11.2 Liquid Waste Management System

The liquid waste management system (LWMS) is designed to monitor, control, collect, process, handle, store, and dispose of liquid radioactive waste generated during normal plant conditions, including anticipated operational occurrences (AOOs) based on NRC RG 1.143 (Reference 1) and NUREG-0017 (Reference 2). The radionuclide concentration of liquid effluent releases at the site discharge point during normal operation including AOOs is below the radionuclide concentration limit in 10 CFR 20, Appendix B (Reference 3), and complies with ALARA criteria of 10 CFR 50, Appendix I (Reference 4) based on the use of industry-proven technologies incorporated into the design. The design also incorporates segregation of liquid waste collection and processing to provide reasonable assurance that the treatment and release objectives are met.

The lessons learned program provides guidance on integrating industry, operating, and construction experience into the APR1400 design. Under this program, NRC generic communications and industry operating and construction experience are maintained in a database that is reviewed, assessed, and integrated into the design as appropriate. The construction and operating experience of nuclear power plants has been incorporated into the database for design improvement.

The LWMS is divided into the following major subsystems:

a. Floor drain subsystem

b. Equipment waste subsystem

c. Chemical waste subsystem

d. Detergent waste subsystem

The radiation level in the processed liquid is verified by radiation monitors prior to release to the environment. Process sampling and effluent radiation monitoring systems are described in Section. 11.5.

11.2.1 Design Bases

11.2.1.1 Design Objectives

The liquid waste management system (LWMS) meets the following design objectives:

a. Capability to process floor drain wastes, equipment wastes, chemical wastes, and detergent wastes to meet release radionuclide concentration limits in accordance with 10 CFR 20, Appendix B (Reference 3), prior to discharge to the environment

b. Capability to recycle treated water in order to minimize the liquid radwaste effluent releases to the environment

c. Capability to segregate the liquid waste streams by the use of separate waste drain headers and waste collection sumps or tanks for each waste stream category

d. Capability to store, sample, and analyze processed liquid to confirm compliance to the release limits prior to the discharge being released to the environment or returned to the waste collection tank for further treatment

e. Capability to prevent unplanned discharges of processed liquid by the use of an administratively controlled discharge valve

f. Capability to provide early detection of leaks and overflows in accordance with NRC RG 4.21 (Reference 5)

11.2.1.2 Design Criteria

The design criteria of LWMS are as follows:

a. The LWMS provides sufficient capacity, redundancy, and flexibility to treat liquid radwaste in order to reduce the radionuclide concentration to the concentration limit of effluents in 10 CFR 20, Appendix B (Reference 3), during equipment downtime and during operation at design basis fission product leakage levels (leakage from fuel producing 1 percent of the reactor power).

b. The LWMS is designed so that releases of radioactive materials to the environment are controlled and monitored in accordance with General Design Criteria (GDC) 60 (Reference 6), GDC 61 (Reference 7) and GDC 64 (Reference 8). Offsite radiation doses measured on an annual basis resulting from the effluents during normal operation and anticipated operational occurrences (AOOs) are maintained within the limits of 10 CFR 50, Appendix I (Reference 4). The release is controlled in accordance with 10 CFR 50.34a (Reference 9).

c. The LWMS is designed with adequate storage capabilities for normal operation, including AOOs, in accordance with ANSI 55.6 (Reference 10), and the capability to connect to and return liquid waste from the mobile liquid waste processing system to accommodate and treat anticipated waste surge volumes. The interconnections between plant systems and mobile liquid waste processing equipment are designed to avoid the contamination of nonradioactive systems and uncontrolled releases of radioactivity to the environment. This design feature meets the requirements of IE Bulletin No. 80-10 (Reference 11).

   The LWMS is designed with hard piping between radioactive and non-radioactive systems in accordance with IE Bulletin 80-10 (Reference 11). Chemical addition piping for pH adjustment is provided with hard piping, and demineralized water is provided for flushing pipe after each transfer of contaminated fluid. These connections are hard pipes and are equipped with double barriers to prevent unintended contamination in accordance with NRC RG 4.21 (Reference 5).

d. The LWMS is not designed for abnormal or accident plant conditions but is designed to hold up and process the liquid wastes generated during normal conditions and AOOs.

e. Design features are included to reduce equipment maintenance, equipment downtime, and leakage of radioactive liquid into the building atmosphere using industry-proven components as specified in NRC RG 1.143 (Reference 1), Figure 2. Table 11.2-7 provides the equipment codes for design and construction as required in Table 1 of NRC RG 1.143 (Reference 1). The structure, system, and components (SSCs) of the LWMS are classified in accordance with the safety classification process described in NRC RG 1.143 (Reference 1), Figure 2, which includes RW-IIa, RW-IIb, and RW-IIc. The SSCs are designed in compliance

with the applicable codes and standards and the guidelines in NRC RG 1.143 (Reference 1). The seismic design criteria and quality group classification applicable to the design of the LWMS are described in Section 3.2. The LWMS design is in compliance with ANSI/ANS 55.6 (Reference 10).

f. Each waste collection tank and monitor tank is provided with an overflow connection at least as large as the inlet. The location of the overflow is above the high-level alarm setpoint. Each cubicle housing these tanks is coated with an impermeable epoxy liner (coating), up to the top of cubicle wall, to facilitate decontamination of the facility in the event of tank leakage and failure. Epoxy coatings in cubicles are Service Level II coatings as defined in NRC RG 1.54 (Reference 12). This design feature, in conjunction with early leak detection, drainage, and transfer capabilities, serves to minimize the release of the radioactive liquid to the groundwater and environment in accordance with Branch Technical Position (BTP) 11-6 (Reference 13), 10 CFR 20.1406 (Reference 14), and NRC RG 4.21 (Reference 5).

g. Each LWMS tank is provided with vent piping that is terminated at the vicinity of inlet duct of the heating, ventilation, and air conditioning (HVAC) system in the compound building. The HVAC system in the compound building is described in Subsection 9.4.7.

h. The LWMS is designed in compliance with ALARA principle for occupational doses as described in NRC RG 8.8 (Reference 15). Sufficient shielding is provided for all equipment in the radiation controlled area (RCA) to prevent unacceptable radiation exposure.

i. The LWMS is designed to provide two radiation monitors in the discharge line inside the compound building. When a predetermined setpoint is exceeded, the monitors generate alarm signals in the radwaste control room that close the discharge line isolation valves to prevent release if either monitor detects activity in excess of the preset or equipment malfunctions during the release. If the isolation valves are closed, the LWMS is designed with enough redundancy and capacity to operate without discharging until the alarm condition is resolved. Administrative control of the lock-closed release path adds additional confidence that operator error is not to cause inadvertent discharges of liquid waste that

contains activity in excess of the limits for release. Offsite effluent concentration and radiation doses to the public, which are measured on annually, are within the limits of 10 CFR 20, Appendix B (Reference 3), and 10 CFR 50, Appendix I (Reference 4), respectively.

j. The quality assurance (QA) program for the design, installation, procurement, and fabrication of LWMS components complies with Regulatory Position C.7 of NRC RG 1.143 (Reference 1) and NRC RG 1.33 (Reference 16). Table 3.2-1 in this Design Control Document (DCD) identifies the seismic category, quality group, and safety class for components of the LWMS. The QA program is designed in accordance with ANSI/ANS 55.6 (Reference 10).

k. The LWMS is designed to operate continuously during normal operating condition and AOOs. For equipment sizing and process capability determination, the LWMS is designed to store and process the maximum design basis input in 1 day. The LWMS includes six waste collection tanks (378,500 L [100,000 gal gross volume]) and two reverse osmosis (R/O) packages, each with 227 L/min (60 gpm) of processing capacity. Additionally, the LWMS contains two monitor tanks (102,206 L [27,000 gal] gross volume each) that hold the treated water prior to discharge. The equipment capacities of LWMS are listed in Table 11.2-6.

l. The LWMS is designed and tested to the codes and standards listed in Table 11.2-7 in accordance with Regulatory Positions C.1.1.1 and C.4 of NRC RG 1.143 (Reference 1).

m. The LWMS is subjected to the design objectives of NRC RG 4.21 (Reference 5) because it contains radioactive liquid from the plant. The required design and operational objectives of NRC RG 4.21 (Reference 5) are addressed in Section 12.3. The LWMS features and programs that meet these objectives are described in Subsection 11.2.2.4.

n. The plant is designed in accordance with applicable codes. The quality assurance procedure (QAP) provides reasonable assurance that the plant is built, maintained, and operated in accordance with U.S. government codes and regulations. The design and QAP demonstrate conformance with10 CFR 20.1406 (Reference 14).

o. In accordance with ANSI/ANS-55.6 (Reference 10), the portions of the compound building that house the principal LWMS equipment are designed to contain the liquid inventory in the event of an operating-basis earthquake (OBE).

p. Filters and tanks in the LWMS, except for the micro-filtration unit, are designed as atmospheric tanks with vents opening into the cubicles and operating at ambient conditions without heat generation or vacuum drawing device. The micro-filtration unit is designed to use a vacuum-drawing device equipped with a rupture disc and relief valve.

11.2.1.3 Method of Treatment

The LWMS provides for the segregated collection of floor drainage, equipment drainage, chemical drainage, and detergent drainage and has permanently installed equipment to store and treat the influent and allow sampling of the contents in the waste collection tanks and monitor tanks. The results of the sample analysis are used to confirm whether the treatment requirements and product specifications are met. Process equipment such as the R/O package contains a pretreatment module that removes suspended solids, oil, and organic contaminants; an R/O module that removes soluble salts and radioactive ions from the waste passing through pretreatment module; and a demineralizer module that removes the radionuclides from the R/O permeate.

Detergent wastes from personnel decontamination showers and detergent-type decontamination solutions drainage are unlikely to have high radioactivity. The detergent waste is collected, filtered, and released through a monitored pathway. In the unlikely event that the radionuclide concentration is above a setpoint, the detergent waste is diverted to the chemical waste tank (CWT) for additional processing.

Depending on site-specific requirements, the COL applicant is to determine whether contaminated laundry is sent to an offsite facility for cleaning or for disposal (COL 11.2(1)).

Tanks are equipped with high-level and high-high level alarms that alert operators to minimize the potential for overflow. If an operator action is not taken, the overflow over the high-high level can be directed to the other storage tank through the cross connections.

11.2.1.4 Radioactive Source Terms in LWMS

Radioactive sources in the radwaste systems include fission and activation radionuclides produced in the core and the reactor coolant. The radioactive source terms in each LWMS component are determined using the DIJESTER Computer Code (Reference 17).

The DIJESTER Code (Reference 17) determines radionuclide inventories and concentrations by solving the differential equations of flow through the component, taking into account of the flow rate, liquid source concentrations, decontamination factors, process time, equipment volume, and decay constant.

Each of the three liquid radwaste streams (chemical waste, floor drain waste, and equipment waste) has several input flows, and each input has a different source concentration. The main flow paths of the liquid radwaste system are shown in Figure 11.2-1. The COL applicant is to provide the piping and instrumentation diagrams (P&IDs) (COL 11.2(2)). The specific activities for each radwaste stream are determined with a fraction of primary coolant activity.

For the purposes of the radioactivity calculation, resin beds in the LWMS demineralizers are assumed to have a service life of 1 year. Although the service life of filters and resins in the LWMS may vary according to the operational conditions, filters and resins are replaced based on the source term strength to provide reasonable assurance that occupational exposures associated with radwaste system operations remain ALARA. The decontamination factors used in the source term calculations are presented in Table 11.2-3. The expected radioactive inventories in LWMS components are provided in Tables 11.2-11 and 11.2-12.

The structure and components of the LWMS are classified according to the safety classification guidance in NRC RG 1.143 (Reference 1). Analyses are performed based on the method given in Figure 2 of NRC RG 1.143 (Reference 1). For conservative analysis, the radiological impact is assumed to be greater than the criteria of either 5 mSv at the unprotected area boundary or 0.05 Sv to facility personnel within the protected boundary. The facility is then considered RW-IIa.

The radioactive inventories in the LWMS components are determined based on 1 percent fuel defect and compared with the A1 and A2 values in Appendix A of 10 CFR 71

(Reference 18). If the radioactivity inventories of a component exceed the A1 quantities, the component is classified as RW-IIa. If the radioactivity inventories are less than A1 quantities and greater than A2 quantities, the component is classified as RW-IIb. All other components are classified as RW-IIc. The results are shown in Table 11.2-6.

11.2.1.5 Site Cost-Benefit Analysis

The cost-benefit analysis approach stipulated by Paragraph II.D of 10 CFR 50, Appendix I (Reference 4) requires that a population dose analysis be performed to demonstrate that the LWMS is designed in accordance with the ALARA criterion.

Because of the extreme site-specific nature of population dose analyses, the cost-benefit analysis is deferred to site-specific environmental reports.

The COL applicant is to perform a site-specific cost-benefit analysis to demonstrate compliance with the regulatory requirements of NRC RG 1.110 (COL 11.2(3)) (Reference 19).

11.2.1.6 Mobile or Temporary Equipment

The LWMS is designed with permanently installed equipment. The LWMS does not include mobile or temporary equipment. Considering the future use of mobile or temporary equipment in accordance with site-specific requirements, the LWMS provides connections for mobile equipment.

The COL applicant is to determine that the use of mobile or temporary equipment and interconnections to plant systems conform to regulatory requirements and guidance such as 10 CFR 50.34a, 10 CFR 20.1406 and NRC RG 1.143 (COL 11.2(4)) (References 9, 14, and 1).

The COL applicant is responsible for the identification of mobile/portable LWMS connections that are considered non-radioactive but may later become radioactive through contact with or contamination by radioactive systems and for the preparation of operating procedures for mobile/portable LWMS connections in conformance with the guidance and

information in Inspection and Enforcement (IE) Bulletin 80-10 (COL 11.2(4)) (Reference 11).

11.2.2 System Description

The LWMS manages liquid wastes generated by the plant during normal operation including AOOs. The boundary of the LWMS starts at the interface valves for each of the input streams potentially containing radioactive material from other plant systems as shown in Figure 11.2-1. For many of these streams, the boundary of the LWMS starts at the respective building sump discharge line. The boundary of the LWMS ends at the isolation valve of the discharge lines to a tank or the discharge header.

The LWMS consists of the following three main subsystems, which are based on characteristics of input streams: equipment waste, floor drain, and chemical waste. The subsystems have six waste collection tanks, six waste collection tank pumps, two reverse osmosis (R/O) packages, two monitor tanks, and two monitor tank pumps to collect treated fluid for analysis. The waste collection tanks (WCTs) and monitor tanks and their associated pumps are located in the compound building. The R/O packages in the compound building are at elevations of 63 ft 0 in and 85 ft 0 in.

The detergent waste subsystem included in the LWMS has two detergent waste tanks, two detergent waste tank pumps, and one filter. The detergent waste tanks and their associated pumps are in the compound building at El. 63 ft 0 in.

Figure 11.2-1 shows a process flow diagram of the LWMS. For the purpose of this DCD, process flow diagrams with process equipment and key control instrumentation are provided to indicate process design, method of operation, and release monitoring.

Inputs to the LWMS include the following:

a. Equipment drainage

b. Floor drainage

c. Chemical drainage

d. Detergent drainage

For a more detailed discussion of the drainage systems, refer to Subsection 9.3.3. Table 11.2-2 includes the inputs to the LWMS. The inputs are taken from ANSI/ANS 55.6, Table 7 (Reference 10). LWMS components are described in Subsection 11.2.2.3 and their data are listed in Table 11.2-6.

