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HANFORD TANK WASTE REMEDIATION SYSTEM FAMILIARIZATION REPORT

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GLOSSARY

This is a glossary of Hanford terminology that has been primarily derived from Agnew (1996) and the Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS) (U.S. Department of Energy, 1996a). Additional terms have been added from other sources. Not all these terms may appear in the TWRS Familiarization Report, but it was deemed useful to compile all these terms for possible future use. The uncertainty as to an exact meaning of a term is indicated by a "?."

1C—1st Cycle Decontamination-(Bismuth Phosphate) $BiPO_4$ process. Often included cladding waste. Held 10 percent of FP, 1 percent of Pu. See also $BiPO_4$, MW, and 2C.

1C1—First cycle decontamination waste from the $BiPO_4$ process, 1944 to 1951.

1C2—First cycle decontamination waste from the $BiPO_4$ process, 1952 to 1956.

1CFeCN—Ferrocyanide sludge produced by in-plant scavenging of 1C supernatant wastes. Used 0.005M ferrocyanide.

1CS—1st Cycle Scavenging waste. TY-101 and TY-103 received 1C waste that was scavenged with FeCN before it was added to the tanks; termed 1CFeCN.

1st Generation Tank—The original tank design encompassing Tank Farms B, C, T, U (excluding the 200 series tanks), and BX. These tanks have an operating capacity of 530,000 gallons, a 75-foot diameter, a 12-inch dish bottom, and a 4-foot knuckle. Also see Type II tanks.

2C—2nd Cycle Waste from $BiPO_4$ process. Supernatant often cribbed, 0.1 percent of FP, 1 percent of Pu. See also $BiPO_4$, MW, and 1C.

2C1—2nd Cycle Waste from $BiPO_4$ process, 1944 to 1951.

2C2—2nd Cycle Waste from $BiPO_4$ process, 1952 to 1956.

2nd Generation Tank—Same as original tank design (1st Generation or Type II) except the operating capacity was increased to 758,000 gallons. Also, see Type III tanks.

202-S—Also known as S Plant where REDOX process ran 1952–1966.

204-AR—Rail Car Unloading Facility, completed in 1981, replaced 204-S as Rail Car Unloading Facility.

211-T—Chemical storage area used for nitric acid and sodium hydroxide storage, and low-level radioactive sludge storage.

221-B—See 222-B Plant.

221-T—Head End facilities (two cells) in 221-T Building are used as a containment systems test facility to develop sodium aerosol data needed for the design of air cleaning equipment for large-scale Liquid Metal Fast Breeder Reactors. 221-T Building (Cell 4) used for interim storage of Pressurized Water Reactor Core II fuel from Shippingport Atomic Power Station. See also T Plant.

GLOSSARY (Cont'd)

222-B—One of the three original Bismuth Phosphate Processing Facilities. Later converted to waste fractional plant. B Plant used for $BiPO_4$ 1944–1952, then for FP recovery. See also B Plant and TK.

222-C—Initially a pilot plant for REDOX, later a pilot plant for PUREX and B Plant waste partitioning. See also C Plant.

222-T—T Plant used for $BiPO_4$ 1944–1952.

222-U—One of the three original Bismuth Phosphate Processing Facilities. Later converted to a uranium recovery plant. See also U Plant.

224—LaF finishing waste. 224-U Waste. See also P, PFP, PRF, TRU, and Z

224-2—Same as 224.

224-AR Vault—Originally designed for treating and transferring tank farm sludges to B Plant and for interim lag storage and transfer of PUREX acid wastes to plant. Also used for lag storage of neutralized high-level waste enroute from B Plant to tank farm storage. Construction completed in 1968; put in standby mode in 1978.

224-F—224-U Waste. LaF Pu Finishing Plant. Same as Z Plant. See also LaF.

224-U—Completed in 1944 as part of U Plant complex. Never used for original purpose. Used as training facility from 1944 to 1950, converted to UO_3 Plant in 1951. Plant shut down in 1972. Restarted in 1984. Feedlines from REDOX and U Plant canyon disconnected. See also 224-F.

224-UA—Constructed in 1957 with six calciners installed. UO_3 Plant capability sufficient to handle UNH stream from REDOX, U Plant, and PUREX.

225-B—See also WESF Plant.

231-Z—Dilute phosphate waste from Z-231 laboratories.

241-Z—Underground sump pit.

242-A—Reduced pressure evaporator in East Area designed for 30 percent solids. A-102 was feed from 1977 to 1980. AW-102 was feed from 1981 to the present.

242-B—Atmospheric evaporator used for concentrating wastes, 1952–1956. B-106 was feed tank.

242-S—Reduced pressure evaporator designed for 30 percent solids 1973–1980. S-102 was feed from 1973 to 1977. SY-102 was feed from 1977 to 1981.

242-T—Atmospheric evaporator used to concentrate wastes. 1952–1956 and 1965–1976. TX-118 was feed tank.

GLOSSARY (Cont'd)

242-Z—Waste treatment facility. Equipment was used to treat PRF waste and extract americium from the waste. Scheduled for decontamination and decommissioning.

244-AR Vault—Originally designed for treating and transferring tank farm sludges to B Plant and for interim lag storage and transfer of PUREX acid wastes to B Plant. Also used for lag storage of neutralized high-level waste enroute from B Plant to tank farm storage.

2706-T—Used as equipment in low-level decontamination facility. See also T Plant, 221-T and 271-T.

271-T—Building used for chemical make-up area and dry storage, and offices. See also T Plant, 2706-T, and 221-T.

2736-ZA—Plutonium Storage and Support Facility. Used to store plutonium in a variety of forms, packaged in metal containers. Also used for shipping, receiving, repackaging, and nondestructive analysis of plutonium. See also 2736-ZAB.

2736-ZAB—Plutonium Storage and Support Facility. Used to store plutonium in a variety of forms, packaged in metal containers. Also used for shipping, receiving, repackaging, and nondestructive analysis of plutonium. See also 2736-ZA.

3rd Generation Tank—The first generation of the Type IV tanks, located in the SX Tank Farm only. These tanks have a 1,000,000-gallon operating capacity, a 75-foot diameter, a 14.875-inch dish bottom, and no knuckle. See also Type IV tanks.

4th Generation Tank—The second generation of the Type IV tanks, located in the A Tank Farm only. These tanks are the same as the third generation except they have a flat bottom. See also Type IV Tanks.

5th Generation Tank—The third generation of the Type IV tanks, found only in the AX Tank Farm. These tanks are the same as the fourth generation with the addition of grid drain slots beneath the steel liner bottom.

A Plant—This is also called the PUREX plant. The PUREX process ran from January 1952–June 1972, then was in standby and ran again from November 1983–1991, and is now shut down. See also PUREX Plant, CWP, and OWW.

A1SltCk—Salt Cake waste generated from the 242-A Evaporator-Crystallizer from 1977 until 1980.

A2SltSlry—Salt Slurry waste generated from the 242-A Evaporator-Crystallizer from 1981 until 1994.

Active—Currently operating or scheduled for further operation.

Active Drywell—Drywell in which radiation readings of greater than 50 counts/second are detected. To be considered "active," these readings must be consistent as to depth and radiation level for repeated readings.

GLOSSARY (Cont'd)

Active Institutional Control—Continued Federal control of the Hanford site along with maintenance and surveillance of facilities.

Active Tank—A tank that contains more than 33,000 gallons of waste and/or is still involved in waste management operations.

AEC—Atomic Energy Commission. See also ERDA and DOE.

Aging Waste—High-level, first cycle solvent extraction waste from the PUREX plant

Air Lift Circulator (ALC)—The air lift circulators installed in aging tanks to promote mixing of the supernate. By maintaining motion within the body of the liquid, the circulators minimize superheat buildup and, consequently, minimize bumping.

ALARA—A requirement and approach to control of radiological or hazardous material whereby individual and collective exposures to the work force and to the general public are managed and controlled to be at levels As Low As Reasonably Achievable. This is not a dose limit but a process that has the objective of attaining doses as far below the applicable controlling limits as is reasonably achievable. It takes into account the social, technical, economic, practical, and public policy factors.

ALE—Fitzner-Eberhardt Arid Land Ecology Reserve. This is a 124-square-mile area in the western part of the Hanford site that has been relatively undisturbed for almost 50 yr. Access is limited to this site for scientific purposes.

ANL—Argonne National Laboratory.

Annulus—The annulus is the space between the inner and outer shells on DSTs. Drain channels in the insulating and/or supporting concrete carry any leakage to the annulus space where conductivity probes and radiation detectors are installed.

ANSI—American National Standard Institute.

Anticline—An arch of stratified rock in which the layers bend downward in opposite directions from the crest.

Aquifer—A body of permeable rock, rock fragments, or soil through which groundwater moves.

ARM—Area Radiation Monitor.

ASME—American Society of Mechanical Engineers.

Assumed Leaker—The integrity classification of a waste storage tank for which surveillance data indicate a loss of liquid attributed to a breach of tank integrity.

GLOSSARY (Cont'd)

Assumed Leaking Tank—In 1984, the criteria designations of "suspect leaker," "questionable integrity," "confirmed leaker," "declared leaker," "borderline," and "dormant" were merged into one category now reported as "assumed leaker."

Assumed Re-Leaker—A designation that exists after a tank has been declared an "assumed leaker" and then the surveillance data indicate a new loss of liquid attributed to a breach of integrity.

ASTM—American Society for Testing and Materials.

AW—Designation of a tank farm. Also can stand for neutralized current acid waste.

AWC—Aging Waste Condensate.

AWWA—American Water Works Association.

B—High-level waste from the B plant.

B Plant (222-B)—A facility located in the 200-East area of the Hanford site. $BiPO_4$ ran in B Plant from April 1945 to October 1952, while Cs/Sr recovery from tank farms ran from 1967-1976, and Cs/Sr recovery from NCAW and CAW ran from 1967-1972, and then from 1983-1991. B Plant's mission from 1967 was to take the acid stream from PUREX through cesium and strontium recovery operations.

Basalt—Dark to medium-dark colored rocks of volcanic origin with relatively low SiO_2 content.

BC—TRU solids from B Plant processing of complexant concentrate waste.

Beyond Design Basis Accident—An accident with an annual frequency of occurring between 1 in 1 million and 1 in 10 million.

BHI—Bechtel Hanford, Inc.

BL—Low-level waste from B Plant.

Boiling Waste—Waste containing sufficient radioactive decay heat to self-boil.

Bottom Referenced Tank—Either a dished bottom tank or a flat bottom tank where the zero point for liquid-level gages is the lowest elevation in the tank.

Bottoms Receivers—Tank designated for receiving evaporator bottoms.

Bottoms (Tank)—Material remaining in waste tanks after most of the tank contents have been pumped out. This is also referred to as tank heel.

GLOSSARY (Cont'd)

BP [Bismuth Phosphate ($BiPO_4$)] Process—First precipitation process used at the Hanford Site for separating plutonium from the irradiated uranium fuels. This process was replaced by REDOX and PUREX processes to gain the advantages of separation and recovery of the uranium and plutonium fission products in B-222 and U-222, 1944–1956. Left U in waste. See also MW, 1C, and 2C.

Bumping, Tank Bump—A tank bump occurs when solids overheat in the lower portion of the tank. The hot solids are mixed with the cooler fluid either by operation of the ALCs or by natural means. The hot solids rapidly transfer heat to the liquid, some of which quickly vaporizes. The sudden pressurization caused by vapor generation is called a "bump."

Burial Ground (garden)—A land area specifically designated to receive packaged contaminated wastes and equipment for burial. Rated volume at the time of construction.

Burping—Burping is a term commonly used to refer to a rollover event due to gas generation. Hydrogen gas generated, notably in tank SY-101, in a lower layer, makes that layer light enough to roll over to the top, potentially releasing flammable gas.

BWIP—Basalt Waste Isolation Project.

C Plant—Strontium Semiworks. Called C Plant or Hot Semiworks earlier, was pilot for both REDOX and PUREX, July 1952 to July 1956. Then reconfigured for Strontium Recovery Pilot Plant from July 1960 to July 1967. See also 222-C, SSW, and HS.

Caisson—An underground structure used to store high-level waste; typical designs include corrugated metal or concrete cylinders, 55-gallon drums welded end-to-end, and vertical steel pipes below grade.

Calcine—To heat a substance to a high temperature, but below its melting point, causing loss of volatile constituents such as moisture; refers also to the material produced by this process.

Caliche—An accumulation of calcareous material formed in soil or sediments in arid regions.

CAM—Continuous Air Monitor.

Canyon—A heavily shielded, partially below grade concrete structure used for remote chemical processing of radioactive fuels or wastes.

CAS, Cascade—Tanks connected in series placed at different elevations allowing liquids to flow from one tank to another. This process filled three or more tanks with one pump by using overflow lines. Normal use was with a sequence of tank numbers, that is, 101, 102, 103, or 110, 111, 112.

CASS—Computer Automated Surveillance System (applies to the AY and AZ Farms).

Catch Tank—Small-capacity single-wall tank, primarily associated with diversion boxes and diverter stations. The tanks collect liquid from diversion boxes, diverter stations, catch stations, and other facilities.

GLOSSARY (Cont'd)

Cathodic Protection (CP)—A method employed to mitigate corrosion of metals, mainly steels, whereby the electrode potential of the steel is brought to a value below its equilibrium potential or to values where active corrosion does not occur.

CAW—Current Acid Waste—this is PUREX acid waste, also called HAW or IWW. See also HAW, IWW, and PAW.

CC—Complexant Concentrate waste.

CDE or CEDE—Committed Effective Dose Equivalent. This is the sum of committed radiological dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. A 70-yr dose commitment period was assumed in the TWRS EIS (U.S. Department of Energy, 1996a)

Cell 23—Waste from Cell 23 at B Plant. Cell 23 contained an evaporator and was used not only during B Plant operations, but to reduce tank waste volume as well.

CERCLA—Comprehensive Environmental Response, Compensation and Liability Act.

CF—Corrosivity Factor. Ratio of the molar concentration of NO_3^- to the combined molar concentrations of NO_2^- and OH^- used to evaluate the potential for localized corrosion of carbon steel in radioactive waste.

CFR—Code of Federal Regulations.

CHP—Cascade Heel Pit.

Ci—Curies.

Cladding Removal Waste—Chemical wastes resulting from dissolving the metal sheath or coating surrounding fuel elements. These chemical wastes usually are contaminated with activation products, fission products, and some transuranic elements.

CLU—Chemical Laboratory Unit.

CMPO—N-diisobutylcarbmoylmethylphosphine oxide.

Complexants—Organic chemicals that assist in chelating metallic atoms.

Conductivity Probe—Measures surface level of conductive liquid (or waste) by detecting electrical conductivity between probe tip and liquid/waste surface as it is lowered into contact.

Confined Aquifer—A subsurface water-bearing region that has defined, relatively impermeable upper and lower boundaries. The impermeable boundary is referred to as a confining layer.

GLOSSARY (Cont'd)

Confirmed or Declared Leaker—The designation of any underground waste storage tank where the data are considered sufficient to support a conclusion with 95 percent confidence that the tank has leaked.

CPLX—Complexed waste. See also CC.

CPP—Cascade Pump Pit.

CPS—Criticality Prevention Specifications.

CPW—Concentrated Phosphate Waste. Waste originating from the decontamination of 100-N Area reactor. Concentration of this waste produces concentrated phosphate waste.

CR Vault—Facility located adjacent to C Farm, used for scavenging campaign following Uranium recovery, 1952–1958. Ferrocyanide was added to tank supernatants in CR-Vault, and then the slurry was returned to C Farm for settling, forming in-farm sediments.

CRB—Columbia River Basalts.

Credible Accident—An accident that has an annual probability of occurrence greater than or equal to 1 in 1 million.

Crib—An underground structure designed to receive liquid waste from tanks or evaporators that can percolate into the soil directly or after traveling through a connected tile field.

Crust—A hard surface layer that has formed in many waste tanks containing concentrated solutions.

CRW—Cladding Removal Waste.

CSB—Container Storage Building is being constructed to provide dry storage for spent fuel from the K basins.

CSP—Cascade Sluice Pit.

CSR—Tank supernatant was sent to B Plant for Cesium recovery using C-105 as a staging tank. From 1967–1976, 21,724 kgal was sent to and 26,290 kgal returned from B Plant. See also IX.

CSS—Concentrated Supernatant Solids.

CST—Caustic Solution, 0.01 M NaOH.

