardous Condition	Unmitigated Frequency	Unmitigated Consequences		
						FW	Onsite	Offsite
11.d-12	Time Procedure	Skip action (overflow recovery pump not started)	Operator error	Uncontrolled Release: If operators do not start overflow recovery pump ECRT-P-301, then there will be no flow. If there is no flow then the STSC will eventually be overfilled with IXM water from the overflow recovery tool and slurry will overflow into the 4-in and 1-in. ventilation exhaust lines, and into the 1-in. ventilation inlet line, leading to a splash and splatter/pool release.	A	L	L	L
				Overpressurization: If the operators do not start overflow recovery pump ECRT-P-301, then there would be no overflow recovery. In an unmitigated scenario, exceeding the sludge limits could result in STS cask overpressurization.	A	L	L	L
				Hydrogen Deflagration: If the operators do not start overflow recovery pump ECRT-P-301, then there would be no overflow recovery. In an unmitigated scenario, exceeding the sludge limits could result in a hydrogen deflagration.	A	H	L	L

APPENDIX E
PEER REVIEW

CHPRC REVIEW CHECKLIST

Document Reviewed:

PRC-STP-00467 Rev 0, SLUDGE TREATMENT PROJECT ENGINEERED CONTAINER RETRIEVAL AND TRANSFER SYSTEM PRELIMINARY DESIGN HAZARD AND OPERABILITY STUDY

Scope of Review:

Peer Review of Document

Yes	No	N/A	
☐	☐	☒	* Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐	Problem completely defined.
☒	☐	☐	Accident scenarios developed in a clear and logical manner.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☐	☐	☒	Computer codes and data files documented.
☐	☐	☒	Data used in calculations explicitly stated in document.
☐	☐	☒	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivation checked including dimensional consistency of results.
☐	☐	☒	Models appropriate and used within range of validity or use outside range of established validity justified.
☐	☐	☒	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
☐	☐	☒	Software input correct and consistent with document reviewed.
☐	☐	☒	Software output consistent with input and with results reported in document reviewed.
☒	☐	☐	Limits/criteria/guidelines applied to analysis results are appropriate and referenced.
☐	☐	☒	Limits/criteria/guidelines checked against references.
☐	☐	☒	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
☒	☐	☐	* Format consistent with appropriate NRC Regulatory Guide or other standards.
☒	☐	☐	Review calculations, comments, and/or notes are attached.
☐	☐	☒	For calculations in which codes/spreadsheets (e.g., RADDOSE, GENII, etc) are used, is the latest revision used? Is the User Authorized?
☒	☐	☐	Document approved.

Robert Meichle *Robert Meichle*
Reviewer (Printed Name and Signature)

7/1/2011
Date

*Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

Attachment to CHPRC Review Checklist

Peer Review of PRC-STP-00467 Rev 0

**Sludge Treatment Project Engineered Container Retrieval and Transfer System
Preliminary Design Hazard and Operability Study**

Problem completely defined. – Hazard analysis consistent with ECRTS Process Description, ECRTS Process Flow Diagram and ECRTS P&ID.

Accident scenarios developed in a clear and logical. – HAZOP methodology appropriate for system evaluation. Method is consistent with HAZOP description in *Guidelines for Hazard Evaluation Procedures* (by the American Institute of Chemical Engineers). Analyses provide unmitigated hazardous conditions that are to be used for future accident analysis and developed in a clear and logical manner.

Necessary assumptions explicitly stated and supported. – Reference Flow Diagram and P&IDs, operational modes, and normal operating conditions consistent with preliminary design provided.

Limits/criteria/guidelines applied to analysis results are appropriate and referenced.

Limits/criteria/guidelines checked against references. – The frequency and consequence guidelines from PRC-STD-NS-8739 (SARAH) as modified by DOE-STD-1189 are provided and their application is appropriate. Guidelines have been checked against references.

Conclusions consistent with analytical results and applicable limits. – The results of the hazards evaluation are consistent with the HAZOP and applicable limits.

Results and conclusions address all points required in the problem statement. – Results and conclusions address all of the preliminary design ECRTS operations. An unmitigated hazard analysis was conducted and natural phenomena hazards were considered.

Format consistent with appropriate NRC Regulatory Guide or other standards. – Format is consistent with requirements and guidance of PRC-PRO-NS-700 and PRC-STD-NS-8739.