The annual average release of nuclides from the plant is determined using the guidance of NUREG-0017 (Reference 2) and NRC RG 1.112 (Reference 20). The code input parameters that are used are provided in Table 11.2-2. Associated projected annual releases are provided in Table 11.2-1. Components and structures of the stated systems are not under adverse vacuum conditions because there are no existing vacuum conditions from component operations.

11.2.2.1 Liquid Waste Processing System Operation

11.2.2.1.1 Waste Input Streams

Sources of radioactive liquid wastes include the following:

a. Floor drain wastes, including but not limited to the reactor containment and auxiliary building floor drains and compound building drains

b. Equipment wastes, including but not limited to the auxiliary building equipment drains

c. Chemical wastes, including but not limited to the radiochemistry laboratory, fuel handling area, and equipment decontamination drains

d. Detergent wastes, including but not limited to the wastes from the personnel decontamination station and detergent-type decontamination solutions, which occur in the unlikely event of high radioactivity surpassing the effectiveness of the detergent waste filter

e. All of the potentially radioactive waste streams, such as the auxiliary steam condensate receiver tanks, steam generator blowdown water, and condensate polishing area sump if they are contaminated so that they cannot meet the applicable regulatory discharge criteria prior to discharge to the environment

11.2.2.1.2 Waste Collection and Storage

The LWMS is not designed for abnormal or accident plant conditions, but the LWMS may hold up the liquid wastes generated during normal conditions and anticipated operational occurrences.

Input to the LWMS is divided into four process trains: floor drain, equipment waste chemical waste, and detergent waste. Wastes are segregated according to the processing.

Floor drains, including but not limited to the reactor containment and auxiliary building floor drains and compound building drains, are routed to the floor drain train and processed in the R/O package.

Equipment wastes, including but not limited to the auxiliary building equipment drains, are routed to the equipment waste train where wastes are processed by the R/O package.

Chemical wastes, including but not limited to the high-level laboratory, low-level laboratory, fuel handling area, and equipment decontamination drains, are directed to the chemical waste train where wastes are normally processed by the R/O package.

Two floor drain tanks and two equipment waste tanks are cross connected by the common header and overflow piping on each tank. During normal operation, the various inputs from equipment waste and floor drain headers are separated and collected in the relevant radwaste tank.

Two chemical waste tanks receive the influent from a common inlet header. Normally, one tank is filled while the other is on standby. Tanks are also equipped with cross-connected and overflow piping. The chemical waste tank also collects borated waste from the boric acid concentrator in the chemical and volume control system.

The chemical drain sump in the auxiliary building collects chemical wastes from the power block and transfers it to the chemical waste tanks in the compound building.

Two detergent waste tanks receive detergent wastes, including but not limited to the wastes from personal decontamination stations and detergent-type decontamination solutions. These wastes are usually discharged directly to the plant discharge channel, but when they are not adequately processed by the detergent waste filter, they are routed to the chemical waste tanks where wastes are processed by the R/O package.

11.2.2.1.3 Waste Sampling

The waste sampling process is similar for all LWMS tanks including the detergent waste tanks. Once a tank is filled, the operator initiates the recirculation/mixing mode by aligning the appropriate valves and starting the pump.

Obtaining a representative sample involves recirculating the tank contents and mixing the equivalent of one or more tank volumes using mixing eductor as described in Subsection 11.2.2.3.1 depending on the type of influent waste and size of the tank.

Once adequate mixing has been achieved, a sample is taken while the pumps are running using the sample connection provided on the recirculation piping. A sample of the liquid waste, except detergent waste, is taken at the sample panel of the process sampling system. The sample of detergent waste is taken at the grab sample sink. The samples are analyzed for chemical composition, gross gamma activity, and pH at the sample laboratory in the compound building.

11.2.2.1.4 Chemical Addition

Following the sample analysis, the operator determines the amount and type of chemicals to be added to the tank. Through permanently piped connections to the equipment waste tanks, floor drain tanks, and chemical waste tanks, acid, caustic, and anti-foam agents can be added to the tanks using metering pumps as necessary.

The chemicals are then mixed with the tank contents using the recirculation/mixing mode, followed by sampling and further chemical addition, if necessary. This process is repeated until the tank contents meet the required fluid chemistry specifications.

11.2.2.1.5 Monitoring and Discharge

LWMS monitor tanks collect liquid processed through the R/O package. Following the sample analysis, the operator determines where the contents of the monitor tank are to be transferred. If the water quality and radionuclide concentrations of the contents in the monitor tank meet the holdup tank requirements, and the plant load following operation is not affected due to the recycle operation, the contents of the monitor tank are transferred to the holdup tanks for plant reuse, or if suitable for offsite release, the contents of the monitor tank are discharged to the offsite release point.

The effluent in the monitor tank is monitored by two radiation monitors prior to dilution in the offsite release point. When radioactivity or other contamination is monitored in the contents of monitor tank, it is transferred to the R/O package for further processing.

11.2.2.2 Liquid Waste Processing System Operation

The LWMS is designed to operate with a tank-to-tank manual batch operation according to the plant condition. Therefore, the LWMS is designed with the high degree of flexibility illustrated on the piping and instrumentation diagrams (P&IDs).

Floor drain and equipment waste are routed to the R/O package. Normally, chemical waste is processed by the R/O package and discharged to the monitor tanks. On the downstream of the chemical waste pumps, there is a provision to connect a mobile chemical waste treatment system that processes the mixed liquid wastes and boric acid concentrates.

The liquid waste processing system has two R/O packages. Each R/O package has four modules: pre-treatment, R/O, demineralizer, and concentrate feed.

The liquid wastes collected in the floor drain tanks, equipment waste tanks, and chemical waste tanks are first passed through a pre-treatment module in which all of the impurities are removed to maintain optimal performance of the R/O module. The passed water is

routed to the R/O module for removal of soluble species. R/O permeate from the R/O module is processed by the demineralizer module for final polishing and then transferred to the monitor tank.

11.2.2.3 Component Description

Component design data of the LWMS are listed in Table 11.2-6. The component design data include equipment flow rates and capacity, construction materials, and design temperatures and pressures. The codes and standards that are applicable to the LWMS components are listed in Table 11.2-7 and are consistent with codes and standards in NRC RG 1.143, Table 1 (Reference 1).

11.2.2.3.1 Tanks

The equipment waste tank is a vertical, cylindrical type. Two tanks are provided in the LWMS and normally receive wastewater with low total dissolved solids (TDS), which has a high radioactivity level in the auxiliary building. The equipment waste tanks are used as backups for the floor drain tanks whenever needed.

The floor drain tank is a vertical, cylindrical type. Two tanks are provided in the LWMS and normally receive wastewater with high TDS, which has a low radioactivity level in the reactor containment building, auxiliary building, compound building, and turbine building.

The chemical waste tank is a vertical, cylindrical type. Two tanks are provided in the LWMS and receive influent from a common inlet header. Normally, one tank is filled while the other is on standby. Tanks are also equipped with cross-connect and overflow piping. The chemical waste tank also collects borated waste from the boric acid concentrator in the chemical and volume control system.

The detergent waste tank is a vertical, cylindrical type. Two detergent waste tanks are provided in the detergent waste system. When one of the two detergent waste tanks is filled, the operator directs the influent to the other empty tank. The tank is sized to accommodate the expected daily peak volume of wastes.

The monitor tank is a vertical, cylindrical type. Two monitor tanks are provided in the LWMS. The monitor tanks are the only tanks in the LWMS from which the processed waste can be released to the environment or returned to the plant for reuse.

Eductors are used in order to provide reasonable assurance of adequate mixing in the tanks.

The acid storage tank is a vertical, cylindrical type and stores sulfuric acid (H_2SO_4). The caustic storage tank is a vertical, cylindrical type and stores sodium hydroxide (NaOH). The chemical additive tank is a vertical, cylindrical type. In the chemical additive tank, the anti-form or flocculant is mixed with demineralized water. The acid batch tank is a horizontal, cylindrical type. In the acid batch tank, the H_2SO_4 from the acid storage tank is diluted before the chemicals are sent to the waste collection tank. The caustic batch tank is a horizontal, cylindrical type. In the caustic batch tank, the NaOH from the caustic storage tank is diluted before the chemicals are sent to the waste collection tank. The seal water storage tank is a vertical, cylindrical type, and stores radwaste water pump seal water.

The construction material for all tanks in the LWMS is stainless steel except for the acid batch tank, which is constructed of Incoloy 825 material.

The cells/cubicles housing tanks that contain significant quantities of radioactive material are coated with epoxy to a height that is sufficient to hold the tank contents in the event of tank failure. The coatings are Service Level II as defined in NRC RG 1.54 (Reference 12) and are subject to the limited QA provisions, selection, qualification, application, testing, maintenance, and inspection provisions and referenced standards of NRC RG 1.54 (Reference 12), as applicable to Service Level II coatings. Post-construction initial inspection is performed by personnel qualified in ASTM D 4537 (Reference 21) and according to the inspection plan guidance of ASTM D 5163 (Reference 22). Level-detecting instrumentation measuring the current tank inventories is provided. High- and low-level alarms are provided. The alarms are annunciated in the radwaste control room and also in the MCR.

11.2.2.3.2 Pumps

Radwaste pumps are a horizontal, centrifugal type and are constructed of stainless steel. Two waste pumps are provided in each waste collection subsystem of the LWMS and transfer radwaste water from the waste collection tank to R/O package for processing.

The detergent waste tank pump is a centrifugal, horizontal type. Two detergent waste tank pumps are provided in the detergent waste system. The monitor tank pump is a horizontal, centrifugal type. Two monitor pumps are provided in the LWMS and transfer the processed wastewater from the monitor tank to the point for offsite release or the chemical and volume control system (CVCS) holdup tank for plant reuse.

Pumps are sized to process the contents of the tank in a single shift. The pump circulates the tank contents (through a mixing-eductor network located in the tank) to provide reasonable assurance of thorough mixing and representative sampling. The pump continually recirculates the tank contents during processing or discharging to prevent settling and potential radioactive crud build-up within the tank. The pump is tripped on low tank level signal automatically.

The acid batch pump is a positive displacement type and transfers diluted H_2SO_4 solution from the acid batch tank to the equipment waste tanks, floor drain tanks, and chemical waste tanks to meet the required pH. The caustic batch pump is a positive displacement type and transfers diluted NaOH solution from the caustic batch tank to the equipment waste tanks, floor drain tanks, and chemical waste tanks to meet the required pH. The seal water pump is a horizontal, centrifugal type and transfers the seal water from the seal water storage tank to the seal water system of each radwaste water pump.

11.2.2.3.3 Detergent Waste Filter

The detergent waste filter is used for removing particles from detergent wastes. The detergent waste filter uses a cartridge-type filter. Cartridge filters are housed in enclosures that assist with a simplified change-out with minimal occupational dose in compliance with the ALARA principle. The filters are located inside a shielded location corresponding to the design basis source term. The filter is contained in a top-loading, vertical stainless steel pressure vessel. Inlet flow is forced into the inside of the filter cartridge from the bottom and directed up into the outside of the filter cartridge. A spent filter cartridge is replaced manually.

The detergent waste filter is installed in an open area (i.e., there are no walls around the filter). The filter vessel is provided with lifting lugs and structural legs for anchoring to the foundation bolts.

11.2.2.3.4 Seal Water Heat Exchanger

The seal water heat exchanger is a shell and tube type and removes heats from the seal water, which is returned from the seal water system of each radwaste water pump.

11.2.2.3.5 R/O Package

Two R/O packages are provided to remove suspended solids, particulate/insoluble activity, some metal and organic complexes, and soluble species from the different streams of wastewater generated during plant operations. Each R/O package is capable of processing a minimum of 227 L/min (60 gpm) in normal operation.

The R/O package consists of the pre-treatment module, R/O module, demineralizer module, and concentrate feed module. The pre-treatment module, which consists of oil removal filter and membrane filter (MF), removes the impurities in the radwaste water to maintain optimal performance of the R/O module. The oil removal filter is a column holding oil removal filter cartridge designed to remove organic contaminants. This serves to protect the downstream ion exchange media from fouling.

The R/O module, which uses spiral wounded type membranes, removes soluble species in the radwaste water. The demineralizer module uses three ion exchangers to polish R/O permeates. The concentrate feed module receives and stores the concentrates generated from the pre-treatment module and R/O module and transfers the concentrates from the concentrate holding tank to the concentrate treatment system of the SWMS.

The R/O package is capable of allowing major maintenance to be acted on one process train while the other train continues to operate. Any component that requires frequent or routine maintenance, inspection, test, and adjustment of calibration is designed so that radiation exposures to operating and maintenance personnel are maintained ALARA.

The R/O package is designed using a modular (skid-mounted) approach to the greatest possible extent to provide reasonable assurance of easy installation and proper arrangement of components. Each R/O package is provided with an appropriate vent, drain, and flush line. The R/O package can be continuously operated from a control panel in the radwaste

control room in the compound building. The control panel contains the controls and instrumentation to automatically control the sequencing of events in the processes.

The demineralizer vessels are stainless steel pressure vessels with inlet distributors, connections equipped with screens to prevent infiltration of resins into the piping, and sluice outlets in the R/O package. Each demineralizer module has three vessels and is sized to process the contents passed through R/O module.

Access is provided to manually load vessels if appropriate. The normal disposition of fully expended (high differential pressure, high radiation or loss of desired isotopic removal capability) media is sluicing to the low-activity spent resin tank in the SWMS for processing and shipment offsite.

11.2.2.4 Design Features

11.2.2.4.1 Design Features for Minimization of Contamination

The APR1400 is designed with features to meet the requirements of 10 CFR 20.1406 (Reference 14) and NRC RG 4.21 (Reference 5). The basic principles of NRC RG 4.21 and the methods of control suggested in the regulations are delineated into four design objectives and two operational objectives, which are defined in Subsection 12.3.1.10. The primary features that address the design and operational objectives for the LWMS are described below.

The LWMS SSCs, including the facility that houses the components, are designed to limit leakage and/or control the spread of contamination. In accordance with NRC RG 4.21 (Reference 5), the LWMS has been evaluated for leakage identification from the SSCs that contain radioactive or potentially radioactive materials, the areas and pathways where probable leakage may occur, and the methods of leakage control incorporated in the design of the system. The leak identification evaluation indicated that the LWMS is designed to facilitate early leak detection and has the capability to assess collected fluids and respond to manage the collected fluids quickly. Thus, unintended contamination of the facility and the environment is minimized and/or prevented by the SSC design, supplemented by operational procedures and programs and inspection and maintenance activities.

Prevention/Minimization of Unintended Contamination

a. The system components, including the collection tanks and the monitor tanks, are fabricated of stainless steel material and are of welded construction for life-cycle planning, thus minimizing leakage and unintended contamination of the facility and the environment.

b. The LWMS tanks are designed with sufficient capacity to provide temporary storage of the liquid waste generated from normal operation including anticipated operational occurrences. The tanks are equipped with cross-connected inlet headers for the control of overflow and to provide reasonable assurance of timely processing. The design minimizes the interruption of normal processing operation, the spread of contamination, and waste generation.

c. The LWMS tanks are designed with ellipsoidal bottoms and mixing educators to minimize settling of suspended solids. The tanks have polished internal surfaces to minimize crud traps.

d. The LWMS is designed with minimum embedded or buried piping. Piping between buildings is designed to be equipped with piping sleeves with leakage directed back to the compound building for collection, thus preventing the spread of contamination.