CTW—Caustic Waste for makeup.

Cullet—Small pieces of glass formed when hot molten glass is quenched in a water bath.

Current Acid Waste—The high level waste stream from the PUREX plant that contains most of the fission products from the dissolved fuel.

CW—Cladding Waste, included with 2C from 1945–1950, and with 1C from 1951–1956.

CW-Al—Aluminum Cladding Waste.

CWHT—Concentrated Waste Holding Tank.

CWP—Cladding Waste PUREX. See also A Plant, PUREX Plant, and OWW.

CWP2—Cladding Waste. PUREX 2?

CWR—Cladding Waste-REDOX. See also REDOX and R.

CWR1—REDOX Cladding Waste from 1952 to 1960.

CWR2—REDOX Cladding Waste from 1961 to 1967.

CWZr1—Cladding Waste from PUREX 1966–1970 that used Zirflex process on Zircaloy clad fuel elements. See also PD and NCRW.

CWZr2—Cladding Waste (REDOX), zirconium cladding.

D & D—Decontamination and Decommissioning.

D2EHPA—di-2-ethylhexyl phosphoric acid.

DBA—Design Basis Accident is a postulated abnormal event for nuclear facilities that is used to establish performance requirements of structures, systems, and components that are necessary to maintain them in a safe shutdown condition indefinitely or to prevent or mitigate consequences so that the general public and operating staff are not exposed to radiation in excess of guideline values.

DBE—Design Basis Earthquake is the maximum intensity earthquake that might occur along the nearest fault to a structure. Structures are built to withstand DBE. This definition as provided in the TWRS EIS may not be conservative. NRC 10 CFR Part 100 App. A, replacing DBE by Safe Shutdown Earthquake (SSE). See under SSE.

DBP—Dibutyl Phosphate.

DBPW—Dilute "B" Plant Waste.

DC—Dilute Complexed. Waste characterized by a high content of organic carbon including organic complexants: ethylenediaminetetra-acetic acid (EDTA), citric acid, hydroxethylenediaminetriacetic acid (HEDTA), and iminodiacetate (IDA) being the major complexants used. Main sources of dilute complexed waste in the double-shell tanks system are salt well liquid inventory. See also EDTA, HEDTA, and IDA.

DCG—Derived Concentration Guide.

GLOSSARY (Cont'd)

DCH 18-Cr-6—Dicyclohexano 18-Crown-6 Ether.

DCS—Dilute Caustic Solution.

DCW—Dilute Complexed Waste.

DDSSF—Dilute Double Shell Slurry Feed.

DF—Decontamination Factor is the factor by which the concentration of radioactive contaminants is reduced, measured by the ratio of initial radioactivity to that after decontamination.

DIL—Dilute Feed for Evaporator input. Interstitial liquid that is not held in place by capillary forces, and will therefore migrate or move by gravity. See also DILFD.

DILFD—Dilute Feed. See also DIL.

Diversion Box—A below-grade concrete enclosure containing the remotely maintained jumpers and spare nozzles for diversion of waste solution to storage tank farms.

DNCPW—Dilute Noncomplexed Waste, defined as waste with no complexants and TOC > 1 weight percent.

DNFSB—Defense Nuclear Facilities Safety Board.

DoD—U.S. Department of Defense.

DOE—U.S. Department of Energy. See also AEC.

DOE/RL—U.S. Department of Energy/Richland (Field Office).

DOH—Washington Department of Health.

Dose Equivalent—Product of the absorbed dose, the quality factor, and any other modifying factors to compare the biological effectiveness of different types of radiation on a common scale.

DQO—Data Quality Objective is a series of planning steps to identify and design more efficient and timely data collection programs.

Drainable Interstitial Liquid—Liquid that is not held in place by capillary forces, and will therefore migrate or move by gravity. Drainable liquid remaining minus supernate. Drainable Interstitial Liquid is calculated based on the salt cake and sludge volumes, using average porosity values or actual data for each tank, when available.

Drainable Remaining Liquid—Supernate plus drainable interstitial.

DRCVR—Dilute Receiver Tank.

GLOSSARY (Cont'd)

Drywell—Vertical boreholes with 6-inch (internal diameter) carbon steel casings positioned radially around single-shell tanks. Periodic monitoring is done by gamma radiation or neutron sensors to obtain scan profiles of radiation or moisture in the soil as a function of well depth, which could be indicative of tank leakage. These wells range between 50 and 250 feet in depth, and are monitored between the range of 50 to 150 feet. The wells are sealed when not in use. The wells are called drywells because they do not penetrate to the water table and are therefore usually "dry."

Drywell (in tank)—A sealed casing within a tank that is attached to a riser and used for access of a gamma or neutron detector, or an acoustical probe to determine the level of interstitial liquid.

DSC—Differential Scanning Calorimetry.

DSS—Double-Shell Slurry in a concentrate of DSSF.

DSSF—Double-Shell Slurry Feed. Waste concentrated just before reaching the sodium aluminate saturation boundary in the evaporator without exceeding receiver tank composition limits. This form is not as concentrated as DSS. See also DSS and DDSSF.

DST—Double-Shell Tank. The newer one million gallon underground waste storage tanks consisting of a concrete shell and two concentric carbon steel liners with an annular space between the liners.

DTPA—diethylene-triamine-penta-acetic acid.

DW—Decontamination Waste.

Ecology—Washington State Department of Ecology.

EDE—Effective Dose Equivalent is a value used for estimating the total risk of potential health effects from radiation exposure. This estimate is the sum of the committed effective dose equivalent from internal deposition of radionuclides in the body and the effective dose equivalent from external radiation.

EDTA—Ethylenediaminetetra-acetic acid. See also, DC, HEDTA, and IDA.

EF—Evaporator Feed.

EFD—Evaporator Feed Dilute.

EGR—Episodic Gas Release.

EIS—Environmental Impact Statement.

Encasement Pipe—The carbon steel pipe used as encasement of the primary pipe in the RCSTS and other transfer pipings.

ENRAF—A gauge fabricated by ENRAF Inc. to determine waste level by detecting variations in the weight of a displacer suspended in the tank waste, which are detected by a force transducer.

GLOSSARY (Cont'd)

EP—Enclosure Pit.

EPA—Environmental Protection Agency.

EPRI—Electric Power Research Institute.

ERA—Expedited Response Action.

ERDA—Energy Research and Development Administration. See also AEC and DOE.

ERDF—Environmental Restoration Disposal Facility.

ERPG—Emergency Response Planning Guideline.

ES&H—Environment, Safety, and Health.

ESRI—Environmental Systems Research Institute, Inc.

ETF—Effluent Treatment Facility.

Evaporator Crystallizer—242-A and 242-S waste concentration facilities that operate at a reduced pressure (vacuum) and are capable of producing a slurry containing about 30 volume percent solids at a specific gravity of greater than 1.6.

Evaporator Feed—Any waste liquid that can be concentrated to form salt cake; for example, low heat waste, dilute interstitial liquor, aged waste, and other radioactive waste solutions.

EVFD—Evaporator Feed Tank.

FDC—Functional Design Criteria.

FeCN—Ferrocyanide wastes created during a scavenging campaign in 1953–1957. See also PFeCN1, PFeCN2, and TFeCN.

FFTF—Fast Flux Test Facility is an experimental nuclear reactor located in the 400 Area used for testing fuels, materials, and designs related to breeder reactor technology. Recently, it is also being considered for tritium production as an alternative to light water reactor or accelerator based technologies.

FIC—A Food Instrument Corporation automatic liquid level gauge based on a conductivity probe. In some tanks, they are electrically connected to the CASS; in other tanks, local readings may also be obtained from a dial.

First and Second Cycle Decontamination Wastes—Waste contained 10 percent of the original fission product activity and 2 percent of the product. Byproduct cake solution was mixed with product waste and neutralized with 50 percent caustic. This waste contained a mixture of suspended solids, hydroxides,

carbonate, phosphate, scavenger metals, and chromium, iron, sodium, and silicofluoride. See also 1C and 2C.

FLSH—Flush water.

FP—Fission Product waste. Cs and Sr recovery began in 222-B in 1967. Cs was removed from PUREX SU (PAW) and Sr from PUREX SL (PAS), and both from Acidic Waste.

Frit—Chemical additives mixed with waste that create a glass when heated. Examples include fusible ceramic oxides and silicates.

FSPLIT—Separates or slots the flow of one or more input streams into two or more output streams.

FTIR—Fourier Transform Infrared spectroscopy technique used to identify molecular species by their vibrational frequencies.

GA—Gain to tank.

GIS—Geographic Information System.

GM Instrument—Instrument for detecting low-level beta and gamma radiation using a Geiger-Mueller tube.

Grout—A fluid mixture of cement-like materials and liquid waste that sets up as a solid mass and is used for waste fixation and immobilization.

GTCC—Greater than Class C waste.

Gunite—A building material consisting of a mixture of cement, sand, and water that is sprayed onto a mold.

HAMMER—Hazardous Materials Management and Emergency Response training center.

Hanford Coordinates—A set of offsets, in feet, from a reference point on the site. These are the units used to lay out these facilities. Conversion to latitude and longitude is possible.

Hard Pan—Term used to describe uranium carbonate phase that formed in solids from MW additions. Proved to be very difficult to sluice.

HASP—Health and Safety Plan.

HAW—Aging waste from PUREX/PFM Processing NPR Nuclear Fuel. See also AGING WASTE, CAW, IWW, NCAW, NFAW, NHAW, PAW, and PFM.

HazOP—Hazards and Operability Study.

GLOSSARY (Cont'd)

HDRL—Hanford Defense Residual Liquid.

HDW—Hanford Defined Waste.

HEDL—Dilute sulfate waste.

HEDTA—N-(2-hydroxyethyl)ethylenediaminetetra-acetate.

Heel—The waste that remains in a tank after the tank is emptied.

HEPA—High-Efficiency Particulate Air. A filter designed to achieve 99.995 percent minimum efficiency in the containment of radioactive particulates greater than 0.3 micrometer in size.

HFW—Hanford Facility Wastes.

HHI—Health Hazard Index.

HHW—High Heat Waste.

HIC—High Integrity Container used as a containment for low-level radioactive wastes.

HLO—Hanford Laboratory Operations waste.

HLW—High-Level Waste. The HLW is defined on the basis of its source as: (i) irradiated reactor fuel, (ii) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated fuel, and (iii) solids into which such liquid wastes have been converted.

HMS—Hanford Meteorological Station.

HS—Hot Semiworks. A pilot facility that had a variety of operations. See also C Plant and SSW.

HSRAM—Hanford Site Risk Assessment Methodology.

HTCE—Historical Tank Content Estimate.

HVAC—Heating, Ventilating, and Air Conditioning.

HWVP—Hanford Waste Vitrification Plant.

IDA—Iminodiacetate. See also, DC, EDTA, and HEDTA.

IDLH—Imminently (or Immediately) Dangerous to Life or Health.

II—Interim Isolated. The administrative designation reflecting the completion of the physical effort required to minimize the addition of liquids into an inactive storage tank, process vault, sump, catch tank,

or diversion box. In June 1993, Interim Isolation was replaced by Intrusion Prevention. (Term obtained from the Tank and Surveillance and Waste Status Summary Report.)

ILL—Interstitial Liquid Level. Liquid that resides in the voids/interstices of the solids.

IMUST—Inactive Miscellaneous Underground Storage Tank. See MUST.

Inactive Tank—A tank that has been removed from liquid processing service, has been pumped to contain less that 33,000 gallons of waste, and is not yet or is in the process of stabilization and interim isolation. This includes all tanks not in active or active-restricted categories. Also included are inactive spare tanks that would be used if an active tank failed.

Incidental waste—Wastes that are not classified as HLW. NRC has defined three criteria that must all be met for wastes to be called incidental waste: (i) wastes that have been processed (or will be further processed) to remove key radionuclides to the maximum extent that is technically and economically practical; (ii) wastes that will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentrations for Class C low-level waste; and (iii) wastes that are to be managed pursuant to the Atomic Energy Act, so that safety requirements comparable to the performance objectives set out in 10 CFR Part 61, Subpart C are satisfied.

INEL—Idaho National Engineering Laboratory.

In-Service Tank—The waste classification of a tank being used, or planned for use, for the storage of liquid (in excess of the heel) in conjunction with production and/or waste processing. All Hanford double-shell tanks are in-service; none of the single-shell tanks are in-service.

Interim Isolation—An administrative designation reflecting the completion of the physical effort required to minimize the addition of liquids into an inactive storage tank, process vault, sump, catch tank, or diversion box. See IP.

Interim Stabilization—A tank which contains less than 50,000 gallons of drainable interstitial liquid and has less than 5,000 gallons of supernatant. If the tank was jet pumped to achieve interim stabilization, then the jet pump flow must have been at or below 0.05 gallons per minute before interim stabilization is completed.

Interstitial Liquor—The liquid within pores of saltcake and sludge. Some of the liquid is capable of drainage, but the rest of the liquid is held by capillary forces.

Intrusion—The unintended entry of any liquid into a waste storage tank.

Intrusion FIC—A mode of operating the FIC surface level monitoring equipment typically used when a waste surface is not electrically conductive. The conductivity probe (plummet) is positioned a small distance above the waste surface. Should that gap be spanned by an intruding liquid, conductivity between the plummet and the waste surface would be established that triggers an alarm in the CASS system. Note that the intrusion FIC level is not an actual measurement of the current waste surface.

Intrusion Mode FIC Setting—The FIC probe is positioned a short distance above the waste surface. If the surface level of the waste in the tank increases, thereby touching the probe tip, a positive indication is received.

IP—Intrusion Prevention. This is an administrative designation reflecting the completion of the physical effort required to minimize the addition of liquid into an inactive storage tank, process vault, catch tank, sump, or diversion box. (Term obtained from the Tank and Surveillance and Waste Status Summary Report.)

IRAP—Integrated Risk Assessment Program.

Isolation—The act of sealing a tank against liquid intrusion from credible sources and confining the atmosphere in the tank. Filtered airways are not sealed to balance the pressure to the atmosphere, and in some cases provide cooling airflow.

IWW—Inorganic Wash Waste.

IX—Ion Exchange Waste. Assumed ion exchange removal efficiency for radionuclides (i.e., americium, strontium, cesium, and technetium). IX identifies waste returned from Cs recovery. See also CSR.

Jet Pump—A modified commercially available low capacity jet pump used as a salt well pump to pump interstitial liquid.

KE and KW—K reactors used to irradiate metallic uranium fuel.

Knuckle—Point where the side wall and the bottom curved surface of a tank meet.

KOP—Knowledge of Process uses process information to derive waste compositions based on some process driver.

LaF—Lanthanum Fluoride waste generated in Plutonium Finishing Plant Operation from 1945 to an unknown period of time. See also 224 and 224-F.

Lag Storage—Space required to temporarily hold solutions or solids so that processes are not upset by variations in throughput.

Lance/Lancing—A long steel pipe, usually 2 to 3 inches in diameter. The top is bent at a 90-degree angle, and contains a check valve, gate valve, and nose connection. The bottom end of the lance is tapered to a 1/2-inch diameter. Water enters the top of the lance, which is forced out the bottom at high pressure. This creates a passageway which may be used for equipment installation.

LANL—Los Alamos National Laboratory.

Laterals—Horizontal drywells positioned under single-shell waste storage tanks to detect radionuclides in the soil which indicate leakage. Laterals are monitored by radiation detection probes. Laterals are

4-inch ID steel pipes located 8 to 10 feet below the tanks concrete base. There are three laterals per tank in only A and SX Farms.

LAW—Low Activity Waste. See LLW and Incidental waste.

LB—Lifting Bale. Riser top has plate flange with lifting bale—possible concrete plug under.

Leak Detection Pit—Collection point for any leakage from AM Farm Tanks. The pits are equipped with radiation and liquid detection instruments.

LEL—Lower Explosive Limit.

LERF—Liquid Effluent Retention Facility.

LETF—Liquid Effluent Treatment Facility.

Level Adjustment—Any update in the waste inventory (or tank level) in a tank. The adjustments usually result from surveillance observations or historical investigations.

Level History—A diagram that shows the history of the waste level and waste level changes in a tank. The diagram also includes other related data.

LFL—Lower Flammability Limit.

Liquid Level Best Engineering Judgment Line—During the initial filling of certain single-shell tanks, only the liquid level was reported. To adjust for the big increase in level height, which occurred when solids were added to the record, a sloped line was used to reflect solids volume between the initial fill and the time the solids data were recorded.