Adequate and Early Leak Detection

a. All LWMS tanks are designed with level instruments to provide reasonable assurance of safe operation of the SSCs. The instruments provide alarms to the main control room and the radwaste control room for operator action in the event of high liquid levels.

b. The cubicles in which the LWMS tanks are located are designed to include leak detection instrumentation to initiate alarms for operator actions in the event of leakage. The leak detection design has the capability to detect a small quantity of leakage for early detection.

Reduction of Cross Contamination, Decontamination, and Waste Generation

a. The SSCs are designed with life-cycle planning through the use of nuclear industry-proven materials compatible with the chemical, physical, and radiological environment, thus minimizing waste generation.

b. The floor drains, equipment drains, chemical drains, and the detergent wastes are collected in segregated tanks in separate cubicles. Because the LWMS is designed to operate in batches, treatment for these collected wastes is determined through sampling and analyses. This design approach minimizes cross contamination and waste generation.

c. The process piping containing contaminated solids is sized to facilitate flow and to provide for velocities that are sufficient to prevent the settling of solids. The piping is designed to reduce crud traps, thus reducing decontamination and waste generation. Decontamination fluid is collected and processed.

d. Utility connections are designed with a minimum of two barriers to prevent contamination of non-radioactive systems from potentially radioactive systems.

Decommissioning Planning

a. The SSCs are designed with decontamination capabilities. Design features such as spargers, welding techniques, and surface finishes are included to minimize the need for decontamination and minimize waste generation.

b. The SSCs are designed for the full service life and are fabricated, to the maximum extent practicable, as individual assemblies for easy removal.

Operations and Documentation

a. The LWMS is designed for automated operation with manual initiation when sufficient liquid volumes are accumulated in each category of collection tanks to warrant processing. Hence, the LWMS is designed to operate in batch modes. Adequate instrumentation, including level, flow rate, and pressure elements, and a

process radiation monitor, is provided to monitor and control the operations to prevent undue interruption and the spread of radiologically contaminated material.

b. Piping is flushed clean after each processing to prevent solids from settling and accumulating. The flushing procedure also minimizes and/or prevents unintended leakage when the piping is not in use.

c. Leak detection instruments are provided to detect individual tank leakage. Adequate clearance around each tank is provided to enable prompt assessment and response when required.

d. The COL applicant is to develop the leak identification program (COL 11.2(5)) to identify site-specific components that contain radioactive materials, buried piping, embedded piping, leak detection methods and capabilities, and the methods that are used to prevent unnecessary contamination of clean components, facility areas, and the environment. The leak identification program, as part of the process control program, is designed to facilitate timely identification of leaks, prompt assessment, and appropriate responses to isolate and mitigate leakage.

e. The COL applicant is to prepare operational procedures and maintenance program as related to leak detection and contamination control (COL 11.2(6)). Procedures and maintenance programs are to be completed before fuel is loaded for commissioning.

f. The COL applicant is to maintain complete documentation of the system design, construction, design modification, field changes, and operations (COL 11.2(7)).

Site Radiological Environmental Monitoring

a. The LWMS is part of the plant and is included in the site process control program and the site radiological environmental monitoring program for monitoring facility and environmental contamination. The COL applicant is to prepare the site process control program and the site radiological environmental monitoring program (COL 11.2(8)). The site radiological environmental monitoring program includes sampling and analysis of effluent to be released, meteorological

conditions, hydrogeological parameters, and potential migration pathways of radioactive contaminants.

11.2.3 Radioactive Effluent Releases

11.2.3.1 Radioactive Effluent Releases and Dose Calculation in Normal Operation

Radioactive liquid effluents are treated by the LWMS and discharged through the plant discharge channel. The design of the LWMS components incorporates the decontamination factors provided in NUREG-0017 (Reference 2), which are presented in Table 11.2-3. The PWR-GALE Code used in the liquid effluents release calculation is modified in accordance with NRC RG 1.112 (Reference 20), which requires applying ANSI/ANS 18.1-1999 (Reference 23).

The treatment process and release point, effluent temperature, effluent flow rate, and size and shape of flow orifice are site specific and are to be presented in the site-specific detail design. The COL applicant is to provide the site-specific information of the LWMS including radioactive release points, effluent temperature, and the shape of flow orifices (COL 11.2(9)).

Annual liquid release source terms are calculated using the PWR-GALE Code, and input parameters are provided in Table 11.2-2. The concentration calculation uses an assumed dilution flow rate of 37,854 L/min (10,000 gpm) provided by cooling tower blowdown, dilution pump, or other plant discharges at discharge point. The COL applicant is to confirm the assumed dilution flow rate based on site-specific parameters (COL 11.2(10)).

The expected radionuclide release rates of the various liquid effluent streams are presented in Table 11.2-1, with corresponding daily flow rates in Table 11.2-2. The total annual radionuclide release rates of the various liquid streams and their corresponding concentrations are adjusted by the annual dilution flow rate to calculate the liquid effluent concentrations. Table 11.2-10 provides the release concentrations for the design basis fuel leakage and the effluent concentration limits in 10 CFR 20, Appendix B (Reference 3).

The equation for calculating the design basis concentrations of the liquid effluent is as follows:

$$C(i) = \frac{R(i) \times MF_i}{F_{dil}}$$

Where:

C(i)	=	Design basis liquid effluent concentration for the i^{th} isotope, Bq/L
R(i)	=	Total annual release rate of the i^{th} isotope, Bq/yr (Table 11.2-1)
MF_i	=	Multiplication factor for the i^{th} isotope (ratio of 1 % fuel defect design basis radionuclide concentration to ANSI/ANS-18.1-1999 expected concentration)
F_{dil}	=	Dilution flow rate at discharge point, L/yr

The sum of concentration ratios for the design basis fuel leakage is 0.18, as presented in Table 11.2-10. This value is less than 1.0, which indicates that the releases meet the regulatory limit.

Offsite doses received by individuals as a result of radioactive liquid releases are calculated using the LADTAP II Code (Reference 24). The input parameters of the LADTAP II Code (Reference 24) are presented in Table 11.2-4. The dilution factor for aquatic food, boating, shoreline, swimming, and drinking water is assumed to be 5 for the normal operating conditions. The results of the dose calculation are presented in Table 11.2-5. The values are compared with the corresponding limits of 10 CFR 50, Appendix I (Reference 4). Maximum individual dose to total body is 0.018 mSv/yr for an adult. This value is less than the regulatory limit of 0.03 mSv/yr presented in 10 CFR 50, Appendix I (Reference 4). The maximum dose to any individual organ is 0.023 mSv/yr, which is the dose to a child's liver. This value is less than the limitation of 0.1 mSv/yr presented in 10 CFR 50, Appendix I (Reference 4).

The COL applicant is to calculate the dose to members of the public following the guidance of NRC RG 1.109 (Reference 25) and NRC RG 1.113 (Reference 26) using site-specific parameters and to compare the doses due to liquid effluents with the numerical design

objectives of Appendix I to 10 CFR 50 (Reference 4), 10 CFR 20.1302 (Reference 27), and 40 CFR 190 (Reference 28) (COL 11.2(11)).

11.2.3.2 Radioactive Effluent Release due to Failure of Radioactive Liquid Tank

It is postulated that a tank containing radioactive liquid is failed in order to evaluate the impacts of the contamination levels on the nearest potable water supply located in an unrestricted area. The acceptance criteria and the methods used for the evaluation are based on the requirements in BTP 11-6 (Reference 13) and the radionuclide concentration limits in 10 CFR 20, Appendix B (Reference 3). In addition, the Interim Staff Guidance (ISG) DC/COL-ISG-013 (Reference 29) stipulates that the COL applicant is to identify the site-specific parameters for the evaluation (COL 11.2(12)). In the absence of site-specific requirements, the minimum dilution factors are calculated using 10 percent of 10 CFR 20, Appendix B, Table 2 (Reference 3) concentration limits and compared with the corresponding expected release radionuclide concentration.

In evaluating the postulated liquid containing tank failure, the CVCS holdup tank is selected because it contains the highest amount of radioactive inventory among the liquid waste collection tanks installed in the yard area.

The radionuclide inventory in the holdup tank is based on the expected fuel defect. The concentration of radioactive liquid after a liquid tank failure is assumed to be unmitigated and diluted by mixing in receiving water. The concentration is divided by 10 CFR 20 Appendix B (Reference 3) limits. Table 11.2-9 summarizes the results of this evaluation and identifies the minimum dilution factor is 1.71×10^3 to sufficiently dilute the failed tank nuclides to 10 percent of the 10 CFR 20 Appendix B (Reference 3) concentration limits. Site-specific hydrologic characteristics related to dilution of liquid tank failure source terms are discussed in Subsection 2.4.13.

The COL applicant is to provide the site-specific volume of the mixing water and hydrogeological data for analysis; the results of the analysis are to demonstrate that the potential groundwater or surface water contamination concentration resulting from radioactive release due to liquid containing tank failure meet the requirements in 10 CFR 20, Appendix B, Table 2 (Reference 3) (COL 11.2(12)).

11.2.3.3 Offsite Dose Calculation Manual

A description of the offsite dose calculation manual is provided in Subsection 11.3.3.3.

11.2.4 Testing and Inspection Requirements

Preoperational testing is discussed in Section 14.2. Prior to installation, the R/O package is tested to verify that is functioning properly. The system control panels are shop tested. The remainder of the system components are tested and inspected prior to shipment. After installation, but prior to initial plant startup, the LWMS is tested to verify pressure integrity, flow characteristics at design condition, and the operability of valves, instrumentation, and controls. During commissioning and initial power operation, samples are taken on a batch basis to verify the load and decontamination efficiency of the R/O package. Instrumentation is recalibrated periodically. The inspection and test are implemented to enable periodic evaluation of system operability and required performance in accordance with NRC RG 1.143 (Reference 1).

Epoxy coatings in cubicles that contain significant quantities of radioactive material are Service Level II coatings as defined in NRC RG 1.54 (Reference 12), and are subject to the limited QA provisions, selection, qualification, application, testing, maintenance and inspection provisions of NRC RG 1.54 (Reference 12) and standards referenced therein, as applicable to Service Level II coatings. Post-construction initial inspection is performed by personnel qualified using ASTM D 4537 (Reference 21) in accordance with inspection plan guidance of ASTM D 5163 (Reference 22).

11.2.5 Combined License Information

COL 11.2(1) The COL applicant is to determine whether contaminated laundry is sent to an offsite facility for cleaning or for disposal.

COL 11.2(2) The COL applicant is to provide the piping and instrumentation diagrams (P&IDs).

COL 11.2(3) The COL applicant is to perform a site-specific cost-benefit analysis to demonstrate compliance with the regulatory requirements of NRC RG 1.110.

COL 11.2(4) The COL applicant is to determine that the mobile or temporary equipment and interconnections to plant systems conform to regulatory requirements and guidance such as 10 CFR 50.34a, 10 CFR 20.1406, and NRC RG 1.143.

COL 11.2(5) The COL applicant is to develop the leak identification program.

COL 11.2(6) The COL applicant is to prepare operational procedures and maintenance programs as related to leak detection and contamination control.

COL 11.2(7) The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations.

COL 11.2(8) The COL applicant is to prepare the site process control program and the site radiological environmental monitoring program.

COL 11.2(9) The COL applicant is to provide the site-specific information of the LWMS including radioactive release points, effluent temperature, shape of flow orifices.

COL 11.2(10) The COL applicant is to confirm the assumed dilution flow rate provided by cooling tower blowdown, dilution pump, or other plant discharged at discharge point based on site-specific parameters.

COL 11.2(11) The COL applicant is to calculate dose to members of the public following the guidance of NRC RG 1.109 and NRC RG 1.113 using site-specific parameters and to compare the doses due to the liquid effluents with the numerical design objectives of Appendix I to 10 CFR 50, 10 CFR 20.1302, and 40 CFR 190.

COL 11.2(12) The COL applicant is to provide the site-specific volume of the mixing water and hydrogeological data for performing an analysis to demonstrate that the potential groundwater or surface water contamination concentration resulting from radioactive release due to liquid containing tank failure meets 10 CFR 20, Appendix B, Table 2.

11.2.6 References

1. NRC RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," Rev. 2, U.S. Nuclear Regulatory Commission, November 2001.

2. NUREG-0017, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWR-GALE Code)," Rev. 1, U.S. Nuclear Regulatory Commission, April 1985.

3. 10 CFR 20, Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage."

4. 10 CFR 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents."

5. NRC RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning," Rev. 0, U.S. Nuclear Regulatory Commission, June 2008.

6. General Design Criteria 60, "Control of Releases of Radioactive Materials to the Environment," 10 CFR 50, Appendix A.

7. General Design Criteria 61, "Fuel Storage and Handling and Radioactivity Control," 10 CFR 50, Appendix A.

8. General Design Criteria 64, "Monitoring Radioactivity Releases," 10 CFR 50, Appendix A.

9. 10 CFR 50.34a, "Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents-Nuclear Power Reactors."

10. ANSI/ANS 55.6, "Liquid Radioactive Waste Processing for Light Water Reactor Plants," American National Standards Institute/American Nuclear Society, July 1993 (Reaffirmed 1999).

11. IE Bulletin No. 80-10, "Contamination of Nonradioactive System and Resulting Potential for Unmonitored, Uncontrolled Release of Radioactivity to Environment," U.S. Nuclear Regulatory Commission, May 6, 1980.

12. NRC RG 1.54, "Service Level I, II, and III Protective Coatings Applied to Nuclear Power Plants," Rev. 2, October 2012.

13. Branch Technical Position 11-6, "Postulated Radioactive Releases due to Liquid-Containing Tank Failures," NUREG-0800, U.S. Nuclear Regulatory Commission, March 2007.

14. 10 CFR 20.1406, "Minimization of Contamination."

15. NRC RG 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as is Reasonably Achievable," Rev. 3, U.S. Nuclear Regulatory Commission, June 1978.

16. NRC RG 1.33, "Quality Assurance Program Requirements (Operation)," U.S. Nuclear Regulatory Commission, February 1978.

17. Sargent and Lundy, "DIJESTER Computer Program User's Guide," December 1988.

18. 10 CFR 71, "Packaging and Transportation of Radioactive Material."

19. NRC RG 1.110, "Cost-Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors," U.S. Nuclear Regulatory Commission, March 1976.

20. NRC RG 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," U.S. Nuclear Regulatory Commission, 2007.

21. ASTM D 4537-04a, "Standard Guide for Establishing Procedures to Qualify and Certify Personnel Performing Coating Work Inspection in Nuclear Facilities," American Society for Testing and Materials.

22. ASTM D 5163-08, "Standard Guide for Establishing a Program for Condition Assessment of Coating Service Level I Coating Systems in Nuclear Power Plants," American Society for Testing and Materials.

23. ANSI/ANS-18.1, "Radioactive Source Terms for Normal Operation of Light Water Reactors," American National Standard Institute/American Nuclear Society, 1999 (Withdrawn 2009).

24. NUREG/CR-4013, "LADTAP II Technical Reference and User Guide," U.S. Nuclear Regulatory Commission, April 1986.

25. NRC RG 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I," Rev. 1, U.S. Nuclear Regulatory Commission, October 1977.

26. NRC RG 1.113, "Estimating Aquatic Dispersion of Effluent from Accidental and Routine Releases for the Purpose of Implementing Appendix I," Rev. 1, U.S. Nuclear Regulatory Commission, April 1977.

27. 10 CFR 20.1302, "Compliance with Dose Limits for Individual Members of the Public."

28. 40 CFR 190, "Environmental Radiation Protection Standards for Nuclear Power Operations."

29. Interim Staff Guidance DC/COL-ISG-013, "Assessing the Radiological Consequences of Accidental Releases of Radioactive Materials from Liquid Waste Tanks for Combined License Applications," U.S. Nuclear Regulatory Commission, January 2013.

Table 11.2-1 (1 of 2)

Expected Liquid Radioactive Effluents During Normal Operations, Including AOOs (Bq/yr)

Nuclide	Primary Coolant Shim Bleed	Liquid Radwaste System	SGBD System	Turbine Building Drains	Adjusted Total	Detergent Waste	Total[(1)]
Na-24	3.85E+05	5.55E+05	0.00E+00	3.42E+06	6.92E+07	0.00E+00	7.03E+07
P-32	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.66E+06	6.66E+06
Cr-51	2.25E+06	3.64E+05	0.00E+00	4.59E+05	4.88E+07	1.74E+08	2.22E+08
Mn-54	2.12E+06	2.06E+05	0.00E+00	2.32E+05	4.07E+07	1.41E+08	1.81E+08
Fe-55	1.67E+06	1.56E+05	0.00E+00	1.75E+05	3.16E+07	2.66E+08	3.00E+08
Fe-59	2.76E+05	3.66E+04	0.00E+00	4.26E+04	5.62E+06	8.14E+07	8.88E+07
Co-58	4.92E+06	5.74E+05	0.00E+00	6.73E+05	9.81E+07	2.92E+08	4.07E+08
Co-60	7.44E+05	6.88E+04	0.00E+00	7.84E+04	1.41E+07	5.18E+08	5.18E+08
Ni-63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.29E+07	6.29E+07
Zn-65	6.66E+05	6.55E+04	0.00E+00	7.47E+04	1.28E+07	0.00E+00	1.30E+07
W-187	4.66E+04	5.07E+04	0.00E+00	2.31E+05	5.22E+06	0.00E+00	5.18E+06
Np-239	1.38E+05	1.04E+05	0.00E+00	2.63E+05	7.99E+06	0.00E+00	8.14E+06
Sr-89	1.36E+05	1.72E+04	0.00E+00	2.02E+04	2.75E+06	3.26E+06	5.92E+06
Sr-90	1.70E+04	1.56E+03	0.00E+00	1.75E+03	3.22E+05	4.81E+05	8.14E+05
Sr-91	2.99E+03	6.51E+03	0.00E+00	5.18E+04	9.69E+05	0.00E+00	9.62E+05
Y-91m	1.93E+03	4.22E+03	0.00E+00	3.30E+04	6.22E+05	0.00E+00	6.29E+05
Y-91	1.20E+04	1.44E+03	0.00E+00	9.21E+02	2.27E+05	3.11E+06	3.33E+06
Y-93	1.49E+04	3.06E+04	0.00E+00	2.28E+04	1.08E+06	0.00E+00	1.07E+06
Zr-95	4.07E+05	4.85E+04	0.00E+00	5.70E+04	8.10E+06	4.07E+07	4.81E+07
Nb-95	4.18E+05	3.74E+04	0.00E+00	3.92E+04	7.81E+06	7.03E+07	7.77E+07
Mo-99	4.96E+05	3.44E+05	0.00E+00	7.99E+05	2.60E+07	2.22E+06	2.81E+07
Tc-99m	4.74E+05	3.26E+05	0.00E+00	5.03E+05	2.06E+07	0.00E+00	2.07E+07
Ru-103	6.55E+06	9.07E+05	0.00E+00	1.10E+06	1.35E+08	1.07E+07	1.44E+08
Rh-103m	6.55E+06	9.07E+05	0.00E+00	1.08E+06	1.35E+08	0.00E+00	1.37E+08
Ru-106	1.21E+08	1.16E+07	0.00E+00	1.32E+07	2.31E+09	3.29E+08	2.63E+09
Rh-106	1.21E+08	1.16E+07	0.00E+00	1.32E+07	2.31E+09	0.00E+00	2.29E+09
Ag-110m	1.70E+06	1.67E+05	0.00E+00	1.89E+05	3.26E+07	4.44E+07	7.77E+07
Ag-110	2.21E+05	2.17E+04	0.00E+00	2.46E+04	4.26E+06	0.00E+00	4.07E+06
Sb-124	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.59E+07	1.59E+07

Table 11.2-1 (2 of 2)

Nuclide	Primary Coolant Shim Bleed	Liquid Radwaste System	SGBD System	Turbine Building Drains	Adjusted Total	Detergent Waste	Total(1)
Te-129m	1.54E+05	2.27E+04	0.00E+00	2.76E+04	3.24E+06	0.00E+00	3.26E+06
Te-129	9.88E+04	1.67E+04	0.00E+00	2.99E+04	2.31E+06	0.00E+00	2.29E+06
Te-131m	4.00E+04	3.89E+04	0.00E+00	1.52E+05	3.65E+06	0.00E+00	3.66E+06
Te-131	7.25E+03	7.10E+03	0.00E+00	2.77E+04	6.66E+05	0.00E+00	6.66E+05
I-131	6.29E+04	2.04E+06	0.00E+00	3.65E+05	3.92E+07	5.92E+07	9.99E+07
Te-132	1.58E+05	1.01E+05	0.00E+00	2.14E+05	7.51E+06	0.00E+00	7.40E+06
I-132	1.63E+05	7.51E+05	0.00E+00	7.73E+05	2.68E+07	0.00E+00	2.66E+07
I-133	4.00E+04	4.55E+06	0.00E+00	3.25E+06	1.25E+08	0.00E+00	1.26E+08
I-134	1.27E-03	3.23E+04	0.00E+00	2.53E+04	9.14E+05	0.00E+00	9.25E+05
Cs-134	4.48E+05	2.62E+05	0.00E+00	6.62E+03	1.13E+07	4.07E+08	4.07E+08
I-135	6.29E+03	2.26E+06	0.00E+00	3.18E+06	8.62E+07	0.00E+00	8.51E+07
Cs-136	3.10E+06	4.96E+06	0.00E+00	1.51E+05	1.30E+08	1.37E+07	1.44E+08
Cs-137	6.55E+05	3.77E+05	0.00E+00	9.73E+03	1.65E+07	5.92E+08	5.92E+08
Ba-137m	6.14E+05	3.52E+05	0.00E+00	9.10E+03	1.54E+07	0.00E+00	1.55E+07
Ba-140	5.29E+06	1.36E+06	0.00E+00	1.81E+06	1.34E+08	3.37E+07	1.67E+08
La-140	6.48E+06	1.90E+06	0.00E+00	2.95E+06	1.80E+08	0.00E+00	1.81E+08
Ce-141	1.19E+05	1.79E+04	0.00E+00	2.16E+04	2.50E+06	8.51E+06	1.11E+07
Ce-143	8.55E+04	8.03E+04	0.00E+00	2.87E+05	7.18E+06	0.00E+00	7.03E+06
Pr-143	1.24E+05	2.36E+04	0.00E+00	3.85E+03	2.39E+06	0.00E+00	2.41E+06
Ce-144	5.29E+06	5.14E+05	0.00E+00	5.70E+05	1.01E+08	1.44E+08	2.44E+08
Pr-144	5.29E+06	5.14E+05	0.00E+00	5.70E+05	1.01E+08	0.00E+00	9.99E+07
Others	2.52E+04	1.97E+03	0.00E+00	2.84E+02	4.37E+05	0.00E+00	4.44E+05
Total (Except Tritium)	3.00E+08	4.85E+07	0.00E+00	5.03E+07	6.33E+09	3.32E+09	9.62E+09
H-3							5.40E+13

(1) The total release effluents include 5.92×10^9 Bq/yr considering AOO.

Table 11.2-2 (1 of 3)

PWR-GALE Code Input Parameters
Used to Calculate Annual Gaseous and Liquid Effluent Releases

Card No	Parameter	Value
1	Name of Reactor	APR1400 NRC (PWR)
2	Thermal Power Level (MWt)	4.06E+03
3	Mass of Primary Coolant (10^6 lb)	6.43E+02
4	Primary System Letdown Rate (gpm)	8.00E+01
5	Letdown Cation Demineralizer Flow (gpm)	0.00E+00
6	Number of Steam Generators	2.00E+00
7	Total Steam Flow (10^6 lb/hr)	1.80E+01
8	Mass of Liquid in Each Steam Generator (10^3 lb)	2.18E+02
9	Blowdown Flow (10^3 lb/hr) Blowdown Treatment Input Option	3.590E+01 0
10	Condensate Demineralizer Regeneration Time (Days)	0.00E+00
11	Condensate Demineralizer Flow Fraction	1.67E-01
12	Shim Bleed Flow Rate (gpd) Fraction of Primary Coolant Activity (PCA)	 6.05E+02 1.0
13	DF (Iodine) DF (Cs) DF (Others)	1.0E+05 4.0E+03 1.0E+05
14	Collection Time (Days) Process Time (Days) Fraction Discharged	5.9E+01 8.5E-01 1.0
15	Equipment Drains Flow rate (gpd) Fraction of Primary Coolant Activity (PCA)	 2.50E+02 1.0
16	DF (Iodine) DF (Cs) DF (Others)	1.0E+05 2.0E+03 1.0E+04
17	Collection Time (Days) Process Time (Days) Fraction Discharged)	5.9E+01 8.5E-01 1.0

Table 11.2-2 (2 of 3)

Card No	Parameter	Value
18	Clean Waste Flow Rate (gpd) Fraction of Primary Coolant Activity (PCA)	 8.660E+2 0.144
19	DF (Iodine) DF (Cs) DF (Others)	1.0E+04 2.0E+03 1.0E+05
20	Collection Time (Days) Process Time (Days) Fraction Discharged	8.3E+00 1.7E-01 1.0
21	Dirty Waste Flow Rate (gpd) Fraction of Primary Coolant Activity (PCA)	 1.406E+03 0.075
22	DF (Iodine) DF (Cs) DF (Others)	1.0E+04 2.0E+03 1.0E+05
23	Collection Time (Days) Process Time (Days) Fraction Discharged	7.6E+00 1.7E-01 1.0
24	Fraction of Blowdown Flow Processed	1.0E+00
25	DF (Iodine) DF (Cs) DF (Others)	1.0E+02 1.0E+01 1.0E+01
26	Collection Time (Days) Process Time (Days) Fraction Discharged	0.0E+00 0.0E+00 0.0
27	Regenerant Flow Rate (gpd)	3.40E+03
28	DF (Iodine) DF (Cs) DF (Others)	1.0E+00 1.0E+00 1.0E+00

Table 11.2-2 (3 of 3)

Card No	Parameter	Value
29	Collection Time (Days) Process Time (Days) Fraction Discharged	0.0E+00 0.0E+00 0.0
30	Is There Continuous Stripping of Full Letdown Flow	0
31	Holdup Time for Xenon (Days)	4.50E+01
32	Holdup Time for Krypton (Days)	3.50E+00
33	Fill Time of Decay Tanks for the Gas Stripper (Days)	0.00E+00
34	Gas Waste System HEPA Efficiency (%)	99.0
35	Fuel Handling Area Filter Efficiency (%) Charcoal HEPA	 0.0 99.0
36	Auxiliary Building Filter Efficiency (%) Charcoal HEPA	 90.0 99.0
37	Containment Volume (10^6 ft^3)	3.13E+00
38	Containment Atmosphere Cleanup System Charcoal Efficiency (%) HEPA Efficiency (%) Flow Rate (10^3 cfm)	 0.0 0.0 0.0
39	Containment High Volume Purge System Charcoal Efficiency (%) HEPA Efficiency (%) Number/yr	 0.0 99.0 2.0
40	Containment Low Volume Purge System Charcoal Efficiency (%) HEPA Efficiency (%) Flow Rate (cfm)	 90.0 99.0 1,500
41	Fraction of Iodine Released from Blowdown Tank Vent	0.00E+00
42	Percent of Iodine Removed from Air Ejector Release	0.00E+00
43	Partition Factor of Detergent Waste	1.00E+00

Table 11.2-3 (1 of 2)

Decontamination Factors for CVCS and LWMS

Shim Bleed Decontamination Factors

Component	Nuclide		
	Iodine	Cs, Rb	Others
CVCS purification IX	1	1	1
CVCS pre-holdup IX	10	2	10
Boric acid concentrator	1	1	1
Boric acid condensate IX	1	1	1
LWMS R/O module	10	10	10
LWMS cation IX	1	10	10
LWMS mixed IX	100	2	100
LWMS mixed IX	10	10	10
Sum	1×10^5	4×10^3	1×10^5 (1)

(1) For conservatism, 10 % of total decontamination factor is applied

Equipment Drain Decontamination Factors

Component	Nuclide		
	Iodine	Cs, Rb	Others
CVCS purification IX	N/A	N/A	N/A
CVCS pre-holdup IX	10	1	1
Boric acid concentrator	1	1	1
Boric acid condensate IX	1	1	1
LWMS R/O module	10	10	10
LWMS cation IX	1	10	10
LWMS mixed IX	100	2	100
LWMS mixed IX	10	10	10
Sum	1×10^5	2×10^3	1×10^4(1)

(1) For conservatism, 10 % of total decontamination factor is applied

Table 11.2-3 (2 of 2)

Clean and Dirty Waste Decontamination Factors

Component	Nuclide		
	Iodine	Cs, Rb	Others
LWMS R/O module	10	10	10
LWMS cation IX	1	10	10
LWMS mixed IX	100	2	100
LWMS mixed IX	10	10	10
Sum	1×10^4	2×10^3	1×10^5

Table 11.2-4

Input Parameters Used for LADTAP II Code

Parameter	Value
Water type selection	Freshwater
Liquid effluent discharge rate, L/min	3.79×10^4
Shore-width factor	0.2
Re-concentration model index	0
Source terms	See Table 11.2-1
Dilution factor for aquatic food and boating	5
Dilution factor for shoreline and swimming	5
Dilution factor for drinking water	5
Dilution factor for irrigation water usage location for the current food product	5
Irrigation rate, $L/m^2 \cdot month$	16.67
Fraction of animal feed not produced with contaminated irrigation water	0
Fraction of animal drinking water not obtained from contaminated irrigation water	0
Transit time for any exposure pathway	0
Midpoint of plant life (years)	30
Other parameters	NRC RG 1.109

Table 11.2-5

Individual Doses from Liquid Effluents (mSv/yr)