Liquid Effluent Retention Facility—A Hanford Site facility being built to temporarily store 242-A Evaporator process condensate containing certain regulated chemicals (e.g., ammonia) that have been classified as liquid waste or dangerous waste. This waste would be treated at the Effluent Treatment Facility.

LLW—Low-Level Waste. Also referred to as Low Activity Waste (see Incidental waste).

LOW—Liquid Observation Well. Liquid observation wells are used for monitoring the Interstitial Liquid Level (ILL) in single-shell waste storage tanks. The wells are constructed of fiberglass, or tefzel-reinforced epoxy-polyester resin. They extend to within 1 inch of the bottom of the tank steel liner. They are sealed at their bottom ends and have a nominal outside diameter of 3.4 inches.

MCL—Maximum Contaminant Level.

MDW—Miscellaneous Dilute Waste.

MIBK—Methyl Isobutyl Ketone (Hexone) is a solvent that was used in the REDOX plant.

GLOSSARY (Cont'd)

MIC—Microbiologically Influenced Corrosion.

MTU—Metric Ton Uranium.

MUST—Miscellaneous Underground Storage Tanks are relatively small steel or concrete containers ranging in capacity from 3,400 liters to 189,000 liters (900 to 50,000 gallons). These were used for solids settling prior to decanting liquids to cribs, neutralizing acidic process wastes, uranium recovery operations, collecting waste transfer leakage, and waste handling and experimentation. Inactive MUSTS (or IMUSTS) are tanks that are out of service, but may still contain wastes. Active MUSTS are tanks that are still being used to transfer wastes between tanks in tank farms.

MW—Metal Waste from $BiPO_4$. Ninety percent of FP, all of U, 1 percent of Pu. The term "metal" at Hanford referred to Pu. Waste from the extraction contained all the Uranium, approximately 90 percent of the original fission product activity, and approximately 1 percent of the Pu product. This waste was brought just to the neutral point with 50 percent caustic and then treated with an excess of sodium carbonate. This procedure yielded almost completely soluble waste at a minimum total volume. The exact composition of the carbonate compounds was not known but was assumed to be a Uranium Phosphate Carbonate mixture. See also 1C and 2C.

MW1—Metal waste from $BiPO_4$, 1944 to 1951.

MW2—Metal waste from $BiPO_4$, 1952 to 1956.

N—Reactor that was the first built to not only produce Pu, but also generate power—used metallic uranium fuel.

NBAW—Neutralized B Plant Acid Waste.

NCAW—Neutralized Current Acid Waste primary HLW stream from PUREX process. It is a liquid waste, high in Cs, Sr, and TRU Content. It is the most radioactive of the waste streams from the reprocessing facility.

NCPL—Non-Complexed Waste general term applied to all Hanford site liquids not identified as complexed. See also NCPLX and NCPLEX.

NCPLEX—Non-Complexed Waste. See also NCPL and NCPLX.

NCPLX—Non-Complexed Waste term applied to all Hanford Site liquids not identified as complexed. See also NCPL and NCPLEX.

NCRW—Neutralized Cladding Removal Waste.

NEPA—National Environmental Policy Act.

NESHAP—National Emission standard for Hazardous Air Pollutants.

GLOSSARY (Cont'd)

Neutralized PUREX Acid Waste—The original plant in 1956 neutralized all of the high-level waste and sent it to the A-241 Tank Farm. As fission product recovery started, a portion of the waste was treated for Strontium Recovery and then neutralized. As of 1967, all of the High-Level Waste left PUREX as an acid solution for treatment at B Plant.

Neutron Probe—Probe equipped with a neutron source and detector. They are used in dry well monitoring to determine the moisture content of the soil as one way to detect leaks in underground waste storage tanks or pipelines.

NFAW—Aging waste from PUREX/PFM high-level waste.

NFPA—National Fire Protection Association.

NHAW—Aging waste from PUREX/PFM processing of NPR fuel.

NIOSH—National Institute of Occupational Safety and Health.

NIST—National Institute of Standards and Technology.

NIT—$HNO_3/KMnO_4$ solution added during evaporator operation. See also PNF.

NOx—Oxides of nitrogen.

NPH—Normal Paraffinic Hydrocarbons were diluent used in Uranium recovery and PUREX processes, and is close to Dodecane, C_{12} H_{26}.

NRC—U.S. Nuclear Regulatory Commission.

NSTF—Near Surface Test Facility is a full-scale demonstration facility designed for testing, engineering, and training.

NTA—Nitrilotriacetic Acid.

Offgas—Gas evolved or generated during thermal treatment processes such as evaporation, incineration, or solidification. Offgas treatment is a generic name for equipment/system used to clean up these gases.

Open Hole Salt Well—A well in which a pump is inserted in solid waste. Frequently used to remove the liquid from tanks containing less than 2 feet of sludge. See also Salt Well.

ORR—Operational Readiness Review.

OSD—Operational Safety Document.

OSHA—Occupational Safety and Health Administration.

OSR—Operational Safety Requirement.

GLOSSARY (Cont'd)

Out-of-Service—A tank which does not meet the definition of an in-service tank. All single-shell tanks are out-of-service.

OVM—Organic Vapor Monitor.

OWW, OWW1, OWW2, OWW3—Organic wash waste from PUREX. Evidently, this was combined with P waste in 1960–1961, but usually kept separate. The solvent used in PUREX was treated before reuse by washing with potassium permanganate and sodium carbonate, followed by dilute nitric acid and then a sodium carbonate wash.

P—PUREX HLW, 1956 to 1972. Sometimes assumed to be 50 percent OWW. Used NPH/TBP to extract both Pu and U. Np was also extracted from 1963 to 1972.

P-10 Pump—A turbine pump used in the first stage of removing liquids from a waste storage tank.

P1—PUREX high-level waste generated between 1955 and 1962.

P2—PUREX high-level waste generated between 1963 and 1967.

PAH—Polycyclic Aromatic Hydrocarbon.

Partially Interim Isolated—The administrative designation reflecting the completion of the physical effort required for Interim Isolation except for isolation of risers and piping that is required for jet pumping or for other methods of stabilization.

PAW—PUREX Acidified Waste.

PCB—Polychlorinated Biphenyl.

PD—PUREX decladding waste.

PEL—Permissible Exposure Limit.

PFeCN—Ferrocyanide sludge produced by in-plant scavenging of waste from uranium recovery.

PFeCN1—Ferrocyanide sludge produced by in-plant scavenging of waste from uranium recovery. Used 0.005 M Ferrocyanide.

PFeCN2—Same as PFeCN1, except used 0.0025 M ferrocyanide used.

PFM—Process Facility Modification Project provides a head end facility for the PUREX Plant in which N-fuel and FFTF fuel can be processed.

PFP—(also called Z Plant) Plutonium Finishing Plant. Pu Finishing Plant waste.

PFPGR—Dilute, non-complexed waste from retrieved PFP solids.

GLOSSARY (Cont'd)

PHP—Plasma Hearth Process.

PL—PUREX low-level waste.

PMW—PUREX miscellaneous waste.

PN—PUREX neutralized cladding waste.

PNF—Partial Neutralization Feed. Indicates addition of nitric acid at an evaporator in an attempt to produce more salt cake during volume reduction. See also NIT.

PNNL—Pacific Northwest National Laboratories [Originally called Pacific Northwest Laboratories (PNL)].

PNW—Partial Neutralization Waste.

Pond (Swamp)—Ground area where uncontaminated or low-level waste water is discharged to seep into the ground.

PPR—Pit Propagation Rate.

PRA—Probabilistic Risk Assessment.

PRF—Plutonium Reclamation Facility—Type of waste generated in Z Plant for "finishing wastes." Solvent based extraction process using CCl_4/TBP.

Primary Addition—An addition of waste from a specific plant or process vault. These additions come from the *Waste Status and Transaction Summary*, WHC-SD-WM-TI-614 and -615, Rev. O, DRAFT.

Primary Pipe—The inner stainless steel pipe in the RCSTS and other transfer pipings.

Primary Tank—The complete enclosed carbon steel tank which is the primary container in DSTs.

PRTR—Plutonium Recycle Test Reactor.

PS—Primary Stabilization. The condition of an inactive waste storage tank after all liquid above the solids, other than isolated surface pockets, has been removed. Isolated surface pockets of liquid are those not pumpable by conventional techniques.

PSA—Probabilistic Safety Assessment.

PUREX—Plutonium Uranium Extraction Plant. Also called A Plant where PUREX process ran from January 1952 to June 1972, then was in standby and ran again from November 1983 to 1991, and is now shut down. See also A Plant, CWP, OWW, and P. It is also used for the reprocessing process.

GLOSSARY (Cont'd)

PWHT—Post Weld Heat Treatment. Treatment conducted by heating the tanks at temperatures around 500 °C in order to relieve stresses associated with welding operations.

Questionable Integrity—Any tank that has a small decrease in liquid level or a radiation increase in an associated dry well, for which the remaining data for the tank is insufficient to support a conclusion with 95 percent confidence that the tank is sound.

R—REDOX High-Level Waste (HLW) was generated from 1952 to 1966. It used methylisobutylketone (hexone) as a solvent, and extracted both uranium and plutonium. S Plant ran from January 1952 to December 1967.

R1—REDOX waste generated between 1952 and 1957.

R2—REDOX waste generated between 1958 and 1966.

RCRA—Resource Conservation and Recovery Act.

RCSTS—Replacement of Cross-Site Transfer System.

RECUPLEX—A process conducted in the Z plant to recover Pu from the Z plant waste stream. Ended in 1962.

REDOX—Reduction Oxidation. Also known as S Plant where REDOX process ran from 1952-1966? See also R, and CWR.

Removed from Service (Tanks)—Any tank that is a confirmed leaker or is not intended for reuse.

Riser—Pipe leading into tank dome.

RSltCk—Salt Cake precipitate from self-concentration in S and SX Farms.

S Plant—The facility at Hanford which contains the original extraction process for recovery of both plutonium and uranium. See also REDOX.

S1SltCk—Salt Cake waste generated from the 242-S evaporator/crystallizer from 1973 until 1976.

S2SltSlry—Salt Cake waste generated from the 242-S Evaporator/Crystallizer from 1977 until 1980.

SAIC—Science Applications International Corporation.

Salt Cake—Crystallized nitrate and other salts deposited in waste tanks, usually after active measures are taken to remove moisture. (Term obtained from the Tank and Surveillance and Waste Status Summary Report.)

GLOSSARY (Cont'd)

Salt Slurries—Same as DSS, estimated from chemical model by precipitation (via evaporator). DSS derives from the supernatants of a variety of wastes following evaporation of water. See also DSS and A2SltSlry.

Salt Well—A hole drilled or sluiced into a salt cake and lined with a cylindrical screen to permit drainage and jet pumping of interstitial liquors.

Salt-Well Pump—A low-capacity pump used to remove interstitial liquid from wells.

SAR—Safety Analysis Report.

Scavenged—Waste which has been treated with ferrocyanide to remove cesium for the supernatant by precipitating it into the sludge.

SCC—Stress Corrosion Cracking.

Side Referenced Tank—A dished-bottom tank where the zero point for the liquid-level gauges is at the elevation that the dished bottom begins.

Sludge—Solids formed after waste neutralization with sodium hydroxide additions. Sludges usually sediment and remain in the tanks into which the waste is originally added. Sludge usually was in the form of suspended solids when the waste was originally received in the tank from the waste generator. In-tank photographs may be used to estimate the volume.

Slugs—An term for uranium fuel elements which had been machined or extruded into short cylinders which were then clad or encased in corrosion-resistant metals.

Sluicing or Sluiced—Dissolve or suspend in solution by action of a high-pressure water stream.

SMM—Supernatant Mixing Model is a component of the HDW for modeling tank waste inventory.

SOE—Safe Operating Envelope.

SOLEX—Solvent Extraction Option.

Sound or Sound Tank—The integrity classification of a waste storage tank for which surveillance data indicate no loss of liquid from a breach of integrity.

Spare—Spare riser with no current function or planned use—possible concrete plug underneath plate.

SRL—Savannah River Laboratory.

SRR—Strontium Recovery Waste. Slurried PUREX sludge from A and AX Farms was sent to B Plant for strontium recovery from 1967–1976. Some 801 kgal was sent to and 2,810 kgal returned from B Plant with A-102, A-106, and AX-103 as staging tanks sending sludge to AR vault and supernatant to C-105.

GLOSSARY (Cont'd)

SRS—Strontium Recovery Supernatant. The sludges sluiced for SRR were washed in AR vault with supernatant from C-105. The resulting supernatants were sent to CSR. Also may refer to strontium sludge. Also may refer to Savannah River Site.

SSE—Safe Shutdown Earthquake is that earthquake which is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. It is that earthquake which produces the maximum vibratory ground motion for which certain structures, systems, and components are designed to remain functional.

SST—Single-Shell Tank.

SSW—Strontium Semiworks. Called C Plant or Hot Semiworks earlier, was pilot for both REDOX and PUREX, July 1952 to July 1956. Then reconfigured for strontium recovery pilot plant from July 1960 to July 1967.

Stabilization—The removal or immobilization, as completely as possible, of the liquid contained in a radioactive waste storage tank by salt well pumping, open hole salt well pumping, adding diatomaceous earth, etc. Both floating suction and salt-well jet pumps are used to remove liquid. In general, this term is also used to refer to treatment of waste to render it immobile or safe for handling or disposal.

Static Tank—A tank with no significant change in liquid level or involvement in transfer operations during a stated period of time.

SU—Supernatant (Drainable Liquid Remaining minus Drainable Interstitial Liquid). Supernate volume is usually derived by subtracting the solids level measurement from the liquid level measurement.

T Plant—Decontamination plant for various equipment. Originally built for $BiPO_4$ process, but since only used for decontamination. $BiPO_4$ ran from December 1944 to August 1956. See also 222-T.

T1SltCk—Salt Cake waste generated from the 242-T Evaporator-Crystallizer from 1951 until 1955.

T2SltCk—Salt Cake waste generated from the 242-T Evaporator-Crystallizer from 1955 until 1965.

Tank Farm—An area containing a number of storage tanks; that is, a chemical tank farm for storage of chemicals used in a plant, or underground waste tank storage of radioactive waste.

TBP—Tri-Butyl Phosphate-waste from solvent based uranium recovery operation in 1950, $OP(OC_4H_9)_3$, which was used in uranium recovery and in PUREX.

TEDF—Treated Effluent Disposal Facility.

Terminal Liquor (TL)—The liquid product from the Evaporation-Crystallization Process that, upon further concentration, forms an unacceptable solid for storage in single-shell tanks. Terminal liquor is characterized by caustic concentration of approximately 5.5 M (the caustic molarity will be lower if the Aluminum Salt Saturation is reached first).

GLOSSARY (Cont'd)

TFeCN—Ferrocyanide sludge produced by in-tank or in-farm scavenging.

TGA—Thermal Gravimetric Analysis.

TH (Th1, Th2)—Thoria HLW or Cladding waste.

Thermowell—A well in a waste tank which contains thermocouples.

THFTCA—Tetrahydrofurantetracarboxylic acid.

THL—Thoria Low Level.

TK—TK-17-2 was an early name for B Plant. See also B Plant and 222-B.

TL—Terminal Liquor.

TLM—Tank Layer Model is a component of HDW model for tank waste inventory.

TOC—Total Organic Carbon.

TPA—Tri-Party Agreement is also known as the Hanford Federal Facility and Consent Order. It is an agreement signed in 1989 and amended in 1994 by the U.S. Department of Energy, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology that identifies milestones for site cleanup.

Trench—A deep furrow in the ground. At Hanford, they are used for the disposal of solid waste.

TRU—Transuranic waste.

TRUEX—Transuranic Extraction.

TSR—Technical Safety Requirement.

TTF—Thermal Treatment Facility.

TWINS—Tank Waste Inventory Network System is a database managed by PNNL.

TWRS—Tank Waste Remediation System.

Type I Tank—These are the 200 series tanks found in B, C, T, and U Farm. They have an operating capacity of 55,000 gallons, a 20-foot diameter, a 6-inch dish bottom, and a 3-foot knuckle. Generation is not associated with Type I tanks.

Type II Tank—These are the original (1st generation) tank designs that are found in B,C,T, and U (excluding the 200 series tanks), and BX Tank Farms. See also 1st Generation Tank.