	Skin	Bone	Liver	Total body	Thyroid	Kidney	Lung	GI-LLI
Ingestion: Fish								
ADULT	-	1.54E-02	1.53E-02	1.12E-02	3.37E-04	5.14E-03	1.77E-03	4.47E-03
TEEN	-	1.65E-02	1.57E-02	6.62E-03	2.89E-04	5.20E-03	2.02E-03	3.29E-03
CHILD	-	2.08E-02	1.37E-02	2.99E-03	2.76E-04	4.38E-03	1.60E-03	1.30E-03
Drinking								
ADULT	-	2.07E-04	6.68E-03	6.61E-03	6.85E-03	6.53E-03	6.44E-03	7.55E-03
TEEN	-	1.98E-04	4.77E-03	4.63E-03	4.89E-03	4.63E-03	4.55E-03	5.35E-03
CHILD	-	5.71E-04	9.18E-03	8.80E-03	9.60E-03	8.90E-03	8.73E-03	9.47E-03
INFANT	-	5.93E-04	9.14E-03	8.60E-03	9.97E-03	8.75E-03	8.58E-03	9.03E-03
Shoreline Activates								
ADULT	2.13E-05	1.81E-05	1.81E-05	1.81E-05	1.81E-05	1.81E-05	1.81E-05	1.81E-05
TEEN	1.19E-04	1.01E-04	1.01E-04	1.01E-04	1.01E-04	1.01E-04	1.01E-04	1.01E-04
CHILD	2.48E-05	2.12E-05	2.12E-05	2.12E-05	2.12E-05	2.12E-05	2.12E-05	2.12E-05
Ingestion of Irrigated Food: Vegetables								
ADULT	-	1.65E-06	4.70E-05	4.65E-05	4.63E-05	4.58E-05	4.51E-05	5.35E-05
TEEN	-	2.74E-06	5.83E-05	5.63E-05	5.69E-05	5.64E-05	5.53E-05	6.58E-05
CHILD	-	6.52E-06	9.27E-05	8.83E-05	9.11E-05	8.94E-05	8.76E-05	9.56E-05
Ingestion of Irrigated Food: Leafy Vegetables								
ADULT	-	1.65E-06	4.70E-05	4.65E-05	4.63E-05	4.58E-05	4.51E-05	5.35E-05
TEEN	-	2.74E-06	5.83E-05	5.63E-05	5.69E-05	5.64E-05	5.53E-05	6.58E-05
CHILD	-	6.52E-06	9.27E-05	8.83E-05	9.11E-05	8.94E-05	8.76E-05	9.56E-05
Ingestion of Irrigated Food: Milk								
ADULT	-	1.60E-06	4.74E-05	4.68E-05	4.65E-05	4.58E-05	4.52E-05	4.51E-05
TEEN	-	2.69E-06	5.90E-05	5.66E-05	5.73E-05	5.63E-05	5.54E-05	5.51E-05
CHILD	-	6.40E-06	9.39E-05	8.83E-05	9.19E-05	8.92E-05	8.78E-05	8.71E-05
Ingestion of Irrigated Food: Meat								
ADULT	-	4.95E-06	4.58E-05	4.61E-05	4.56E-05	5.35E-05	4.50E-05	3.24E-04
TEEN	-	8.50E-06	5.63E-05	5.65E-05	5.59E-05	6.96E-05	5.51E-05	4.11E-04
CHILD	-	2.09E-05	8.94E-05	9.00E-05	8.90E-05	1.12E-04	8.73E-05	3.71E-04
Sum of all Pathways								
ADULT	2.13E-05	1.56E-02	2.22E-02	1.80E-02	7.39E-03	1.19E-02	8.41E-03	1.25E-02
TEEN	1.19E-04	1.68E-02	2.08E-02	1.16E-02	5.51E-03	1.02E-02	6.89E-03	9.34E-03
CHILD	2.48E-05	2.14E-02	2.33E-02	1.22E-02	1.03E-02	1.37E-02	1.07E-02	1.14E-02
INFANT	-	5.93E-04	9.14E-03	8.60E-03	9.97E-03	8.75E-03	8.58E-03	9.03E-03

Table 11.2-6 (1 of 5)

Equipment List in the LWMS

Tanks

Equipment Characteristic	Description
Equipment Name Quantity (each) Design capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Floor Drain Tank 2 68,137 (18,000) ATM 93.3 (200) Stainless steel RW-IIa
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Equipment Waste Tank 2 68,137 (18,000) ATM 93.3 (200) Stainless steel RW-IIa
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Chemical Waste Tank 2 [34,069 (9,000)] ATM 93.3 (200) Stainless steel RW-IIc
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Monitor Tank 2 [102,206 (27,000)] ATM 93.3 (200) Stainless steel RW-IIc
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Acid Storage Tank 1 1,703 (450) ATM 100 (212) Stainless steel N/A[(1)]

Table 11.2-6 (2 of 5)

Tanks (cont'd)

Equipment Characteristic	Description
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Acid Batch Tank 1 189 (50) ATM 100 (212) Incoloy 825 N/A[(1)]
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Caustic Storage Tank 1 1,703 (450) ATM 100 (212) Stainless Steel N/A[(1)]
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Seal Water Storage Tank 1 1,741 (460) ATM 93.3 (200) Stainless Steel N/A[(1)]
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Caustic Batch Tank 1 189 (50) ATM 100 (212) Stainless Steel N/A[(1)]
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, °C (°F) Material Radwaste Safety Class	Chemical Additive Tank 1 416 (110) ATM 93.3 (200) Stainless Steel N/A[(1)]

Table 11.2-6 (3 of 6)

Tanks (cont'd)

Equipment Characteristic	Description
Equipment Name Quantity (each) Design Capacity, L (gal) Design pressure, kg/cm^2G (psig) Design temperature, ^oC (^oF) Material Radwaste Safety Class	Detergent Waste Tank 2 22,712 (6,000) ATM 93.3 (200) Stainless Steel RW-IIc

Pumps

Equipment Characteristic	Description
Equipment Name Quantity (each) Design Capacity, L/min (gpm) Design Process Flow Rate, L/min (gpm) Design temperature, ^oC (^oF) Material Radwaste Safety Class	Floor Drain Pump 2 (100 % capacity per each unit) 568 (150) per each unit 227 (60) per each unit 93.3 (200) Stainless Steel RW-IIa
Equipment Name Quantity (each) Design Capacity, L/min (gpm) Design Process Flow Rate, L/min (gpm) Design temperature, ^oC (^oF) Material Radwaste Safety Class	Equipment Waste Pump 2 (100 % capacity per each unit) 568 (150) per each unit 227 (60) per each unit 93.3 (200) Stainless Steel RW-IIa
Equipment Name Quantity (each) Design Capacity, L/min (gpm) Design Process Flow Rate, L/min (gpm) Design temperature, ^oC (^oF) Material Radwaste Safety Class	Chemical Waste Pump 2 (100 % capacity per each unit) 416 (110) per each unit 227 (60) per each unit 93.3 (200) Stainless Steel RW-IIc
Equipment Name Quantity (each) Design Capacity, L/min (gpm) Design Process Flow Rate, L/min (gpm) Design temperature, ^oC (^oF) Material Radwaste Safety Class	Monitor Tank Pump 2 (100 % capacity per each unit) 1060 (280) per each unit 341 (90) per each unit 93.3 (200) Stainless Steel RW-IIc

Table 11.2-6 (4 of 5)

Pumps (cont'd)

Equipment Characteristic	Description
Equipment Name	Seal Water Pump
Quantity (each)	2 (100 % capacity per each unit)
Design Capacity, L/min (gpm)	227 (60) per each unit
Design temperature, °C (°F)	93.3 (200)
Material	Stainless Steel
Radwaste Safety Class	N/A(1)
Equipment Name	Acid Batch Pump
Quantity (each)	1
Design Capacity, L/min (gpm)	19 (5)
Design temperature, °C (°F)	100 (212)
Material	Incoloy 825
Radwaste Safety Class	N/A(1)
Equipment Name	Caustic Batch Pump
Quantity (each)	1
Design Capacity, L/min (gpm)	19 (5)
Design temperature, °C (°F)	100 (212)
Material	Stainless Steel
Radwaste Safety Class	N/A(1)
Equipment Name	Chemical Additive Pump
Quantity (each)	1
Design Capacity, L/min (gpm)	38 (10)
Design temperature, °C (°F)	93.3 (200)
Material	Stainless Steel
Radwaste Safety Class	N/A(1)
Equipment Name	Detergent Waste Tank Pump
Quantity (each)	2 (100 % capacity per each unit)
Design Capacity, L/min (gpm)	568 (150)
Design Process Flow Rate, L/min (gpm)	189 (50)
Design temperature, °C (°F)	93.3 (200)
Material	Stainless Steel
Radwaste Safety Class	N/A(1)

Table 11.2-6 (5 of 5)

Miscellaneous

Equipment Characteristic	Description
Equipment Name	Detergent Waste Filter
Quantity (each)	1
Design Capacity, L/min (gpm)	189 (50)
Design pressure, kg/cm^2G (psig)	ATM
Design temperature, ^oC (^oF)	93.3 (200)
Material	Stainless Steel
Radwaste Safety Class	RW-IIc
Equipment Name	LRS Seal Water Heat Exchanger
Quantity (for Both Units)	1
Type	Shell and Tube
Heat Transfer, kcal/hr (Btu/hr)	2.5×10^4 (1.0×10^{-5})
Design pressure, kg/cm^2G (psig)	14.1 (200)
Design temperature, ^oC (^oF)	93.3 (200)
Material	Stainless Steel
Radwaste Safety Class	RW-IIc
Equipment Name	R/O Package
Quantity (each)	100 % capacity 2 train
Design Capacity, L/min (gpm)	227 (60)
Design Process Flow Rate, L/min (gpm)	227 (60)
Design pressure, kg/cm^2G (psig)	14.1 (200)
Design temperature, ^oC (^oF)	93.3 (200)
Material	Stainless Steel
Radwaste Safety Class	
MF Membrane	RW-IIc
RO Feed Tank	RW-IIb
RO Feed Pump	RW-IIb
RO Module	RW-IIa
IX Feed Tank	RW-IIc
IX Feed Pump	RW-IIc
Cation Bed	RW-IIa
Mixed Bed 1	RW-IIa
Mixed Bed 2	RW-IIc

(1) The equipment classified as N/A is non-radwaste component

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Table 11.2-7

Codes and Standards for Equipment in the LWMS

Equipment	Design and Fabrication	Material	Welder Qualifications and Procedures	Inspection and Testing
Tanks:		ASME Sec. II	ASME Sec. IX	
Atmospheric or	API 650 (atmospheric)			API 650 (atmospheric)
0 – 1.05 kg/cm^2 (0 – 15 psig) (steel)	API 620 (0 – 1.05 kg/cm^2 [0 – 15 psig])			API 620 (0 –1 .05 kg/cm^2 [0 – 15 psig])
Pressure Vessels	ASME Sec. VIII, Div. 1 or Div. 2	ASME Sec. II	ASME Sec. IX	ASME Sec. VIII, Div. 1 or Div. 2
Pumps	API-610; API-674; API-675; ASME Sec. VIII, Div. 1 or Div. 2	ASME Sec. II	ASME Sec. IX	ASME Sec. III, Class 3
Piping and Valves	ASME B31.3	ASME Sec. II	ASME Sec. IX	ASME B31.3
Ion Exchangers	ASME Sec. VIII, Div. 1	ASME Sec. II	ASME Sec. IX	ASME Sec. VIII, Div. 1
Filters	ASME Sec. VIII, Div. 1	ASME Sec. II	ASME Sec. IX	ASME Sec. VIII, Div. 1

Table 11.2-8

Radioactive Atmospheric Tank Overflow Protection

Tanks	Level Monitoring	Potential Overflow Alarm	Method for Containing Overflow
Equipment Waste Tank	Radwaste Control Room	Radwaste Control Room	Overflow from one radwaste tank flows to the other radwaste tank with the ultimate overflow of both tanks directed to the compound building sump.
Floor Drain Tanks	Radwaste Control Room	Radwaste Control Room	Same as above
Chemical Waste Tanks	Radwaste Control Room	Radwaste Control Room	Same as above
Monitor Tanks	Radwaste Control Room	Radwaste Control Room	Same as above

Table 11.2-9 (1 of 2)

Radioactive Concentrations in Nearest Portable Water
Due to Liquid Waste Containing Tank Failure

Nuclide	Holdup Tank inventory (Bq/cm^3)	Concentration at Nearest Potable Water (1) (Bq/cm^3)	10 CFR 20, Appendix B (Bq/cm^3)	Ratio
Br-84	8.81E-05	5.14E-08	1.48E+01	3.47E-09
I-131	2.26E-02	1.32E-05	3.70E-02	3.57E-04
I-132	1.64E-03	9.54E-07	3.70E+00	2.58E-07
I-133	1.38E-02	8.07E-06	2.59E-01	3.12E-05
I-134	9.43E-04	5.51E-07	1.48E+01	3.72E-08
I-135	5.79E-03	3.38E-06	1.11E+00	3.04E-06
Rb-88	2.83E-03	1.65E-06	1.48E+01	1.12E-07
Cs-134	8.81E-04	5.14E-07	3.33E-02	1.54E-05
Cs-136	9.43E-03	5.51E-06	2.22E-01	2.48E-05
Cs-137	1.32E-03	7.71E-07	3.70E-02	2.08E-05
Na-24	2.20E-02	1.28E-05	1.85E+00	6.94E-06
Cr-51	9.43E-02	5.51E-05	1.85E+01	2.98E-06
Mn-54	8.18E-02	4.77E-05	1.11E+00	4.30E-05
Fe-55	6.29E-02	3.67E-05	3.70E+00	9.92E-06
Fe-59	1.13E-02	6.61E-06	3.70E-01	1.79E-05
Co-58	1.95E-01	1.14E-04	7.40E-01	1.54E-04
Co-60	2.96E-02	1.73E-05	1.11E-01	1.55E-04
Zn-65	2.64E-02	1.54E-05	1.85E-02	8.33E-05
Sr-89	5.47E-03	3.19E-06	2.96E-01	1.08E-05
Sr-90	6.92E-04	4.04E-07	1.85E-02	2.18E-05
Sr-91	2.58E-04	1.50E-07	7.40E-01	2.03E-07
Y-91m	4.72E-03	2.75E-06	7.40E+01	3.72E-08
Y-91	2.01E-02	1.17E-05	2.96E-01	3.97E-05
Y-93	5.16E-01	3.01E-04	7.40E-01	4.07E-04
Zr-95	1.64E-02	9.54E-06	7.40E-01	1.29E-05
Nb-95	9.43E-03	5.51E-06	1.11E+00	4.96E-06
Mo-99	2.26E-02	1.32E+05	7.40E-01	1.79E-05

Table 11.2-9 (2 of 2)

Nuclide	Holdup Tank Inventory (Bq/cm^3)	Concentration at Nearest Potable Water [(1)] (Bq/cm^3)	10 CFR 20, Appendix B (Bq/cm^3)	Ratio
TC-99m	6.92E-04	4.04E-07	3.70E+01	1.09E-08
Ru-103	2.70E-01	1.58E-04	1.11E+00	1.42E-04
Ru-106	4.78E+00	2.79E-03	1.11E-01	2.51E-02
Ag-110m	6.92E-02	4.04E-05	2.22E-01	1.82E-04
Te-129m	5.91E-03	3.45E-06	2.59E-01	1.33E-05
Te-129	2.96E-04	1.73E-07	1.48E+01	1.17E-08
Te-131m	1.26E-03	7.34E-07	2.96E-01	2.48E-06
Te-131	3.33E-05	1.95E-08	2.96E+00	6.57E-09
Te-132	6.16E-03	3.60E-06	3.33E-01	1.08E-05
Ba-137m	1.32E-03	7.71E-07	—	—
Ba-140	2.39E-01	1.39E-04	2.96E-01	4.71E-04
La-140	4.47E-02	2.61E-05	3.33E-01	7.83E-05
Ce-141	4.97E-03	2.90E-06	1.11E+00	2.61E-06
Ce-143	3.77E-03	2.20E-06	7.40E-01	2.98E-06
Ce-144	2.08E-01	1.21E-04	1.11E-01	1.09E-03
W-187	2.20E-03	1.28E-06	1.11E+00	1.16E-06
Np-239	6.16E-03	3.60E-06	7.40E-01	4.86E-06
H-3	4.53E+03	2.79E-03	1.11E-01	2.51E-02
			SUM	1.00E-01

(1) Dilution factor of 1.71E+03 is assumed to meet the 10 % of 10 CFR 20, Appendix B limits

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Table 11.2-10 (1 of 2)

Design Basis Liquid Effluent Concentration at the Site Boundary

Nuclide	Design Basis Release[1] (Bq/yr)	Effluent Concentration (Bq/m^3)	10 CFR 20, Appendix B Limits (Bq/m^3)	Ratio
Na-24	7.03E+07	3.53E+00	1.85E+06	1.91E-06
P-32	6.66E+06	3.35E-01	3.33E+05	1.01E-06
Cr-51	9.61E+08	4.83E+01	1.85E+07	2.61E-06
Mn-54	1.81E+08	9.11E+00	1.11E+06	8.21E-06
Fe-55	3.00E+08	1.51E+01	3.70E+06	4.07E-06
Fe-59	8.88E+07	4.46E+00	3.70E+05	1.21E-05
Co-58	4.07E+08	2.05E+01	7.40E+05	2.76E-05
Co-60	5.18E+08	2.60E+01	1.11E+05	2.35E-04
Ni-63	6.29E+07	3.16E+00	3.70E+06	8.54E-07
Zn-65	1.30E+07	6.51E-01	1.85E+05	3.52E-06
W-187	5.18E+06	2.60E-01	1.11E+06	2.35E-07
Np-239	8.14E+06	4.09E-01	7.40E+05	5.53E-07
Sr-89	1.34E+08	6.74E+00	2.96E+05	2.28E-05
Sr-90	1.47E+07	7.38E-01	1.85E+04	3.99E-05
Sr-91	4.89E+06	2.46E-01	7.40E+05	3.32E-07
Y-91m	3.99E+06	2.01E-01	7.40E+03	2.71E-05
Y-91	2.96E+08	1.49E+01	2.96E+05	5.03E-05
Y-93	1.07E+06	5.39E-02	7.40E+05	7.29E-08
Zr-95	7.24E+07	3.64E+00	7.40E+05	4.92E-06
Nb-95	1.39E+08	6.97E+00	1.11E+06	6.28E-06
Mo-99	1.21E+09	6.06E+01	7.40E+05	8.19E-05
Tc-99m	7.55E+08	3.79E+01	3.70E+07	1.03E-06
Ru-103	1.44E+08	7.25E+00	1.11E+06	6.53E-06
Rh-103m	1.37E+08	6.88E+00	2.22E+08	3.10E-08
Ru-106	2.63E+09	1.32E+02	1.11E+05	1.19E-03
Rh-106	2.29E+09	1.15E+02	-	-
Ag-110m	7.77E+07	3.91E+00	2.22E+05	1.76E-05

Table 11.2-10 (2 of 2)

Nuclide	Design Basis Release[(1)] (Bq/yr)	Effluent Concentration (Bq/m^3)	10 CFR 20, Appendix B Limits (Bq/m^3)	Ratio
Ag-110	4.07E+06	2.05E-01	-	-
Sb-124	1.59E+07	8.00E-01	2.59E+05	3.09E-06
Te-129m	5.74E+07	2.89E+00	2.59E+05	1.11E-05
Te-129	2.29E+06	1.15E-01	1.48E+07	7.79E-09
Te-131m	6.78E+07	3.41E+00	2.96E+05	1.15E-05
Te-131	1.01E+06	5.09E-02	7.40E+02	6.88E-05
I-131	9.99E+09	5.02E+02	3.70E+04	1.36E-02
Te-132	8.35E+08	4.20E+01	3.33E+05	1.26E-04
I-132	3.08E+08	1.55E+01	3.70E+06	4.18E-06
I-133	1.71E+10	8.57E+02	2.59E+05	3.31E-03
I-134	4.05E+06	2.04E-01	1.48E+07	1.38E-08
Cs-134	3.47E+09	1.74E+02	3.33E+04	5.24E-03
I-135	3.08E+09	1.55E+02	1.11E+06	1.40E-04
Cs-136	7.09E+09	3.56E+02	2.22E+05	1.60E-03
Cs-137	5.92E+10	2.98E+03	3.70E+04	8.04E-02
Ba-137m	1.55E+07	7.81E-01	-	-
Ba-140	1.67E+08	8.37E+00	2.96E+05	2.83E-05
La-140	1.81E+08	9.11E+00	3.33E+05	2.74E-05
Ce-141	1.11E+07	5.58E-01	1.11E+06	5.03E-07
Ce-143	7.03E+06	3.53E-01	7.40E+05	4.77E-07
Pr-143	2.41E+06	1.21E-01	7.40E+05	1.63E-07
Ce-144	2.44E+08	1.23E+01	1.11E+05	1.11E-04
Pr-144	9.99E+07	5.02E+00	2.22E+07	2.26E-07
H-3	5.40E+13	2.72E+06	3.70E+07	7.34E-02
Pr-144	9.99E+07	5.02E+00	2.22E+07	2.26E-07
H-3	5.40E+13	2.72E+06	3.70E+07	7.34E-02
			SUM	1.80E-01

(1) Release rate of design basis fuel leakage is adjusted from expected liquid radioactive effluents (Table 11.2-1) using multiplication factors that are the ratios of design-basis fuel failure primary coolant activity to expected activity.

Table 11.2-11 (1 of 2)

Expected Radioactive Source Terms for LWMS Tanks (Bq/cm^3)

Nuclide	Equipment Waste Tank	Floor Drain Tank	Chemical Waste Tank	Monitor Tank
Br-84	1.91E+02	2.63E+02	5.97E+00	2.71E-03
I-131	2.63E+01	3.62E+01	8.23E-01	3.23E-02
I-132	7.26E+02	9.99E+02	2.27E+01	4.67E-02
I-133	3.33E+02	4.58E+02	1.04E+01	1.71E-01
I-134	1.20E+03	1.65E+03	3.74E+01	2.77E-02
I-135	6.82E+02	9.37E+02	2.13E+01	1.22E-01
Rb-88	2.26E+03	3.11E+03	7.07E+01	8.96E-02
Cs-134	5.09E-01	7.00E-01	1.59E-02	3.53E-03
Cs-136	1.18E+01	1.63E+01	3.70E-01	7.57E-02
Cs-137	7.26E-01	9.99E-01	2.27E-02	5.04E-03
Na-24	5.79E+02	7.96E+02	1.81E+01	2.25E-02
Cr-51	3.94E+01	5.41E+01	1.23E+00	5.26E-03
Mn-54	2.03E+01	2.79E+01	6.34E-01	2.81E-03
Fe-55	1.52E+01	2.09E+01	4.75E-01	2.11E-03
Fe-59	3.81E+00	5.24E+00	1.19E-01	5.16E-04
Co-58	5.82E+01	8.01E+01	1.82E+00	7.96E-03
Co-60	6.72E+00	9.24E+00	2.10E-01	9.32E-04
Zn-65	6.46E+00	8.89E+00	2.02E-01	8.93E-04
Sr-89	1.77E+00	2.44E+00	5.54E-02	2.41E-04
Sr-90	1.52E-01	2.09E-01	4.75E-03	2.11E-05
Sr-91	1.17E+01	1.61E+01	3.67E-01	3.02E-04
Y-91m	5.50E+00	7.57E+00	1.72E-01	1.89E-04
Y-91	6.59E-02	9.06E-02	2.06E-03	1.83E-05
Y-93	5.15E+01	7.08E+01	1.61E+00	1.40E-03
Zr-95	4.93E+00	6.78E+00	1.54E-01	6.73E-04

Table 11.2-11 (2 of 2)

Nuclide	Equipment Waste Tank	Floor Drain Tank	Chemical Waste Tank	Monitor Tank
Nb-95	3.55E+00	4.88E+00	1.11E-01	4.98E-04
Mo-99	8.03E+01	1.10E+02	2.51E+00	7.75E-03
Tc-99m	5.73E+01	7.88E+01	1.79E+00	7.12E-03
Ru-103	9.50E+01	1.31E+02	2.97E+00	1.28E-02
Ru-106	1.14E+03	1.57E+03	3.57E+01	1.58E-01
Ag-110m	1.65E+01	2.27E+01	5.15E-01	2.28E-03
Te-129m	2.41E+00	3.31E+00	7.52E-02	3.24E-04
Te-129	2.87E+02	3.95E+02	8.97E+00	1.08E-03
Te-131m	1.87E+01	2.57E+01	5.84E-01	1.23E-03
Te-131	9.18E+01	1.26E+02	2.87E+00	3.23E-04
Te-132	2.14E+01	2.94E+01	6.68E-01	2.17E-03
Ba-137m	7.26E-01	9.99E-01	2.27E-02	4.71E-03
Ba-140	1.64E+02	2.26E+02	5.14E+00	2.10E-02
La-140	3.13E+02	4.30E+02	9.77E+00	3.38E-02
Ce-141	1.90E+00	2.61E+00	5.94E-02	2.55E-04
Ce-143	3.49E+01	4.80E+01	1.09E+00	2.44E-03
Ce-144	5.06E+01	6.95E+01	1.58E+00	6.99E-03
W-187	3.10E+01	4.27E+01	9.70E-01	1.76E-03

Table 11.2-12 (1 of 3)

Expected Radioactive Source Terms for Other LWMS Components (Bq)

Nuclide	Reverse Osmosis	Cation Bed	Mixed Bed 1	Mixed Bed 2
Na-24	2.14E+11	2.15E+10	2.36E+09	2.15E+07
Cr-51	1.25E+11	1.25E+10	1.38E+09	1.25E+07
Mn-54	7.11E+10	7.11E+09	7.82E+08	7.11E+06
Fe-55	5.36E+10	5.36E+09	5.90E+08	5.36E+06
Co-58	1.98E+11	1.98E+10	2.17E+09	1.98E+07
Fe-59	1.26E+10	1.26E+09	1.39E+08	1.26E+06
Co-60	2.37E+10	2.37E+09	2.61E+08	2.37E+06
Zn-65	2.26E+10	2.26E+09	2.49E+08	2.26E+06
Br-84	2.68E+09	3.75E+07	3.11E+08	2.86E+06
Rb-88	1.87E+10	2.09E+09	1.36E+08	1.05E+08
Sr-89	5.92E+09	5.93E+08	6.52E+07	5.93E+05
Y-89m	5.92E+05	5.92E+04	6.52E+03	5.92E+01
Sr-90	5.38E+08	5.38E+07	5.92E+06	5.38E+04
Y-90m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-90	3.24E+08	3.24E+07	3.56E+06	3.24E+04
Sr-91	2.80E+09	2.81E+08	3.09E+07	2.81E+05
Y-91m	1.76E+09	1.76E+08	1.94E+07	1.76E+05
Y-91	4.85E+08	4.85E+07	5.34E+06	4.85E+04
Y-93	1.30E+10	1.30E+09	1.43E+08	1.30E+06
Zr-93	1.32E+02	1.32E+01	1.45E+00	1.32E-02
Nb-93m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-95	1.67E+10	1.67E+09	1.83E+08	1.67E+06
Nb-95m	1.69E+08	1.69E+07	1.86E+06	1.69E+04
Nb-95	1.29E+10	1.29E+09	1.42E+08	1.29E+06
Mo-99	1.17E+11	1.17E+10	1.29E+09	1.17E+07
Tc-99m	1.09E+11	1.09E+10	1.20E+09	1.09E+07
Tc-99	6.36E+03	6.36E+02	6.99E+01	6.36E-01
Ru-103	3.12E+11	3.12E+10	3.43E+09	3.12E+07

Table 11.2-12 (2 of 3)

Nuclide	Reverse Osmosis	Cation Bed	Mixed Bed 1	Mixed Bed 2
Rh-103m	3.10E+11	3.10E+10	3.41E+09	3.10E+07
Ru-106	4.01E+12	4.01E+11	4.41E+10	4.01E+08
Rh-106m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh-106	4.01E+12	4.01E+11	4.41E+10	4.01E+08
Ag-110m	5.76E+10	5.76E+09	6.34E+08	5.76E+06
Ag-110	7.49E+08	7.49E+07	8.24E+06	7.49E+04
Te-129m	7.80E+09	7.81E+08	8.59E+07	7.81E+05
Te-129	1.33E+10	1.36E+09	1.49E+08	1.36E+06
I-129	1.16E+01	1.16E+00	1.28E-01	1.16E-03
Te-131m	1.37E+10	1.37E+09	1.51E+08	1.37E+06
Te-131	3.49E+09	3.58E+08	3.92E+07	3.58E+05
I-131	7.23E+10	6.59E+08	7.30E+09	6.64E+07
Xe-131m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	3.45E+10	3.46E+09	3.80E+08	3.46E+06
I-132	7.61E+10	3.57E+09	5.04E+09	4.59E+07
I-133	1.72E+11	6.54E+07	1.89E+10	1.72E+08
Xe-133m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-134	2.67E+10	2.35E+08	3.04E+09	2.78E+07
Cs-134	1.79E+09	1.79E+08	9.97E+06	8.97E+06
I-135	1.13E+11	1.34E+08	1.25E+10	1.14E+08
Xe-135m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-136	3.35E+10	3.36E+09	1.87E+08	1.68E+08
Cs-137	2.57E+09	2.57E+08	1.43E+07	1.29E+07
Ba-137m	2.40E+09	2.40E+08	1.34E+07	1.20E+07
Ba-140	4.65E+11	4.65E+10	5.11E+09	4.65E+07

Table 11.2-12 (3 of 3)

Nuclide	Reverse Osmosis	Cation Bed	Mixed Bed 1	Mixed Bed 2
La-140	6.53E+11	6.53E+10	7.19E+09	6.53E+07
Ce-141	6.15E+09	6.15E+08	6.77E+07	6.15E+05
Ce-143	2.80E+10	2.80E+09	3.08E+08	2.80E+06
Pr-143	8.09E+09	8.09E+08	8.89E+07	8.09E+05
Ce-144	1.77E+11	1.77E+10	1.95E+09	1.77E+07
Pr-144	1.77E+11	1.77E+10	1.94E+09	1.77E+07
W-187	1.82E+10	1.82E+09	2.00E+08	1.82E+06
Np-239	3.53E+10	3.53E+09	3.89E+08	3.53E+06