GLOSSARY (Cont'd)

Type III Tank—These are the 2nd generation tank designs that are found in BY, S, TX, and TY Tank Farms. See also 2nd Generation Tank.

Type IV Tank—These are 3rd, 4th, and 5th generation tank designs that are found in SX, A, and AX Tank Farms, respectively. See also 3rd Generation Tank, 4th Generation Tank, and 5th Generation Tank.

Type V Tank—These are the first double-shell tank designs that are found in AY, AZ, and SY Tank Farms.

U Plant—Uranium Recovery Plant from March 1952 to January 1958, UO_3 Plant from then until September 1972. Restarted in March 1984, and is now shut down.

U1U2—Dilute, non-complexed waste from U1/U2 ground water pumping.

UFL—Upper Flammability Limit.

UOR—Unusual Occurrence Report.

UR—Uranium Recovery Operation in 222-U, 1952-1957. Created TBP (primary waste) and FeCN (scavenging wastes). TBP waste called UR waste in Defined Waste report.

Uranium Oxide Plant—This is a processing facility associated with the PUREX plant that converted the liquid uranium nitrate into a uranium trioxide powder through calcination. The plant was built in 1943 to 1944 and operated from 1951 to 1972 and from 1984 to 1989.

USQ—Unreviewed Safety Question. This is a program that aims to identify known or suspected operating conditions outside the known safe limits (also called authorization bases).

Vadose Zone—The region of soil and rock between the ground surface and the top of the water table in which pore spaces are only partially filled with water.

VOC—Volatile Organic Compounds.

Waste Tank Safety Issue—A potentially unsafe condition in the handling of waste material in underground storage tanks that requires corrective action to reduce or eliminate the unsafe condition. (Term obtained from the Tank and Surveillance and Waste Status Summary Report.)

Watch-list Tank—An underground storage tank containing waste that requires special safety precautions because it may have a serious potential for release of high-level radioactive waste because of uncontrolled increases in temperatures or pressure. Special restrictions have been placed on these tanks by "Safety Measures for Waste Tanks at Hanford Nuclear Reservation," Section 3137 of the National Defense Authorization Act for Fiscal Year 1991, November 5, 1990, Public Law 101-501 (also known as the Wyden Amendment). (Term obtained from the Tank and Surveillance and Waste Status Summary Report.)

GLOSSARY (Cont'd)

WESF-Plant—Waste Encapsulation and Storage Facility. Construction was completed in 1974. Capable of producing up to 350 capsules of cesium and 175 capsules of strontium per year. 1575 cesium capsules and 625 strontium capsules produced between 1974 and 1985.

WHC—Westinghouse Hanford Company.

WIPP—Waste Isolation Pilot Plant.

WRAP—Hanford's first major solid waste processing plant, serving to analyze and repackage containers of waste left from the Hanford defense mission and generated by cleanup activities.

WSCF—Waste Sampling and Characterization Facility.

WVDP—West Valley Demonstration Project.

Z—Z Plant waste. 234-5Z waste/Z Plant Pu Finishing.

Z Plant—Pu finishing plant. Operated from 1949 to 1991; now in standby.

ZAW—Zirconium Acidified Waste (PUREX waste stream from Zirconium) cladded fuel.

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QUALITY OF DATA: Sources of data are referenced in each chapter. The respective sources of non-CNWRA data should be consulted for determining their levels of quality assurance.

EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) established the Tank Waste Remediation System (TWRS) program at the Hanford site to manage the retrieval and cleanup of radioactive waste contained in 177 aging underground storage tanks. The DOE plans to privatize the waste solidification operations under a two-phase program. In Phase I, a feasibility study, scheduled for completion in January 1998, would be conducted by two contract teams, and one or more demonstration facilities would be constructed for solidifying about 10 percent of the waste by June 2011. In Phase II, which will be a full-scale operation phase, all the wastes are planned to be processed. Under a Memorandum of Understanding, reached between the Nuclear Regulatory Commission (NRC) and DOE for Phase I activities, the NRC will develop sufficient knowledge of the physical and operational situation of the Hanford waste tanks and Phase I activities to enable the NRC to (i) assist the DOE in performing reviews in a manner consistent with the NRC regulatory approach, and (ii) be prepared to develop an effective regulatory program for the possible licensing of DOE contractor-owned and -operated facilities during Phase II. The review of information pertaining to the Hanford site, tanks, and TWRS reported in this document is a first step in this process.

Chapter 2 summarizes the information available regarding the Hanford site geography and geology, status of knowledge regarding site contamination, processes leading to waste generation, tank farms, transfer systems, and ongoing activities pertaining to TWRS. This chapter also describes the status of characterization of site contamination. While groundwater contamination has been rather extensively characterized, there is less information available on the vadose zone.

Identification and quantification of Hanford tank waste contents are subjects of extensive study. Chapter 3 of this report includes a general description of double-shell tank and single-shell tank waste characteristics, and a discussion of tank inventories of chemicals and radionuclides. The wastes have been produced over a long period of time by a variety of processes. Characterization of tank contents chemically and radiologically is, therefore, a challenging task. Two approaches to this question are being employed, each complementing the other: direct sample assay and estimation based on facility records. The former is limited by the extreme physical and chemical heterogeneity of the tank contents, while the latter may be unreliable due to incomplete or inaccurate documentation of process and waste transfer transactions. The DOE effort is centered on determination of a "best-basis" value for each constituent in each tank, based on a combination of the assay and historical data. Until that evaluation process is completed, the historically-based Hanford Defined Waste (HDW) model being developed at Los Alamos National Laboratory (LANL) is the most complete and thorough dataset of tank inventory estimates. The Center for Nuclear Waste Regulatory Analyses (CNWRA) has prepared a database (based on inventories from the HDW model) allowing access of tank information utilizing ARC/INFO geographical information system software. The geographic and geologic map presented in chapter 2 can be combined in ArcView with the location of the tank farms, if their coordinates can be accurately described, to represent the complete spatial description of the tank farms for eventual hazard analysis.

Chapter 4 reviews the various hazards posed by tank wastes and associated with the retrieval and mixing of wastes prior to solidification. The safety issues associated with solidification will be discussed in another report as part of subtask 1.2. The hazards posed by tank wastes and the TWRS activities are classified under four Watch-list categories: (i) flammable gas, (ii) organic oxidation, (iii) ferrocyanide oxidation, and (iv) high-heat. Other hazards identified in this review include: crust burn associated with secondary ignition of organic-nitrate/nitrite mixtures in the crust layer, High-Efficiency Particulate Air filter blow out associated with flammable gas ignition, environmental hazards and flammability due to

organic solvents, known and unknown leaking tanks, criticality, and lightning strikes. This report also evaluates potential safety concerns associated with retrieval, mixing, and transfer of tank wastes. Two important concerns in this regard are: (i) safety problems arising from commingling wastes under interim storage, and (ii) operability of waste transfer systems that may be impeded by plugging, trapped flammable gas, exothermic reactions, and corroded lines. The physical and chemical data needs for compatibility assessments are provided in chapter 4.

The time constraints did not permit a comprehensive or critical review of the information on the Hanford site and TWRS activities. However, based on the reviews performed to date, the status of knowledge and additional information requirements, as outlined in chapter 5, may be summarized as follows.

- Knowledge of vadose zone contamination in the potential areas of TWRS activity and waste disposal is sparse, although several investigations are under way to characterize contamination migration in the vadose zone under some of the tanks (e.g., SX tanks), and in the 600 Area associated with a commercial Low-Level Waste disposal site. On the other hand, considerable effort has been made in characterizing the groundwater contamination in the unconfined aquifer. Understanding vadose zone contamination is necessary for performance assessments associated with Low Activity Waste disposal, as well as hazard analyses related to waste retrieval and solidification.

- Knowledge of tank waste contents and chemistry is evolving, due to ongoing waste characterization programs and estimations based on facility records. However, better understanding of the chemical interactions of various waste constituents is necessary to assess the safety aspects of retrieval and mixing of wastes from different tanks, and to determine the operating envelopes for solidification. Knowledge of the distribution of chemical species within the tanks is also necessary for evaluation of contaminant migration under the tanks.

- There is a paucity of easily accessible documentation on the location, design, and problems associated with waste transfer lines within the 200 Areas and the cross-transfer line. It is known that some of these transfer lines have suffered from plugging and leakage. Knowledge of processes leading to plugging and extent of leakage is necessary to better understand safety hazards associated with waste mixing and transfer to the privatization facilities.

- The evaporator/crystallizer in the 200-East area, which has been monitored closely over the past few years, has shown a service life before materials replacement of about 10 years. However, it is not known how the service life will be affected by the mixture of wastes expected during the Phase II operations.

- The information on the Hanford site and various components of the TWRS is scattered and, in some cases, not easily accessible. It is recommended that this report be augmented as further information is gained, to assist in future safety analyses.

1 INTRODUCTION

The U.S. Department of Energy (DOE) established the Tank Waste Remediation System (TWRS) program at the Hanford site in 1991 to manage the maintenance and cleanup of radioactive waste contained in 177 aging underground storage tanks. The DOE is legally bound to remediate the waste tanks under the Hanford Federal Facilities Agreement and Consent Order of 1989 (Ecology, 1994), also known as the Tri-Party Agreement (TPA). To accomplish the TWRS requirements, the DOE plans to privatize the waste treatment and immobilization operations. The TWRS privatization is divided into two phases, a proof-of-concept or demonstration phase (Phase I) and a full-scale operations phase (Phase II). The Phase I program, scheduled for completion in 2012, is divided into Part A (feasibility study), which is scheduled for completion in January 1998, and Part B (demonstration pilot plant study), which is scheduled for completion in June 2011. A Memorandum of Understanding has been reached between the DOE and the Nuclear Regulatory Commission (NRC)[1] for Phase I activities, which provides for the NRC to acquire sufficient knowledge of the physical and operational situation at the Hanford waste tanks and processes involved in Phase I activities to enable the NRC to (i) assist the DOE in performing reviews in a manner consistent with the NRC regulatory approach and (ii) be prepared to develop an effective regulatory program for the possible licensing of DOE contractor-owned and contractor-operated facilities during Phase II. A program to assist the NRC in developing technical and regulatory tools for the TWRS privatization activities was established at the Center for Nuclear Waste Regulatory Analyses (CNWRA). The program consists of four tasks, of which only task 1 (Familiarization and Regulatory Development and Safety Review) is currently active. The objective of the CNWRA activities in subtask 1.1 is to gather detailed, current information related to the Hanford site in general, and the 200 Area tank farms in particular, that will be useful to support execution of other subtasks.

The volume of information on the Hanford site and activities related to environmental cleanup is quite large (over 6,500 documents in the DOE bibliographic database that can be accessed via the Internet). Because of the limited time available to acquire the relevant documents and review the information for inclusion in the present report, this report is necessarily neither critical nor complete in addressing the information. This report is prepared in a modular format so that, as further information is acquired, corrections or augmentation of the present report can be made in the future. Chapter 2 of the report provides a description of the site and facilities. Included in this chapter are the descriptions of site geology and geohydrology and the present understanding of sitewide contamination of both radioactive and hazardous species. Histories and brief descriptions of the processes that produced the wastes are also provided. Finally, descriptions of various operational areas, especially of the tank farms and transfer facilities, and ongoing activities relevant to TWRS are included. Chapter 3 of the report and appendix A provide a tank-by-tank description of waste content. The list of tank waste contents is derived from the Tank Waste Inventory Network System (TWINS) database. As part of the familiarization activities in subtask 1.1, a pictorial database of tanks was constructed using a Geographic Information System. A summary of the information available in this database is provided in chapter 3. Chapter 4 reviews the hazards posed by tank wastes and TWRS operations, with the exclusion of waste solidification operations, which have not been initiated at the Hanford site as part of the TWRS. Detailed information of tank waste contents is provided in the appendix. A glossary of frequently used terms is also included with the report.

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[1] Memorandum of Understanding Between the Nuclear Regulatory Commission and The U.S. Department of Energy, January 29, 1997, Federal Register, V. 62, No. 52, 12861. March 18, 1997.

2 DESCRIPTION OF SITE AND FACILITIES

2.1 INTRODUCTION

The purpose of this chapter is to provide a brief description of the Hanford site, locations of tank farms, tanks, reactors, and processing plants, and the history of construction based on a preliminary survey of some of the reports that are publicly available. The chapter also describes ongoing operations, such as decontamination, monitoring, and construction of systems for waste retrieval and handling, and summarizes the present knowledge of site contamination. While most of the description is focused on the 200 Areas, a brief description of past and present activities in the 100 and 300 Areas is also provided.

The Federal government established the Hanford site in 1943 to produce plutonium (Pu) for national defense purposes. The site occupies approximately 1450 sq km (560 sq mi) north of the city of Richland. The location of the Hanford site is shown in figure 2-1. The site is roughly 50 km north to south and 40 km east to west. About 6 percent of the land has been actively used, and this is divided into several widely dispersed operational areas:

- The 100-B/C, D, F, H, KE, KW, and N Areas along the south shore of the Columbia River in the northern portion of the site contain the reactors and fuel storage basins.

- The 200-East and -West Areas in the center of the site, where the tank waste remediation system activities are being carried out, contain the reprocessing plants, underground storage tanks, evaporators, effluent treatment facilities, shallow disposal areas known as cribs, a spent fuel storage facility that is under construction, and the future privatized solidification facilities. A commercial Low-Level Waste site, licensed by the state of Washington and operated by US Ecology, is also located near the 200 Areas.

- The 200 Area North, located between the 200 Areas East and West and slightly to the north of these areas, was used between 1945 to 1952 to store spent fuel from the 100 Area reactors (U.S. Department of Energy, 1992b). Three storage facilities, containing storage basins and transfer facilities, were built to accommodate excess irradiated fuel that could not be processed on schedule due to problems encountered in the B and T plants. In June of 1952, the more efficient S plant was built for processing the irradiated fuel and, subsequently, the spent fuel was removed from the buildings in the 200 N storage basins. The fuels were typically stored for 40 to 60 days before reprocessing. This cooling time was primarily to reduce the radioactivity of gaseous fission products (primarily iodine) before the dissolution of fuel in the separations plants. Water from two wells located east of the facilities was used to cool the fuel stored in the basin. This water was discharged to a pond located south of the facility (U.S. Department of Energy, 1992b). Low levels of radiation have been detected underground at several locations in the 200-N Area, indicating that some of the Al-clad fuel leaked and transferred radionuclides to the cooling water. All fuel storage facilities were shut down in June 1952. The fuel was removed, fuel storage basins drained and cleaned, and the water was pumped to shallow trenches located about 30 m northwest of the storage buildings (U.S. Department of Energy, 1992b).