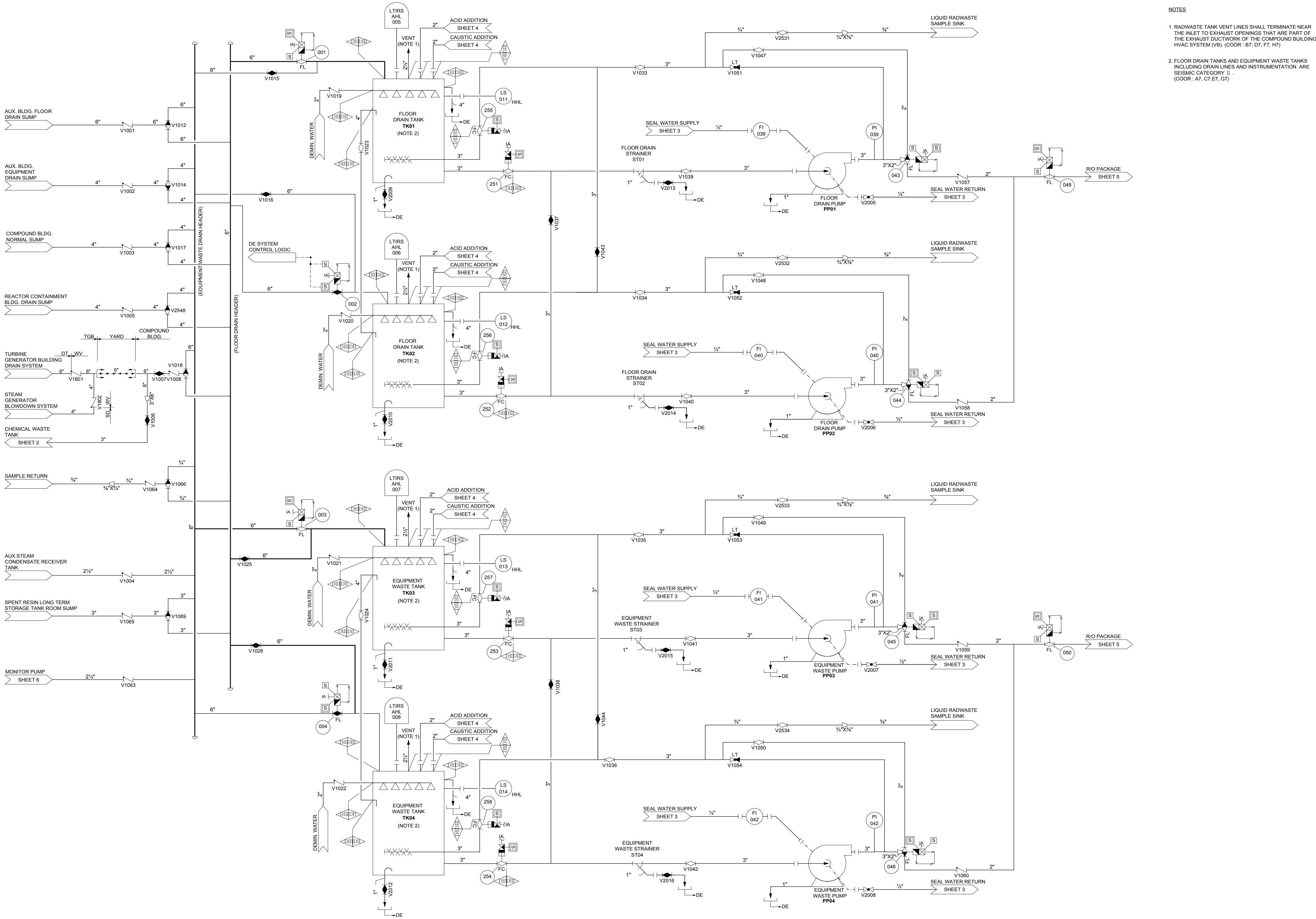

Figure 11.2-1 Liquid Radwaste System Flow Diagram (1 of 7)

NOTES

1. CHEMICAL WASTE TANK VENT SHALL TERMINATE NEAR THE INLET TO EXHAUST OPENINGS THAT ARE PART OF THE EXHAUST DUCTWORK OF THE COMPOUND BUILDING HVAC SYSTEM(VB). (COOR : D7, F7)

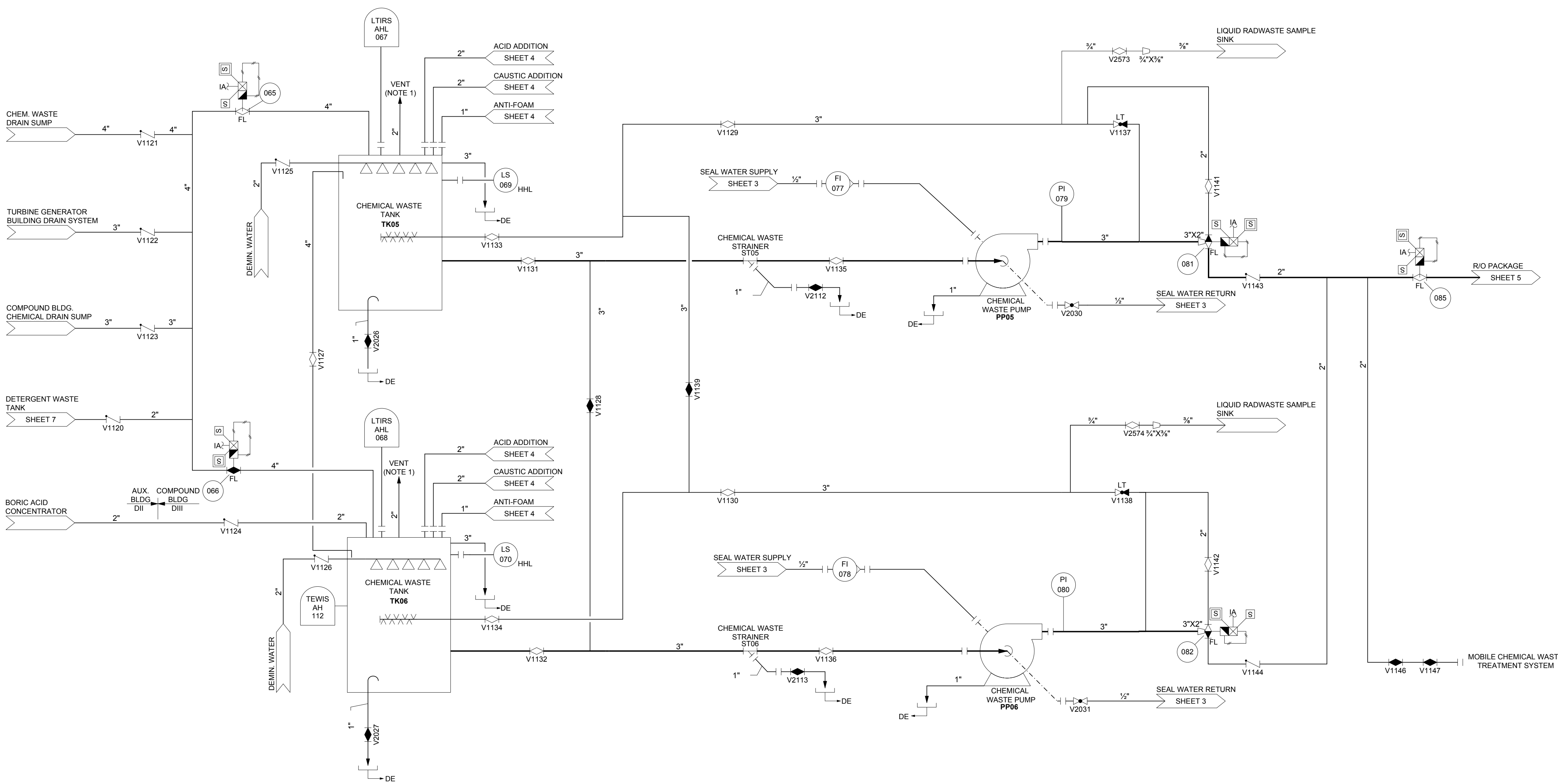

Figure 11.2-1 Liquid Radwaste System Flow Diagram (2 of 7)

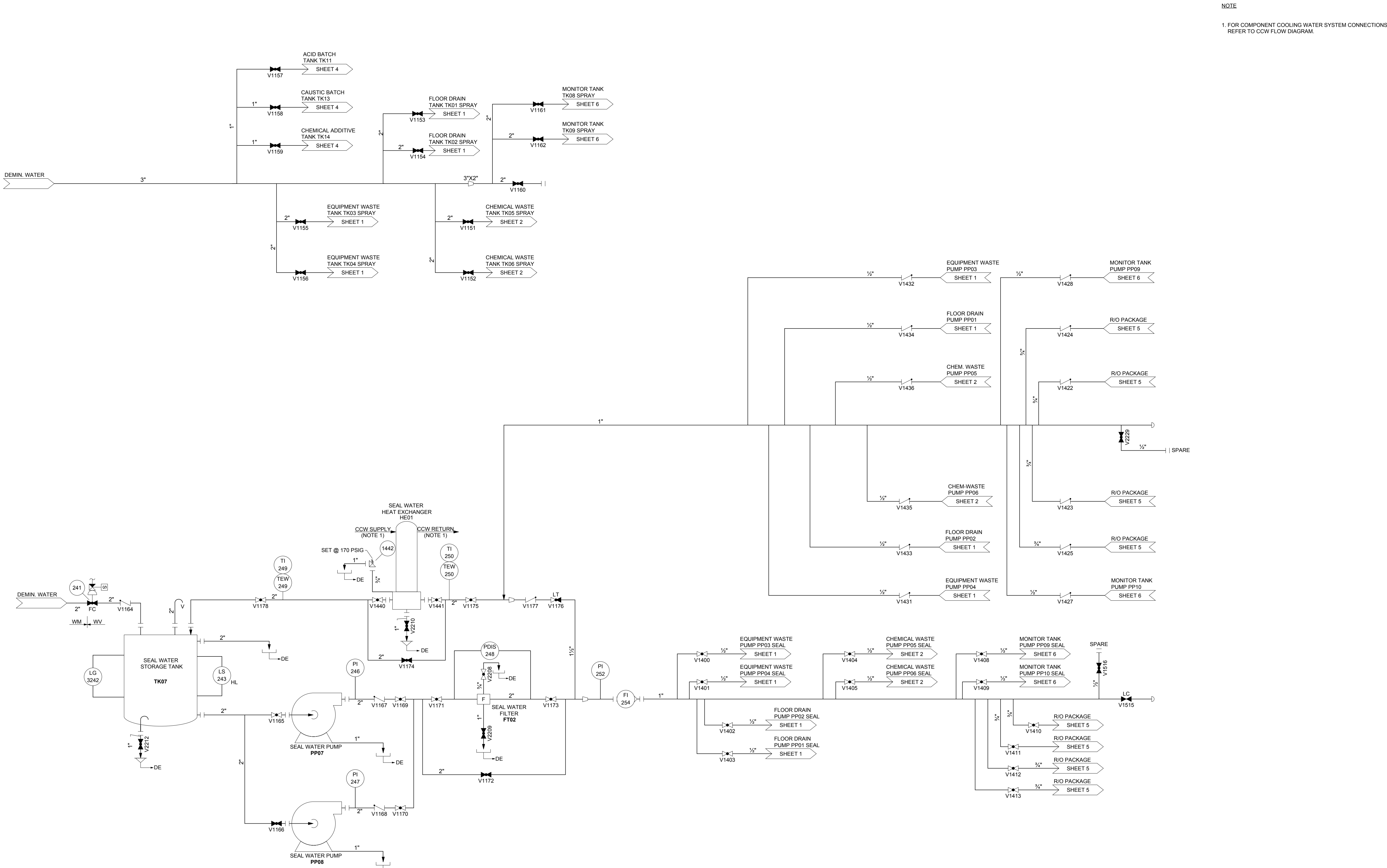

Figure 11.2-1 Liquid Radwaste System Flow Diagram (3 of 7)

NOTES

1. ANNUNCIATOR WILL BE MOUNTED NEAR TRUCK FILL AREA.

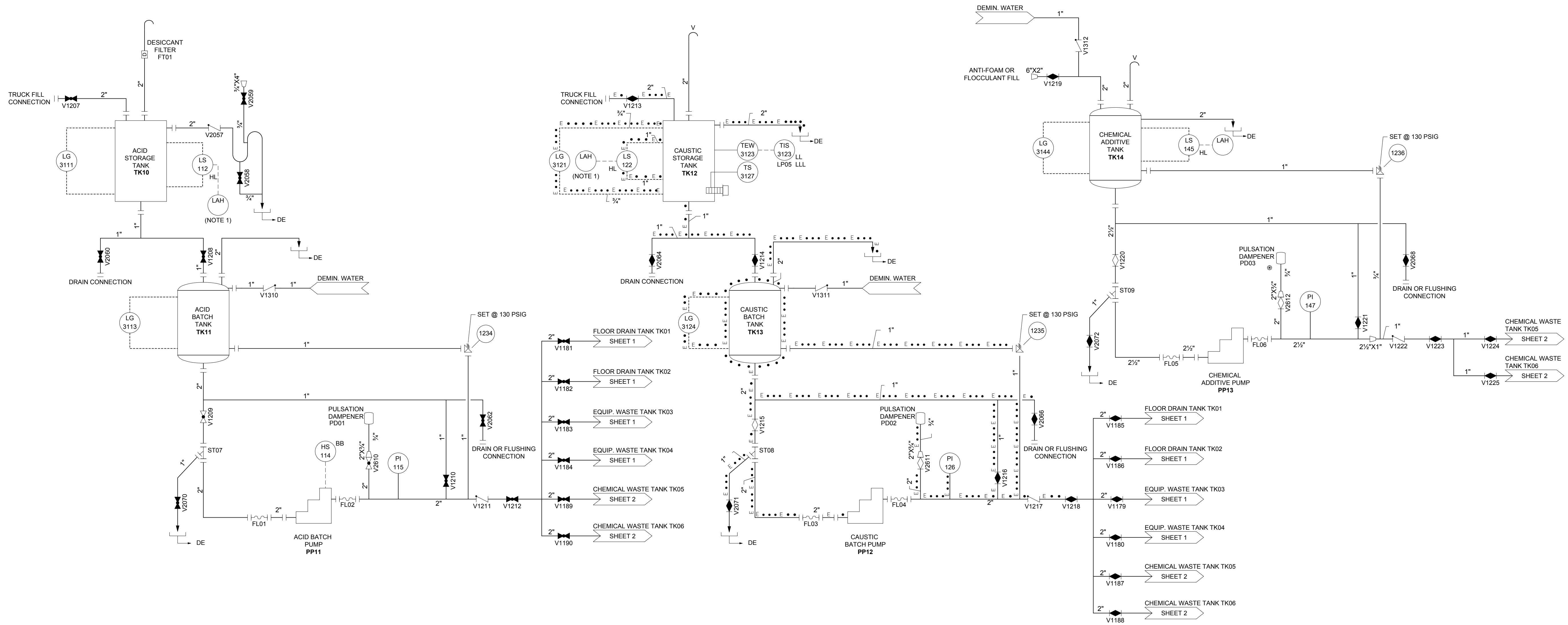

Figure 11.2-1 Liquid Radwaste System Flow Diagram (4 of 7)

NOTES

1. R/O MODULE,CATION BED AND MIXED BEDS ARE SEISMIC CATEGORY Ⅲ UNLESS OTHERWISE SHOWN. (COOR : C4, F4, C5, F5, C6, F6, C7, F7)