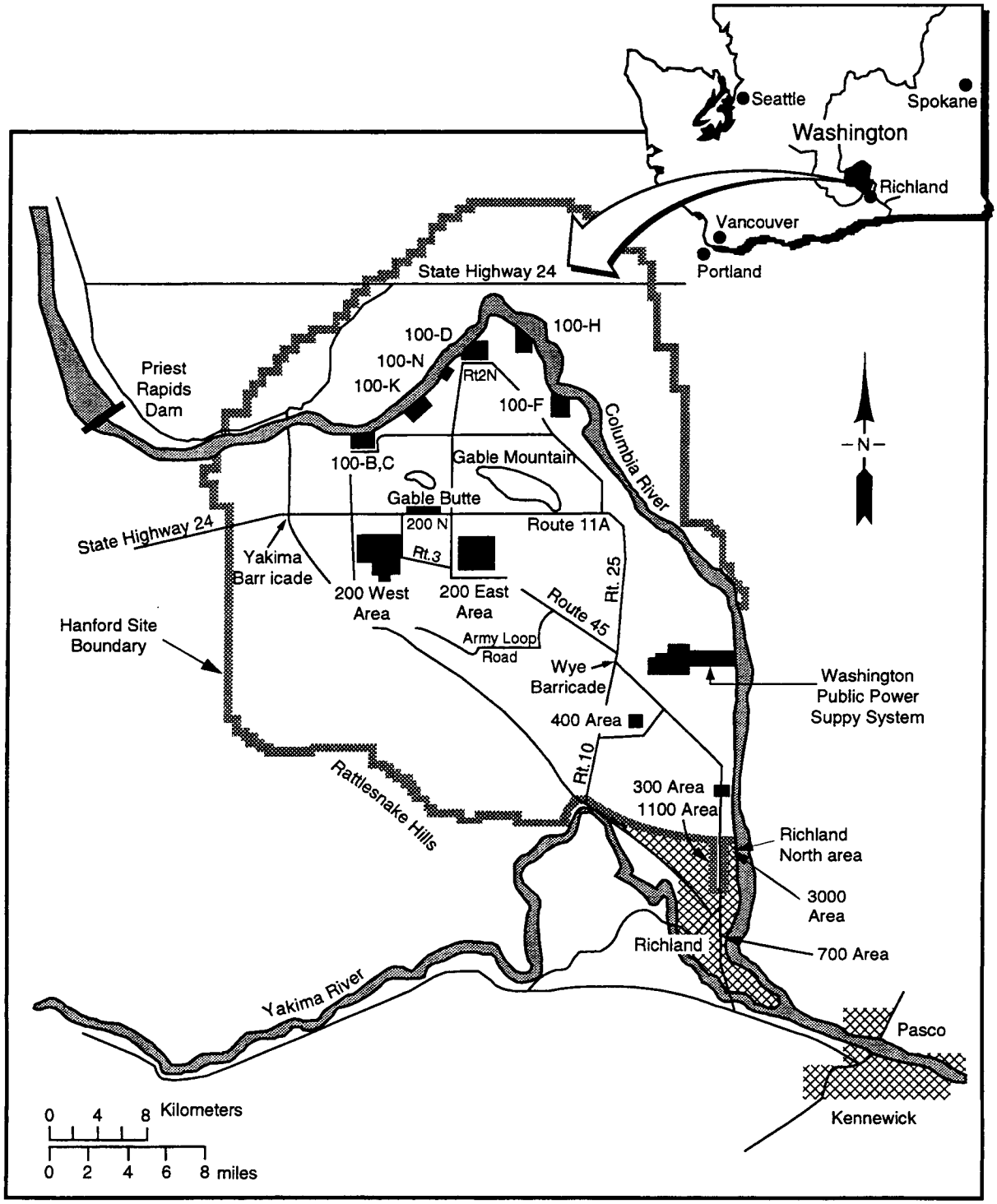

Figure 2-1. Hanford site location map

- The 300 Area near the southern border of the site was originally conceived as a process improvement and fuel fabrication area. However, the array of activities in this area has increased to encompass construction of vitrification test facilities and a variety of research activities through the Pacific Northwest National Laboratories (PNNL) located in this area.

- The 400 Area is the home of the Fast Flux Test Facility (FFTF), which was constructed as a prototype breeder reactor facility. The WNP-2 reactor of a commercial power production company, Washington Public Power Supply System, is also located near the 400 Area, along the Columbia River.

- The 600 Area is the area between the operational areas.

- The 700, 1100, and 3000 Area facilities in the Richland area mainly provide vehicle maintenance and administrative support to site activities.

The Pu production mission ended in 1989 and since then the Hanford site mission has been diversified to include waste management and environmental restoration.

2.2 SITE DESCRIPTION

The site description presented in this section covers the site geology, hydrology, climate, and potential natural hazards. Information presented in this section is taken from the Tank Waste Environmental Impact Statement (U.S. Department of Energy, 1996a) and U.S. Geologic Survey (1987), which may be consulted as primary sources. The Hanford site occupies approximately 1,450 km^2 in the Pasco Basin of the Columbia Plateau of southeastern Washington State (figure 2-2). The Columbia River flows through the northern and eastern parts of the site and forms the southeastern boundary. The Yakima River is south of the reservation and flows to the east into the Columbia River between the cities of Richland and Kennewick, which are south of the southeast corner of the Hanford site. Most of the site is undeveloped land occupied by shrubs and grasslands.

2.2.1 Geology and Geohydrology

The Columbia Plateau is a large physiographic province of southeastern Washington, northeastern Oregon, and west-central Idaho. This province is generally underlain by thick sequences of the Miocene Columbia River Basalts (CRBs). Basalt flows tens of meters thick (Carmichael et al., 1974), individually cover areas of thousands of square kilometers and are stacked up to several kilometers thick (Tolan et al., 1989). The Pasco Basin is an area of limited topographic relief bounded by a monocline on the east and anticlinal ridges elsewhere (U.S. Department of Energy, 1996a). The elevation of the Hanford site ranges from 120 m above sea level at the Columbia River at the south end of the site to approximately 230 m in the central and northwestern parts. Waste tank farms are located on the slightly elevated and flat Central Plateau in the central part of the Hanford site (figure 2.1).

The CRBs at the Hanford site are over 3 km thick. River deposits consisting of gravel, sand, and silt are interbedded between some of the basalt flows and are called the Ellensburg Formation. These rocks are gently folded at the Hanford site, and the waste tank farms are located between the Gable Mountain anticline on the north and the Cold Creek syncline on the south (U.S. Department of Energy, 1996a). These geologic structures have important controls on topography, suprabasalt sedimentation, and

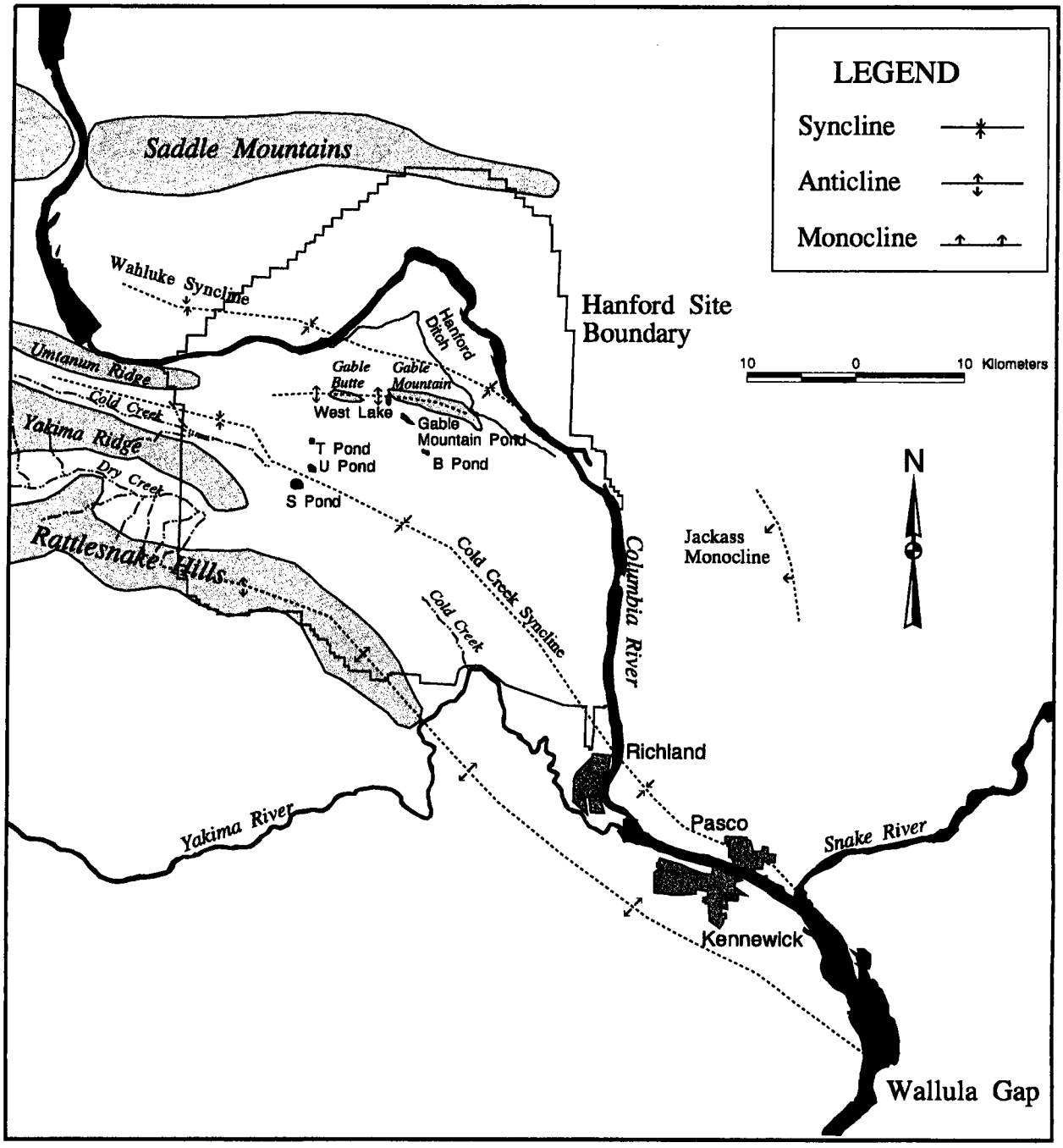

Figure 2-2. Map showing geologic and geographic features of the Hanford site. Base map data are modified from the U.S. Geological Survey 1:250,000 scale Walla Walla topographic map. Geologic data (folds) are modified from Tolan et al (1989). Ponds are identified in U.S. Geological Survey (1987). West Lake and Jackass Monocline identified in U.S. Department of Energy (1996b). Roads and other geographic features are shown in figure 2-1.

flow of groundwater and surface water. For example, in the Gable Mountain anticline, relatively impermeable basalts occur above the water table and crop out at the ground surface, which impedes groundwater flow across this structure (U.S. Geologic Survey, 1987).

Suprabasalt sediments up to 230 m thick at the Hanford site include the Ringold and overlying Hanford Formations which are separated by an erosional unconformity over most of the site and by aeolian silt of the Palouse Formation in the western part of the site (figure 2-3). The Ringold Formation consists of river, lake, floodplain, and alluvial fan deposits composed of gravel, sand, silt, and clay. Ringold sedimentary rocks are generally well sorted and semiconsolidated. The upper unit of the Ringold Formation consists of discontinuous, relatively impermeable fine sand, silt, and clay. A band of this rock type located between the waste tank farms and the Columbia River reduces the hydraulic connection between the area of the tank farms and the river. The lower part of the Ringold Formation is dominated by gravels which are divided by a lower horizontal mud unit. The lower mud may serve as a confining bed for the aquifer in underlying gravels (U.S. Geologic Survey, 1987, U.S. Department of Energy, 1996a).

The Hanford Formation, which is exposed at the ground surface over most of the Hanford site, is composed of unconsolidated sand, gravel, boulders, and silt deposited by floodwaters of the Columbia River. This formation ranges up to 106 m thick in the vicinity of the waste tank farms (Pacific Northwest National Laboratories. 1996b).[1] Over much of the surface at the reservation, the Hanford Formation consists of reworked sand dunes. This formation is heterogeneous but predominantly coarse grained. Waste tanks are located in the Hanford Formation (U.S. Department of Energy, 1996a).

Surface water at the Hanford site comprises the large Columbia River, the Yakima River, West Lake located about 5 km north of the 200-E Area, springs at the base of the elevated terrain on the west side of the site, and ephemeral streams (Dry Creek and Cold Creek) which flow rarely from west to east only in association with heavy storms. Natural infiltration through the thick (70 to 90 m) unsaturated zone is estimated to be small, for example less than 1 mm per year. Natural recharge to the saturated groundwater system occurs from the Columbia River to the north, Cold Creek, Dry Creek, and upland areas to the west of the site (U.S. Department of Energy, 1996a).

Groundwater flow in the unconfined aquifer under natural conditions is from west to east in the central part of the Hanford site. The unconfined aquifer is predominantly in the Ringold Formation or in the Hanford Formation near its contact with the Ringold Formation. Prior to operations at the Hanford site, the water table was about 90 m below the ground surface in the present vicinity of the waste tank farms (U.S. Geologic Survey, 1987). Heterogeneity in the Ringold Formation, notably relatively impermeable horizontal clay units, promote lateral rather than vertical flow in the aquifer. Natural discharge from the unconfined aquifer is to the Columbia River to the east and southeast of the site and to West Lake. Confined aquifers exist in the lower Ringold Formation below impermeable units and in the Ellensburg Formation between basalt flows. These confined systems are largely or completely isolated from Hanford site activities (U.S. Department of Energy, 1996a).

Surface water and groundwater in the unconfined aquifer at the Hanford site are dilute, oxidizing, and have near neutral pH. The oxidation state diminishes and pH increases with depth in the

[1] The maximum thickness of the Hanford Formation is reported erroneously to be 65 m in the Tank Waste Environmental Impact Statement (U.S. Department of Energy, 1996a).

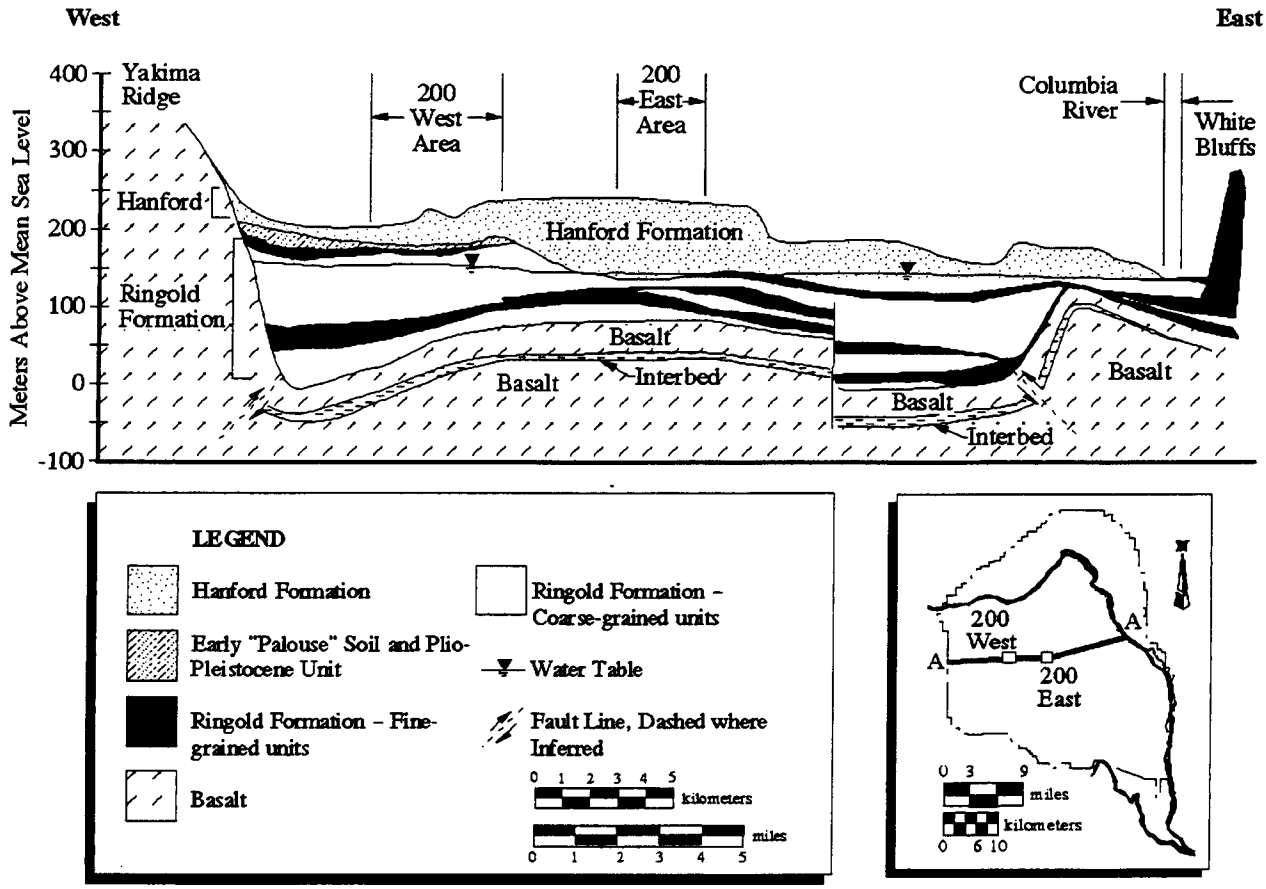

Figure 2-3. Geologic cross-section across the central part of the Hanford site. Waste tanks are located in the Hanford Formation. [Figure adapted from the Tank Waste Remediation System Environmental Impact Statement (U.S. Department of Energy, 1996a)].

confined aquifers. Dissolved calcium and magnesium are higher in spring and unconfined aquifer waters than in aquifers in basalts, whereas other dissolved constituents tend to increase with depth (Early et al., 1986).

Industrial water discharged from Hanford site operations elevated the water table and modified the groundwater chemistry, particularly in the vicinity of the 200 Areas. Recharge of the unconfined aquifer in areas of waste water discharge due to industrial activities exceeds by far the natural recharge. Groundwater mounds that formed under the 200 Areas resulted in some flow to the north between Gable Butte and Gable Mountain. The artificial groundwater mounds are presently diminishing toward natural conditions (U.S. Geologic Survey, 1987). Present hydrologic and hydrochemical variations in the unconfined aquifer below the 200 Areas are transient, depending more strongly on human activities than natural conditions.

2.2.2 Meteorology and Natural Hazards

In the rain shadow of the Cascade Range, the climate at the Hanford site is semiarid. Average rainfall is about 17 cm/yr. The driest month in summer averages 0.5 cm/mo, and the wettest month in winter averages 2.5 cm/mo. The weather is cold (on an average about 25 days per year below 0 °C) in the winter and hot (on an average 51 days per year over 32 °C) in the summer. The average relative humidity is 33.3 percent in the summer and 80.2 percent in the winter. Prevailing winds are from west-northwest and northwest in all months of the year. Monthly average wind speeds range from 10 km/hr in December to 15 km/hr in June (U.S. Department of Energy, 1996a). Peak gusts occur from south-southwest, southwest, and west-southwest. Severe wind conditions occur about 10 times a year, most commonly during May through August. There were no reported incidents of violent tornadoes in the region surrounding the Hanford site from 1945 through 1980. The annual probability of a tornado striking the region has been estimated to be 2.7×10^{-5} to 3.7×10^{-5} (Markee et al., 1974).

Potential natural hazards at the Hanford site include flooding, catastrophic flooding, volcanic ash deposition, and seismicity. Cold Creek flows intermittently through the site west and east of the area of the tank farms. Exceptional flooding of Cold Creek due to intense rainfall could affect the TWRS operations area, but there is no record of flooding to this extent (U.S. Department of Energy, 1996a). Flow in the Columbia River is presently controlled by numerous dams above and below the Hanford site. During the Pleistocene, however, repeated failures of glacial dams released huge volumes of water into the Columbia Plateau and created floods at the Hanford site over 100 m deep. These immense floods eroded the channelled scablands north of the Hanford site and deposited the sediments of the Hanford Formation (Baker and Nummedal, 1978).

The Cascade Range to the west of the Hanford site has active continental margin stratovolcanoes. Ash from the 1980 eruption of Mount St. Helens fell at the Hanford site. A major eruption of a Cascade volcano could potentially deposit centimeters of ash at the Hanford site. Seismicity in the area is low. The Rattlesnake-Wallula structural alignment, which passes along the southwestern margin of the Hanford Reservation, is estimated to be capable of a maximum 6.5 Richter magnitude earthquake (U.S. Department of Energy, 1996a).

2.3 SITE CONTAMINATION

2.3.1 Overview

This subsection presents a description of contamination at the Hanford site. Recent Hanford site assessment studies, publications, and environmental monitoring reports were used as supporting material and references for this summary, and no new field evaluations were performed.

For many years, facility operations have contributed to the extensive site contamination at the Hanford site, which is present in different media and in many areas onsite and offsite. Site conditions, contamination, and affected environment at the Hanford site have been studied and documented for many decades, resulting in the compilation of volumes of historical data for evaluating changes that may occur in the concentration and dispersion of contaminants over time.

Current environmental monitoring programs include monitoring facility effluents at the point of release to the environment, and analyzing diverse media and conditions near all types of operating facilities. Environmental surveillance is a separate program consisting of comprehensive multimedia sampling and analysis that is conducted site-wide and for surrounding areas.

A key purpose of the Hanford site monitoring programs is to verify compliance with DOE, U.S. Environmental Protection Agency (EPA), and Washington State standards for the protection of human health and the environment. The atmosphere and surface water have been determined to be the primary pathways for movement and subsequent release of radioactive and chemical substances to the environment, with groundwater providing connection with springs.

In general, concentrations of radionuclides released in effluents have not significantly changed over the last few years since the decommissioning of most production facilities, with many effluents approaching naturally occurring radioactivity levels. Results from the 1995 monitoring were consistent with past results, indicating higher concentrations of radionuclides and chemical substances present in distinct operational areas. A generalized listing of sources of contaminants released is given in table 2-1.

Table 2-1. Sources of various contaminants in the Hanford site (Pacific Northwest National Laboratories, 1996a)

Operations and Facilities	Area	Contaminants Released
Reactor operations—activation products/gamma emitters	100	^{3}H, ^{60}Co, ^{90}Sr, ^{99}Tc, ^{125}Sb, Cr^{6+}, SO_4^{2-}, NO_3^-, U
Pu purification	200	Pu, ^{241}Am, carbon tetrachloride, chloroform, NO_3^-
Irradiated fuel processing—fission products	200, 600	^{3}H, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, Pu, U, CN^-, Cr^{6+}, F^-, NO_3^-
Fuel fabrication	300	^{99}Tc, U, Cr^{6+}, Cu, trichloroethylene

2.3.2 Soil Contamination

Hanford site soil contamination resulted mainly from the use of cribs, holding ponds, tank farms, septic tanks, ditches, solid waste landfills, and other structural features that had the potential for release. Historically, characterization of soil contamination has been limited in comparison to groundwater investigations because of the latter's greater potential for offsite migration of contaminants. However, soil contaminants are tracked at the Hanford site through surface soil and vadose zone monitoring programs. The vadose zone monitoring includes soil sample collection from the zone between the ground surface and water table. Samples are analyzed for radionuclides and chemical substances to assess concentrations and the potential for contaminant migration through the soil to the groundwater. Approximately 53 billion liters (14 billion gallons) of liquid wastes have been discharged from the effluent facilities to the soil from over 300 disposal sites (Pacific Northwest National Laboratories, 1996b).

Onsite surface and near-surface soils had concentrations elevated above applicable regulatory limits of cobalt-60 (Co-60), strontium-90 (Sr-90), cesium-137 (Cs-137), Pu-239, Pu-240, and uranium (U), with highest levels at or near waste disposal areas. Monitoring results from 1983 to the present generally indicate no significant changes in radionuclide concentrations except for Sr-90, which has declined due to radiological decay and has shown downward migration (U.S. Department of Energy, 1996a). Sr-90 and Cs-137 have similar half-lives and, therefore, would be expected to show similar evidence of radiological decay at the site. However, these differences may be from uncertainties existing in the measured values of these radionuclides and in waste disposal activities at the various facilities.

In 1995, borehole and well logging operations were performed to identify, characterize, and track radionuclides in the soils, including about 70 boreholes around effluent disposal facilities, and about 250 dry wells out of the proposed 750 wells in the Tank Farms Vadose Zone Characterization project. Thus far, it has been shown that Cs-137 has reached greater depths than previously determined beneath the 200-West Area, recorded at a depth of at least 38 m (125 ft) which is the top of a low-permeability confining bed with underlying groundwater levels at about 64 m (210 ft) (Pacific Northwest National Laboratories, 1996b).

Additional ongoing subsurface investigations are being performed at the US Ecology commercial low-level radioactive waste (LLRW) facility located between the 200 Areas, at the southwest corner of the 200-East Area on the Hanford site. The US Ecology facility has been in operation since 1965 and has disposal trenches containing radionuclides and hazardous chemicals. Limited documentation exists for the types, concentrations, and quantities of radionuclides and hazardous chemicals that were disposed of in most of the trenches. As the result of an EPA Resource Conservation and Recovery Act (RCRA) facility assessment (RFA) of the US Ecology facility, the site was determined to be a potential source for contaminant release and the trenches were identified as Solid Waste Management Units (SWMUs) under the Hanford facility RCRA hazardous waste permit and corrective action program (Landau Associates, Inc., 1996).

In response to these RCRA requirements and its existing permit, US Ecology has begun implementation of a three-phased site investigation to assess potential releases of hazardous waste constituents from the disposal trenches into the vadose zone beneath the trenches. Phase I represents proposed monitoring activities from existing systems; Phase II includes installation of proposed compliance monitoring facilities in accordance with the LLRW licensing requirements; and Phase III consists of additional proposed monitoring systems and changes to existing monitoring plans for

regulatory compliance based on Phase I and II data. Phase I and proposed Phase II facilities are shown in figure 2-4.

Existing vadose zone monitoring systems consist of three soil vapor monitoring wells, three solar stills, and six trench cap areas. Soil gas samples collected from the soil vapor monitoring wells are analyzed for methane, radon, tritium, fixed gases, and benzene, toluene, ethyl benzene, and xylene. Various trench caps from trenches 5 and 7 are regularly sampled and analyzed for radon. The solar stills are used for the collection of tritium samples (Landau Associates, Inc., 1996).

Site contamination values presented in the following paragraphs are based on 1992, 1993, and 1994 US Ecology monitoring data. Low concentrations of some volatile constituents (maximum concentrations of ethyl benzene and xylene at 1 mg/m^3 and 3 mg/m^3 , respectively) primarily in the gas phase, have been detected at the trench edges indicating limited migration. Samples collected from the soil vaporing monitoring wells show slight elevations above background concentrations of carbon dioxide and methane, and reduced oxygen concentrations, which may be indicative of organic wastes decomposition (Landau Associates, Inc., 1996).

Background concentrations for tritium were exceeded in both vapor monitoring wells and the solar stills with recorded maximum concentrations of about 0.0004 μCi/cc and 4100 pCi/L, respectively. Based on these findings, tritium migration from the trenches is indicated. Radon concentrations were elevated in well VW-101, measuring up to $>$1627 pCi/L, and close to background concentrations in well VW-102. Although trench cap radon concentrations were measured at levels below background, these low concentrations are believed to be the result of dilution from the surrounding atmosphere (Landau Associates, Inc., 1996).

In 1991, soil samples also were collected from about the 45–85 ft range below land surface during the vadose zone monitoring well installations and analyzed for volatile organic constituents. Analytical results indicated no volatile constituents were present. No indication of radionuclides analysis was given for these samples in the US Ecology reference report.

Graphics presenting detailed areas of soil contamination were not readily available at the time of this writing. However, through continued DOE work to better determine the extent and magnitude of soil contamination, maps delineating site surface and subsurface soil contaminants should become available.

2.3.3 Surface Water and Sediment Contamination

Surface water and sediment samples are collected from riverbank springs and the Columbia River, with additional surface water monitoring of onsite ponds and offsite water sources. Water samples collected from the surface water disposal units and springs for the 1995 monitoring program were analyzed for Pu-238, Pu-239, Pu-240, tritium (H-3), Sr-90, U, and gamma-emitting radionuclides, as well as pH, temperature, and nitrate. Surface water disposal units in the 200 Areas consist of holding ponds, such as the B and U Ponds, and drainage ditches. The results indicated that radionuclide concentrations in the surface water in the 200 Areas were mostly at or below detection limits, and below DOE Derived Concentration Guides of 100 millirem per year (mrem/yr). Nitrate concentrations were below applicable Drinking Water Standards and pH measurements were below liquid effluent RCRA standards.

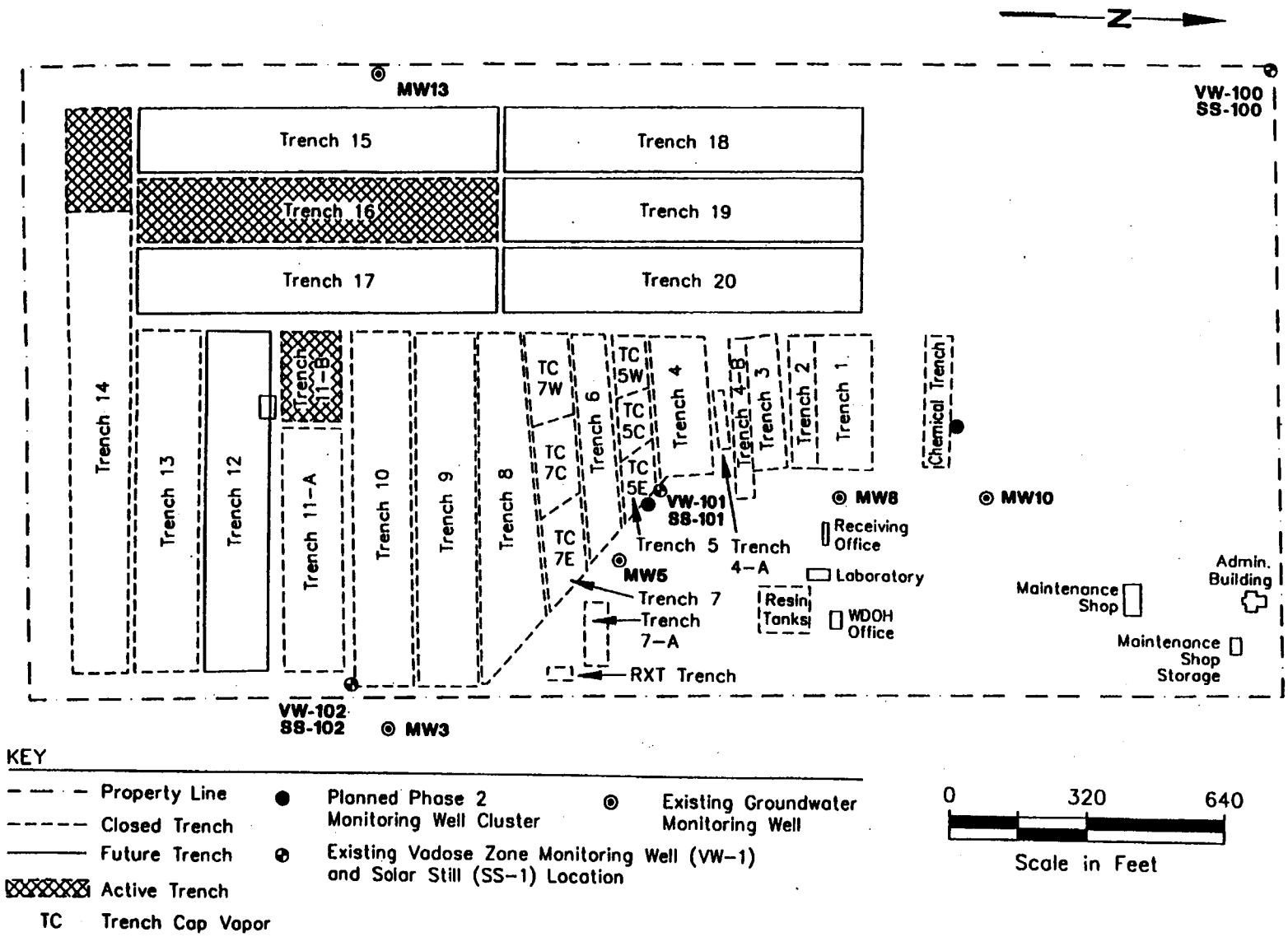

Figure 2-4. US Ecology low-level radioactive waste facility site map (Landau Associates, Inc., 1996)

Contaminant transport through springs to the Columbia River from the past operations of the N-Reactor is a major concern at the Hanford site. The 1995 monitoring results for the 100-N Area groundwater springs located along the Columbia River shoreline indicated that radionuclide concentrations were highest near the N-springs effluent monitoring well, but below the concentrations actually measured in the well. These concentrations were conservatively estimated based on the modeled groundwater discharge rate of 10 L/min (2.64 gal/min) multiplied by higher radionuclide concentrations present in the N-springs effluent monitoring well (Pacific Northwest National Laboratories, 1996b).

Riverbank spring water measurements in 1995 indicated no radiological contaminant concentrations above the DOE Derived Concentration Guides. Although there are no current ambient surface water quality standards for U, the total U concentration in the proposed EPA Drinking Water Standard was exceeded in the 300 Area spring. Washington State ambient surface water quality criteria levels for Sr-90 and H-3 were exceeded in the 100-H Area, and the 100-B Area and old Hanford Townsite riverbank springs, respectively.

The 100-K Area spring was the only site reported to contain nonradiological contaminants above regulatory limits. Copper and zinc exceeded the Washington State ambient surface water acute toxicity levels, cadmium exceeded chronic toxicity levels, and trichloroethylene concentrations were indicated above the EPA standard.

Generally, surface water samples collected in 1995 from various locations along the Columbia River near the Hanford site contain radionuclides at concentrations well below regulatory standards. As expected, highest H-3 and total U concentrations were detected along shorelines located near operational facilities, groundwater seepage areas, irrigation return canals, and downstream of the Hanford site, with lowest concentrations recorded at upstream locations. Since 1990, H-3 concentrations present in the Priest Rapids Dam (upstream of Hanford site) and Richland Pumphouse (downstream of Hanford site) have declined slightly with higher concentrations recorded near 150 pCi/L, well below the ambient water quality standard (AWQS) of 20,000 pCi/L (Pacific Northwest National Laboratories, 1996b).