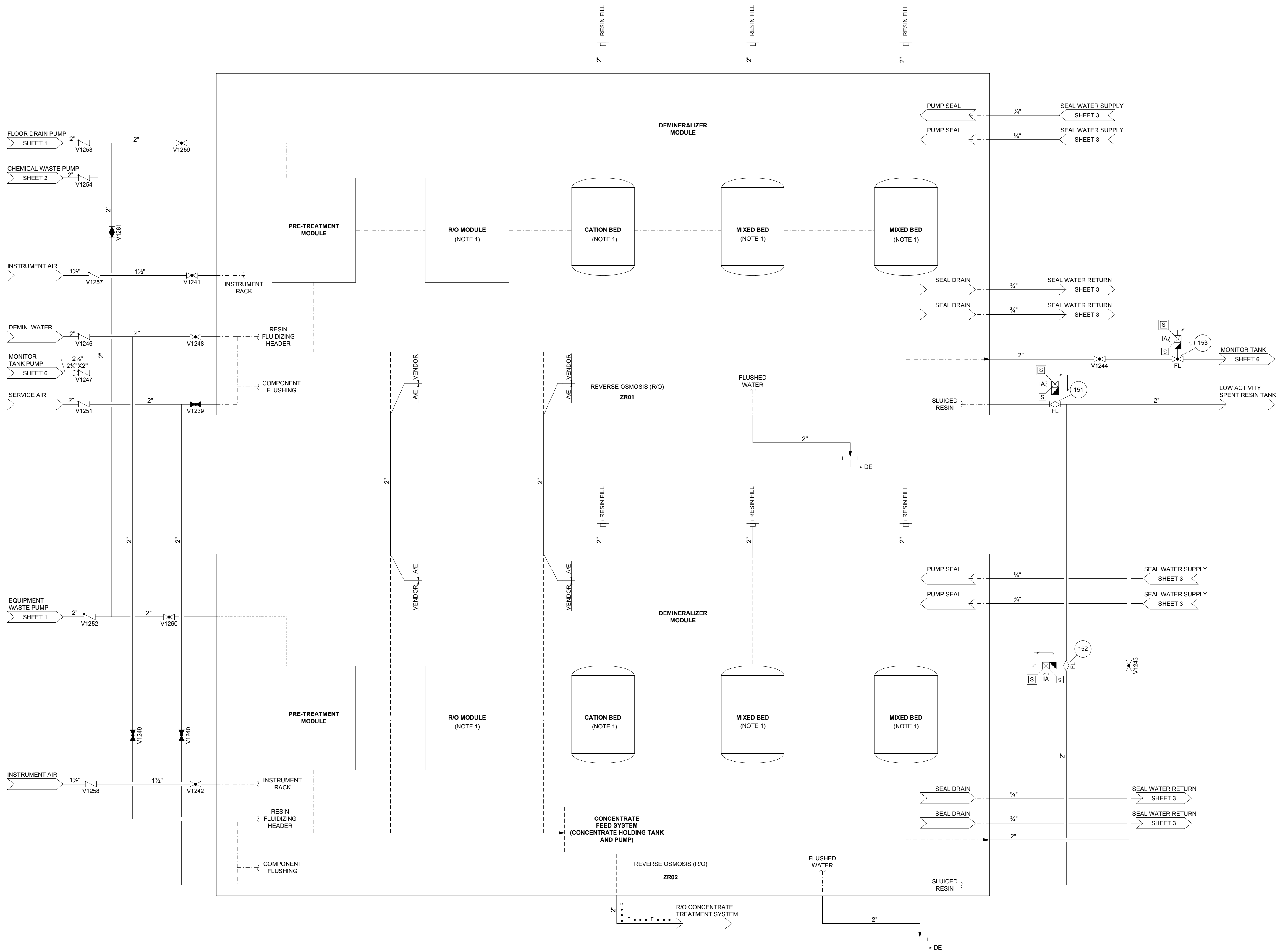

Figure 11.2-1 Liquid Radwaste System Flow Diagram (5 of 7)

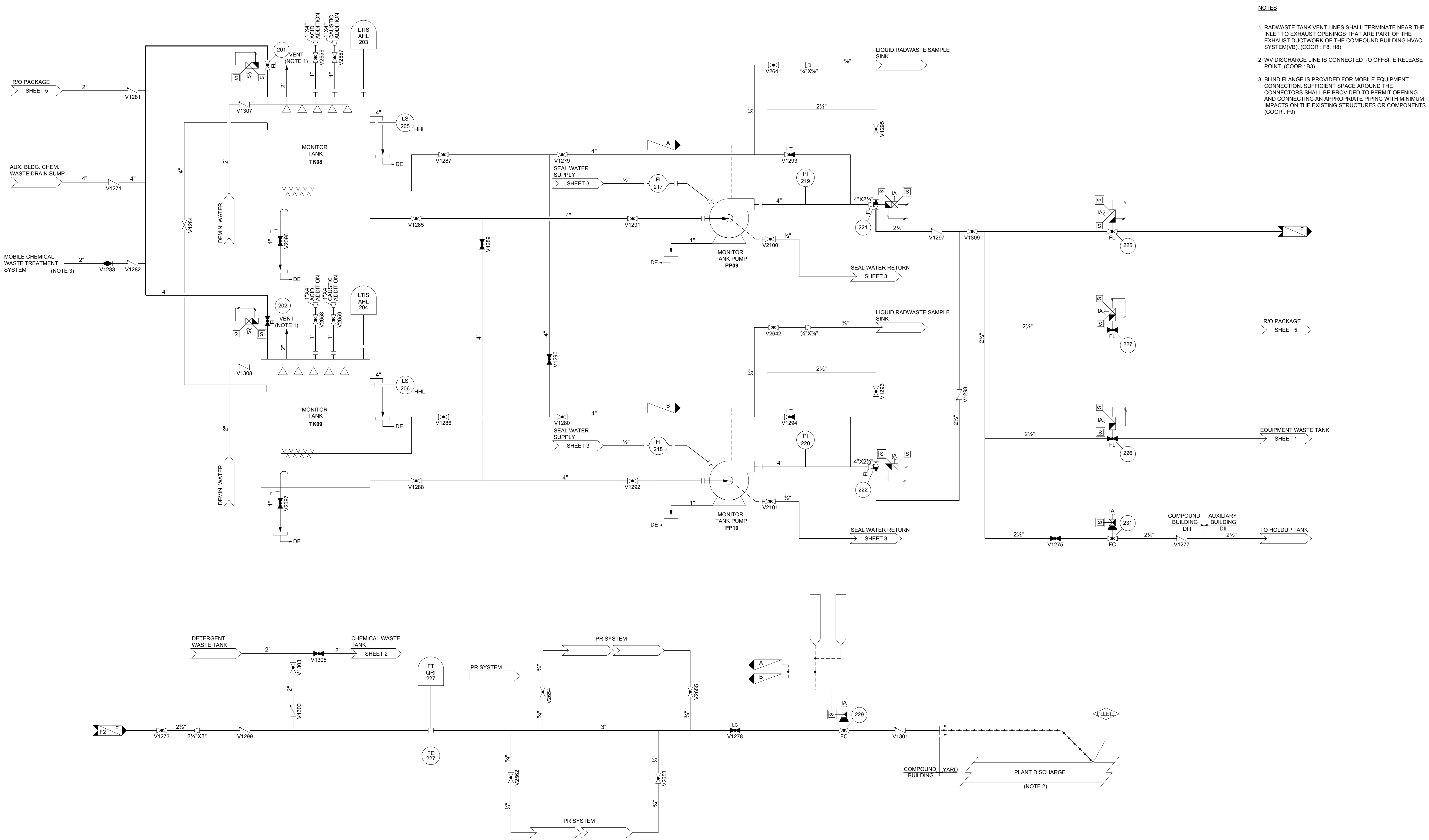

Figure 11.2-1 Liquid Radwaste System Flow Diagram (6 of 7)

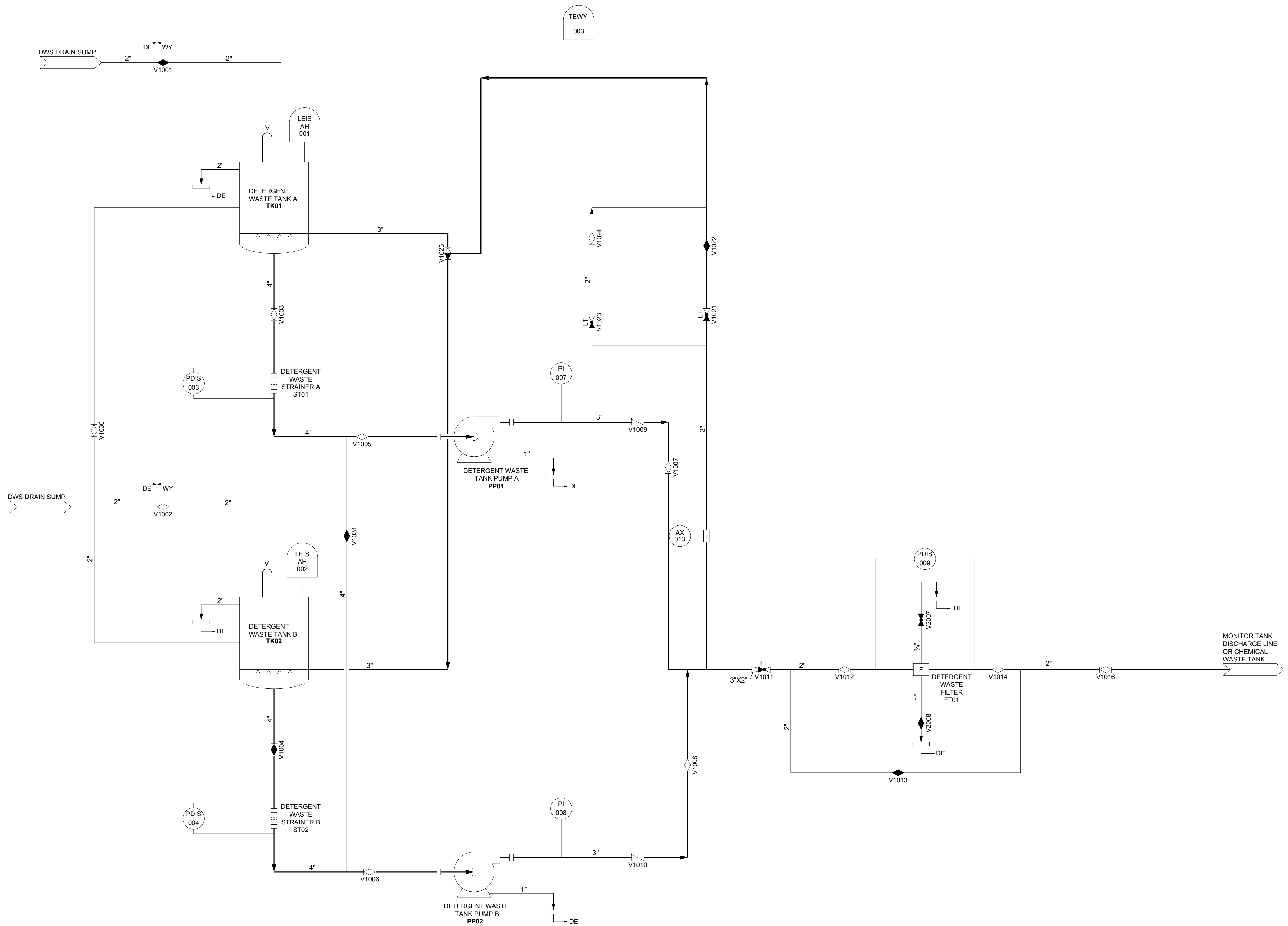

Figure 11.2-1 Liquid Radwaste System Flow Diagram (7 of 7)

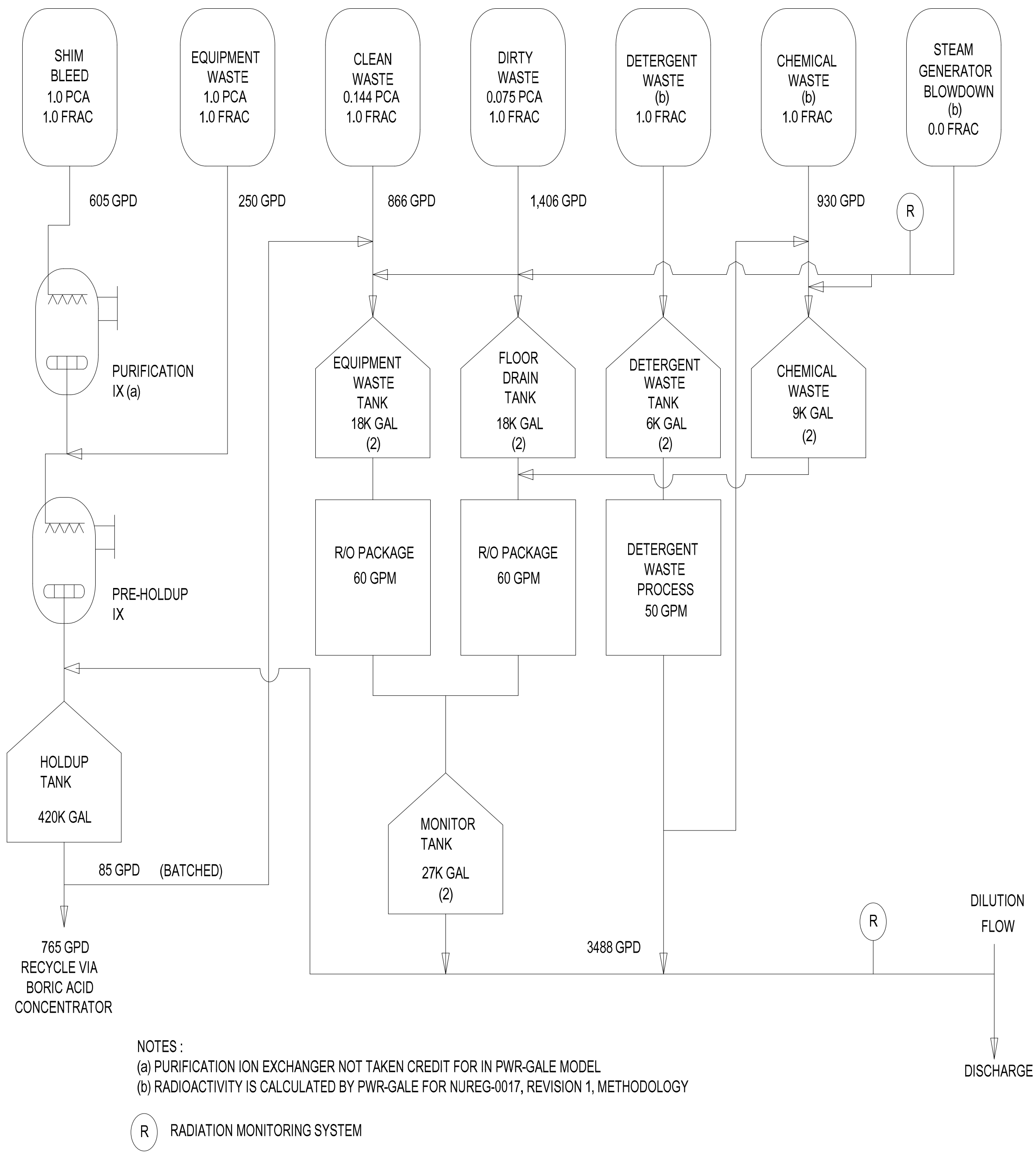

Figure 11.2-2 Simplified Liquid Process Model