Preliminary results from the U.S. Geological Survey National Stream Quality Accounting Network Program indicate that applicable standards for a Class A-designated surface water body were met in 1995. Metals and anions detected in the Pacific Northwest National Laboratories 1995 Columbia River water samples were below Washington State ambient surface water quality criteria levels for acute toxicity. Chronic toxicity testing results indicated regulatory limits for all metals and anions were met except for lead. Lead concentrations were above the Washington State limits in all Columbia River transect samples with the exception of those collected along the 300 Area transect. Future monitoring will require the use of a lower detection limits analytical method for some parameters since the minimum detection levels for cadmium and mercury exceeded chronic toxicity testing standards and that of silver exceeded the acute toxicity standard (Pacific Northwest National Laboratories, 1996b). Volatile organic compounds (VOCs) occasionally detected in the water were within regulatory limits.

Other nearby offsite water analyzed in 1995 included sources used for irrigation and/or drinking water. Radionuclide concentrations for these sources were reported below the applicable DOE Derived Concentration Guides, Washington State ambient surface water quality criteria levels, and Drinking Water Standards. The total U limit in the proposed EPA Drinking Water Standard was exceeded at one location, although all other locations exhibited naturally occurring regional levels.

Onsite sediment and aquatic vegetation samples were analyzed for Pu-239 and 240, Sr-90, U, and gamma-emitting radionuclides. The results indicated elevated radionuclides in some samples, however, all results were below applicable radiological control standards.

Surface sediments collected in 1995 from various Columbia River shoreline locations indicated highest elevated levels of beryllium (Be-7), Sr-90, Pu-239 and 240, Co-60, U-235 and 238, and europium (Eu-155). Metals were detected in all samples collected and analyzed. McNary Dam sediments had the highest median concentrations for most metals and the maximum and highest median concentrations of chromium were reported from the riverbank spring sediments.

2.3.4 Groundwater Contamination

A comprehensive surveillance program exists for periodically monitoring the groundwater originating beneath the Hanford site because of the magnitude, and the lateral and vertical extent of contamination plumes, both onsite and offsite, composed of radionuclides and hazardous compounds. Some of the highest levels of groundwater contamination exist in the contaminant plumes that have originated from the 200 Areas. In the 200-East Area, the B and Plutonium Uranium Extraction (PUREX) plants and associated operations are primarily responsible for releases to the environment. In the 200-West Area, the Reduction-Oxidation (REDOX), U, and T plants, and the TX and TY tank farms, are the primary sources of contaminant release.

A groundwater monitor well network comprised of about 800 wells is maintained at the Hanford site. Wells are monitored in intervals ranging from monthly to annually, with selected wells less frequently. Pathways for human exposure to contaminated groundwater are from onsite water supply wells and discharge to the Columbia River. The majority of wells are placed and screened within the lower unconfined aquifer, however, the upper confined aquifer is also monitored because it, too, is a potential pathway for offsite contaminant migration. Additional wells have been constructed along the site perimeter and in various offsite locations (upgradient and downgradient) to monitor contaminant migration and determine background conditions for establishing baseline water quality criteria.

Water supplies in and around the Hanford site that pose risks to human exposure to contaminants include three onsite water supplies and the Richland city water supply wells. Wells near these water systems are also monitored on a regular basis. Waste disposal facility areas are regulated by RCRA, and other areas are regulated under the EPA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Wells that do not fall within these two EPA programs are monitored under general surveillance and other monitoring programs established at the Hanford site.

Annual monitoring of the Hanford site drinking water system indicated elevated H-3 levels (about 20,000 pCi/L) in the 400 Area drinking water when a backup water supply was used for several months. Otherwise, the annual average H-3 concentration was in compliance at 8,424 pCi/L (Pacific Northwest National Laboratories, 1996b).

Contaminants of concern detected in the groundwater on a sitewide basis include many radionuclides and chemical compounds that have been detected by analyses incorporating up to about 17 radiological parameters and 20 inorganic and organic parameters (not individual compounds), such as heavy metals, VOCs, polychlorinated biphenyls (PCBs), and semivolatile organic compounds. Based on the 1995 monitoring program results, radionuclides and chemical compounds detected at concentrations

greater than the maximum contaminant level or interim Drinking Water Standard were mapped as shown in figures 2-5a and 2-5b, respectively (Pacific Northwest National Laboratories, 1996a). It must be noted that the proposed privatization facilities for the TWRS will be located at the eastern boundary of 200-East area.

Radionuclides detected above Drinking Water Standard levels in one or more wells were Cs-137, Co-60, iodine (I-129), Pu, Sr-90, technetium (Tc-99), H-3, and U. In addition, total alpha and beta levels also exceeded drinking water standard levels. DOE Derived Concentration Guide groundwater limits for H-3, Sr-90, Pu, and U were also exceeded.

H-3 is the most mobile radionuclide contaminant and is present throughout onsite groundwater plumes originating from the 200-East and 200-West Areas, extending into the 300 and 600 Areas, and discharging into the Columbia River at and near the 100-N Area, and possibly also the 100-K Area. The 200-East plume, with reported concentrations above the regulatory Maximum Contaminant Levels (MCLs), trends towards the east and southeast, into the 300 Area and the Columbia River. Physical flow barriers created by the North Richland well field recharge ponds and Yakima River prevent this plume from migrating further south toward the city of Richland. H-3 concentrations above the MCLs are also present in groundwater at the 100-B, 100-D, and 100-F Areas (Pacific Northwest National Laboratories, 1996a).

Although I-129 and H-3 were released from the same sources, migration and subsequent discharge of I-129 into the Columbia River is known, but not confirmed at levels exceeding Drinking Water Standards. The 200-East Area, 200-West Area, and 600 Areas all have plumes with reported I-129 concentrations greater than Drinking Water Standards.

Sr-90, U, and Tc-99 plumes are present in the 100, 200-East and -West, and 600 Areas (U is also in the 300 Area) with reported concentrations above the Drinking Water Standards and/or DOE Derived Concentration Guide limits. Discharge of Sr-90 from these plumes into the Columbia River is known. U is suspected of discharging into the Columbia River, but there is no supporting data to indicate that migration and subsequent discharge of elevated concentrations of Tc-99 into the Columbia River is occurring. Co-60, Cs-137, and Pu are present in the groundwater but appear to be mainly restricted to the 200-East Area and 600 Area, with each contaminant only reported in one or two wells at concentrations exceeding Drinking Water Standards and/or DOE Derived Concentration Guide limits.

The inorganic and organic chemical compounds detected above MCLs include carbon tetrachloride, chloroform, chromium, cyanide, fluoride, nitrate, and trichloroethylene. Although tetrachloroethylene was not detected above the MCL in the 1995 monitoring program, in previous years it has been reported in groundwater above the MCL.

Nitrate is mobile in groundwater and can be used to delineate nonradiological contamination at the Hanford site. Nitrate plumes extend throughout the site at the 100, 200-East, 200-West, 600, 1100 and Richland North Areas. Locations where the MCL for nitrate was exceeded include all 100 Areas except 100-B, and the 200 and 600 Areas. Nitrate is also suspected of originating offsite to the west and southwest from agricultural fertilizer and irrigation, and potentially the Siemens Power Corporation facilities. Suspected areas of impact include the 100-F Area, the western part of the 600 Area, and the Richland North Area.

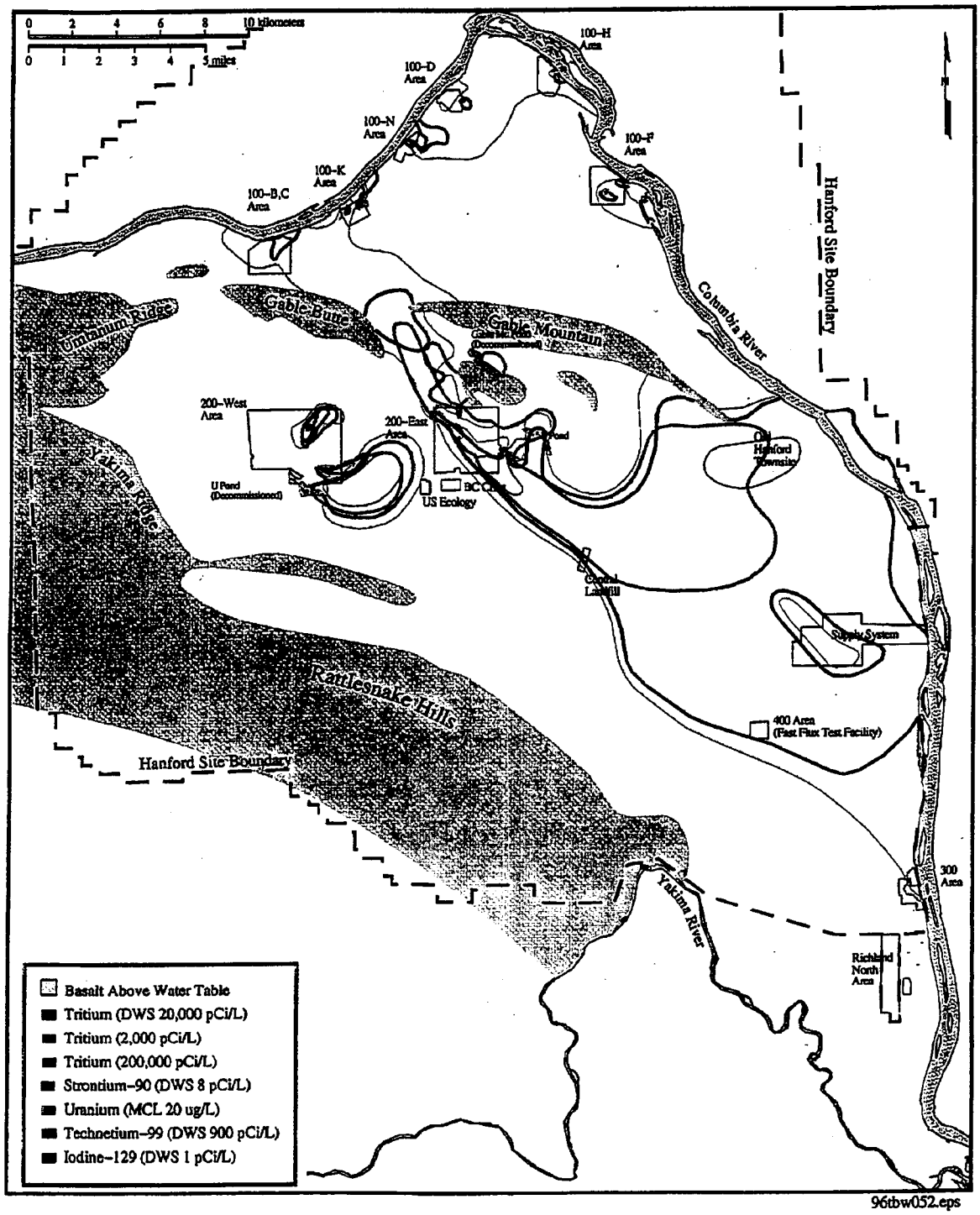

Figure 2-5a. Distribution of major radionuclides in groundwater at concentrations above the maximum contaminant level or interim drinking water standard (Pacific Northwest National Laboratories, 1996a.)

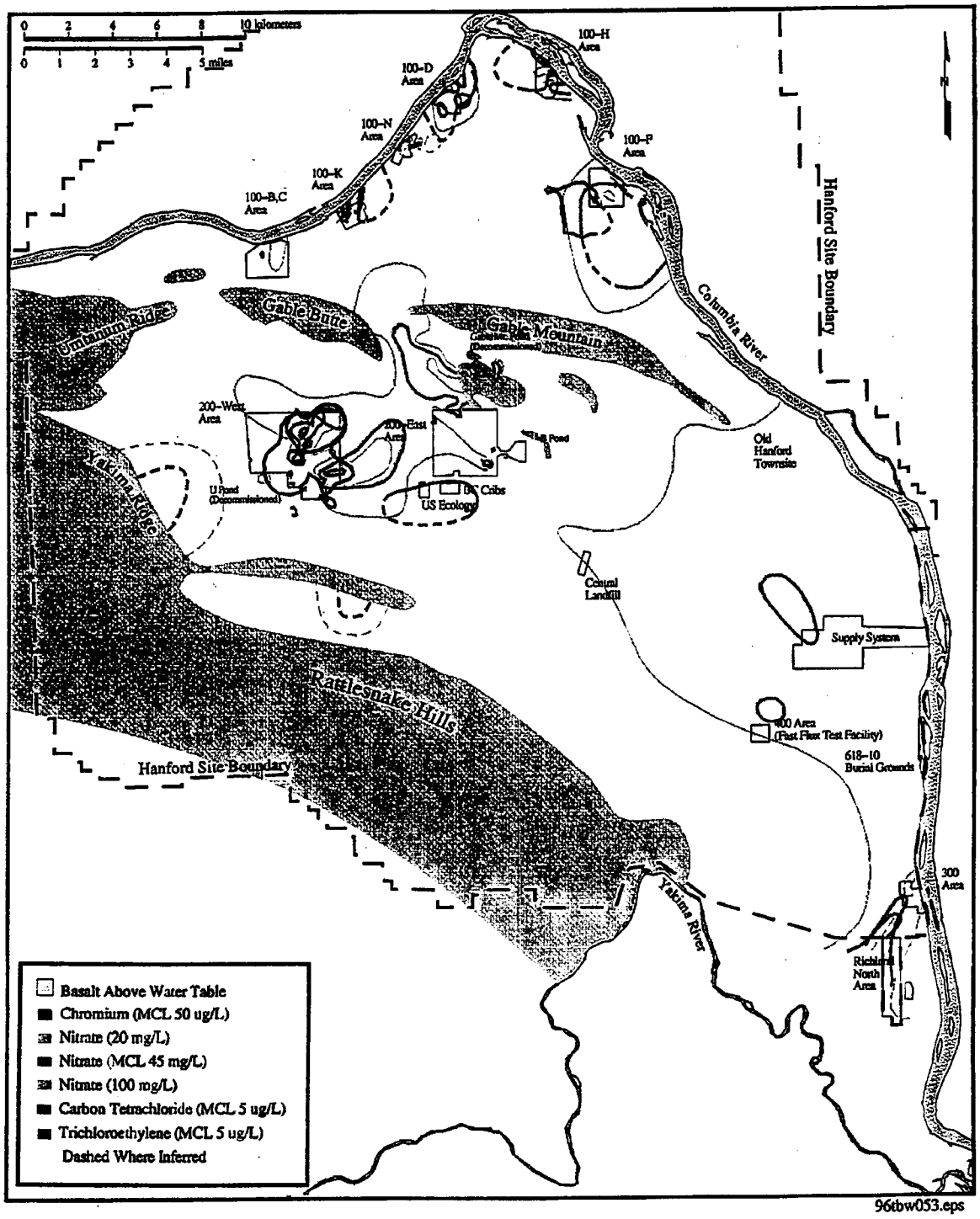

Figure 2-5b. Distribution of major hazardous chemicals in groundwater at concentrations above the maximum contaminant level (Pacific Northwest National Laboratories, 1996a.)

Chromium concentrations were detected above the MCL in most of the 100 Areas, and in the 200 and 600 Areas. Fluoride and cyanide were detected above Drinking Water Standards in groundwater from the 200-West Area and 600 Area (just north of the 200-East Area), respectively.

A vast plume of carbon tetrachloride and, to a lesser extent, its suspected degradation product, chloroform, has been mapped beneath the 200-West and 600 Areas. Groundwater analyses indicate concentrations in excess of the MCLs for both contaminants. Less extensive plumes of trichloroethylene containing concentrations above the MCL have been mapped beneath the 100-F, 100-K, 200-West, 300, and 600 Areas (Pacific Northwest National Laboratories, 1996a).

Based on the 1995 report, the only nonradiological contaminants being discharged offsite into the Columbia River in elevated concentrations are chromium and nitrate.

Generally, radionuclide and hazardous chemical contaminant concentrations in groundwater may have declined slightly in some areas, but overall they have not significantly changed over the last 5 years.

2.3.5 Air Contamination

Under the Clean Air Act amendments of 1990, the Hanford site is a designated major source for one or more criteria pollutants and for hazardous air pollutants. Presently, the Hanford site must comply with the radionuclide National Emission Standard for Hazardous Air Pollutants (NESHAP) of 10 mrem/yr (U.S. Department of Energy, 1996a).

Near-facility air monitoring for radioactivity is done by a network of continuously operating samplers positioned at 47 locations, most in the prevailing downwind directions, and primarily within about 500 m of nuclear facilities or sites having the potential for environmental releases. For the 1995 Annual Environmental Monitoring program, contaminants detected in the 200 Areas were Cs-137, Pu-239 and 240, Sr-90, and U, and for the 100-N Area Co-60 and infrequently Pu-239 and 240 were detected. Elevated air concentrations for these radionuclides were detected near facilities while offsite concentrations were measured at lower concentrations. However, no radionuclides were detected above regulated limits. Radionuclide air concentrations are showing a decreasing trend, particularly in the 200 Areas due to facility shutdowns and improved operations (U.S. Department of Energy, 1996a).

Air surveillance includes continuous air sampling of 40 onsite locations, the site perimeter, and in nearby and distant communities for analysis of radioactive materials that are collected as filtered particulates at all sites, and also as selected gaseous radionuclides at strategic sites. Differences in concentrations for worldwide radionuclides sources, such as naturally occurring and historical nuclear fallout, were accounted for by measuring the site perimeter and distant regional locations concentrations.

Total beta air concentrations for the site perimeter and distant locations were not significantly different. However, total alpha air concentrations for the perimeter were slightly higher than distant location measurements. No gamma radionuclides from the Hanford site were consistently detected.

Specific radionuclides detected during the 1995 air surveillance program include H-3, I-129, Sr-90, and Pu-239 and 240. Measured concentrations were evaluated according to the DOE Derived

Concentration Guide, which is the air concentration that would result in a radiation dose equal to the DOE public dose limit in millirems per year.

Site perimeter concentrations of H-3 and I-129 were slightly elevated compared to distant locations. However, the elevated H-3 concentrations were not statistically significant, and concentrations of I-129 measured only 0.000002 percent of the DOE Derived Concentration Guide of 70 pCi/m^3. Sr-90 was only detected onsite with the maximum concentration at 0.003 percent of the DOE Derived Concentration Guide of 9 pCi/m^3. Site perimeter and distant location concentrations of Pu-239 and 240 were similar with a maximum concentration at 0.02 percent of the DOE Derived Concentration Guide of 0.1 pCi/m^3 (Pacific Northwest National Laboratories, 1996b).

Chemical contaminants of concern included in the air sampling program were PCBs, polycyclic aromatic hydrocarbons (PAHs), chlorinated pesticides, and phthalate plasticizers. All but the phthalate plasticizers were detected in the 1995 monitoring data. Total average concentrations ranged from 490 to 660 pg/m^3 for PCBs. The highest average concentrations for the 14 PAHs and 16 chlorinated pesticides detected were 800–2500 pg/m^3 for phenanthrene and 550–3,500 pg/m^3 for Endosulfan I, respectively (Pacific Northwest National Laboratories, 1996b).

In the absence of regulatory standards, air concentrations for these organic pollutants are evaluated according to health risk-based concentrations, which means that concentrations below risk-based levels are less than 1×10^{-6} for cancer risk and less than 1.0 hazard quotient for non-cancer risk. Only the maximum total PCB concentrations exceeded risk-based concentrations and they were two times the accepted risk-based levels (Pacific Northwest National Laboratories, 1996b).

Overall, the air quality in the Hanford site vicinity is good with particulates being the only air pollutant that exceeds regulatory standards. Monitoring results for 1994 and 1995 indicated onsite and offsite concentrations of radionuclides and hazardous air pollutants were below applicable limits.

2.3.6 Surface Soil, Vegetation, and Wildlife Contamination

Soil and vegetation sampling results at the Hanford site indicate that samples collected on or adjacent to waste disposal operational areas typically have higher concentrations of contaminants than those collected from distant locations. Offsite surveillance monitoring of soils and vegetation are not currently performed because of the onsite remediation operations and cessation of Pu production operations.

Elevated Sr-90 and Cs-137 levels were detected in the 1995 fish and wildlife sampling effort, with overall levels of radionuclide accumulations in small amounts for specific radionuclides indicative possibly of fallout or Hanford site sources. Sr-90 was detected in goose eggshells and fish while Cs-137 was present in some goose muscle samples (Pacific Northwest National Laboratories, 1996b).

Agricultural and food products from around the Hanford site were sampled and analyzed for numerous radionuclides and only a few contained low radionuclide concentrations that were slightly elevated above background conditions. These samples were from milk (collected at downwind locations from the site) containing I-129 levels that indicate a steady decline in concentration over the last six years; wine samples containing H-3 levels below hazardous consumption levels, and alfalfa with Sr-90

concentrations that appear to be related to the use of Columbia River irrigation water (Pacific Northwest National Laboratories, 1996b).

2.4 FACILITY AND AREA RADIOLOGICAL SURVEYS

In addition to media monitoring, radiation levels emanating from facility structures and operational areas are surveyed. Radiation surveys are conducted using thermoluminescent dosimeters and hand-held microrem meters.

The 100-N Area, specifically the 1301-N and 1325-N Liquid Disposal Facilities, contained or received liquid effluent from the N Reactor and had the highest direct radiation measurements. Significant decreases in exposure levels up to 12 percent were seen in the 1990–1995 time frame, due to continuing radioactive decay and facility closures. Restoration projects in the 100 Area contributed to elevated radiation dose rates, however, the overall effects were measurable decreases upon completion of cleanup activities (Pacific Northwest National Laboratories, 1996b).

Waste-handling facilities in the 200 (tank farms), 300, and 600 Areas had the highest radiation dose measurements. The average annual 1995 radiation dose was about 120 mrem/yr for the 200 Areas, 140 mrem/yr for the 300 Area, and 120 mrem/yr for the 600 Area, which represents a decrease of about 12, 18, and 12 percent, respectively, from 1994. The 400 Area reported the lowest average dose rate of 77 mrem/yr, representing an annual decrease of 32 percent.

In general, radiation doses throughout the site have been declining due to better environmental management practices, facility closures, radioactive decay, and restoration activities. The calculated maximum total radiation airborne dose of 0.006 mrem was much lower than the public exposure limits of 10 mrem/yr and 100 mrem/yr as set by EPA and DOE, respectively.

2.4.1 Remedial Action Summary

For each of the designated facility areas, a brief summary of the existing and proposed remedial actions is provided in the following paragraphs. This material has been extracted primarily from the 1996 Baseline Environmental Management Report (U.S. Department of Energy, 1996e). Figure 2-6 provides a sitewide overview of the magnitude of the proposed restoration of buildings and reactors for decontamination and decommissioning, and soil and waste to be excavated.

2.4.1.1 100 Area

Approximately 640 acres of property have been identified as contaminated in the 100 Areas, thus requiring risk analysis and identification of sites for remediation. Currently, about 75 percent of the soil and groundwater contamination and remediation technologies evaluations for high-priority sites within the 100 Areas have been completed with the remaining low-priority areas to be characterized by fiscal year (FY) 1988.

Remediation activities in the 100 Area include the excavation and replacement of an estimated 3 Mm^3 (4 Myd^3) of contaminated soils, analysis of about 20,000 soil samples, and restoration of 640 acres of surface area. Proposed groundwater treatment technologies include ion exchange for removal of chromium and radionuclides, with remaining (unremovable) H-3 contaminants reinjected up-gradient

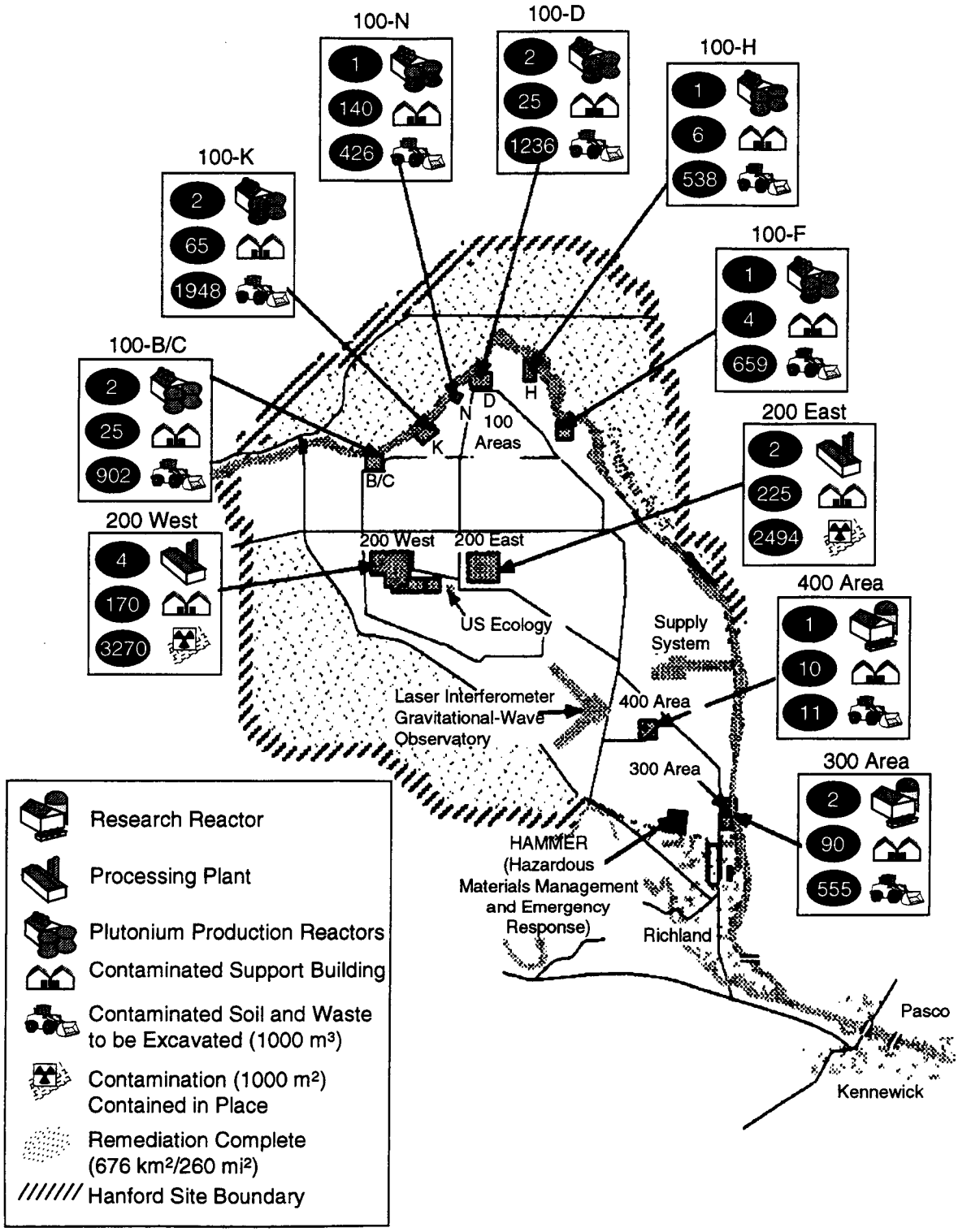

Figure 2-6. Proposed environmental restoration (U.S. Department of Energy, 1996e.)

from the river shoreline. Proposed treatment will continue until about FY 2002 and monitoring through FY 2018, or as determined at that time. It is expected that drinking water standards may not be attained, and groundwater use will remain restricted.

2.4.1.2 200 Area

The 200 Areas, East and West, have undergone detailed evaluations of existing waste sites and remediation priorities have been determined. Field investigations for determining soil and groundwater contamination and potential movement of contaminants in these media are still in progress and assumed to continue in FY 1998. Areas along the Columbia River have been designated the highest priority for remedial action.

For the 200 Area, the majority of contaminated soil and solid waste will be contained in place, using engineered caps and barriers to minimize contaminant migration, and the remaining uncontainable areas excavated and disposed in the Environmental Restoration Disposal Facility. Remediation is expected to be completed by FY 2038 with an estimated 6 Mm^2 (7.1 Myd^2) of caps installed. Limited soil remediation to date includes stabilization of some contaminated surface radiation areas and installation of vapor extraction systems for the removal of carbon tetrachloride, minimizing the potential for downward migration of contaminants into the groundwater.

As previously discussed, groundwater contamination of hazardous chemicals and radionuclides beneath the 200 Area is extensive and feasible treatment alternatives are currently being evaluated. Select areas already have pump and treat systems that were installed in 1994 for groundwater remediation activities for radionuclides and carbon tetrachloride. Similar systems are proposed for remediation at other areas to reduce high levels of hazardous chemical and/or radionuclides contaminant concentrations and future dispersion.

2.4.1.3 300 Area

Site characterization of the 300 Area is almost completed, with some soil and building areas to be characterized upon decommissioning. The 300 Area contamination consists primarily of petrochemicals and solvents with some radioactive materials, comprising about 50 acres of soils and buildings in industrial areas.

Remediation alternatives under consideration include retrieval of buried transuranic waste and soil washing for removal of U. The surface and subsurface soils are proposed to be remediated to industrial use levels with low-level radionuclides or hazardous chemicals disposed of at the Environmental Restoration Disposal Facility. All, approximately 276 m^3 (360 yd^3,) transuranic contaminated soil and buried waste is planned for disposal. It has been determined that contaminant concentrations in the groundwater originating from the 300 Area are decreasing and are currently at levels that do not pose a threat to the environment or public health. No remedial action is proposed for the groundwater at the 300 Area.

2.4.1.4 400 Area

Site characterization is complete for the 400 Area and remedial designs have been developed. The soil and debris contamination in this area is small in comparison to the other areas, with about

2,300 m^3 (3,000 yd^3) of low-level waste and hazardous chemicals identified for excavation and disposal in the Environmental Restoration Disposal Facility.

Additionally, decommissioning of the Fast Flux Test Facility is proposed which will involve removing heavily contaminated materials and entombing lightly contaminated structures. The entombed structures will be further protected by constructing an earthen berm around them with a cap on top. Approximately 935 m^3 (1,223 yd^3) of Low-Level Waste (LLW) and 71 m^3 (93 yd^3) of hazardous waste are estimated from this facility for disposal in the Environmental Restoration Disposal Facility. Area 400 is not an originating source of groundwater contamination.

2.4.1.5 Other Hanford Areas

Other areas developed for use at the Hanford site as buffer space or support operations include the 600 and 1100 Areas, the Arid Lands Ecology Reserve, and the North Slope. Remediation activities are already completed for all areas except the 600 Area. Site characterization at the 600 Area is almost complete with proposed surface and subsurface soil and debris contamination expected to require minimal excavation and subsequent disposal in the Environmental Restoration Disposal Facility. Regulatory approval for a No Further Action Required determination was issued for the groundwater in these areas.

2.5 ORIGIN OF WASTES

The primary source of the waste at the Hanford site is the historical irradiation and processing of U fuel to extract Pu. The fuels consisted of Al-Si clad metallic U fuel (B, D, F reactors) as well as the zirconium (Zr)-clad metallic U fuel (N and K reactors) (Wodrich, 1996). A total of about 100,000 metric tons of U (MTU) was processed, with about 74,000 MTU from the PUREX[2] process, 19,000 from the REDOX process, and the rest from the T and B plants. Reprocessing of the fuel started in 1944 and rose to a peak in the 1964–1965 time period (Gerber, 1992a; Wodrich, 1996), as shown in figure 2-7. Other important sources of waste at the site include (i) spent fuel stored in the K reactor basins and associated sludges due to corrosion products, fission products, and wind-blown debris; and (ii) various pilot-scale operations conducted in the 300 Area prior to full-scale operations in the 100 and 200 Areas. This section focuses on the reprocessing operations. A timeline of the processes leading to waste generation is shown in figure 2-8 (Agnew, 1997).

2.5.1 Fuel and Cladding Dissolution

The fuel from the B, D, and F reactors was processed to dissolve and remove the cladding using a caustic solution. Prior to 1952, the fuel was fabricated by encasing the U metal in a cladding (or jacket) using the triple dip method (Gerber, 1993). This process consisted of cleaning the bare U rods in nitric acid, placing them in a pre-cleaned steel sleeve, and then dipping them in succession in molten baths of bronze, tin, and an aluminum-silicon mixture. Following these dips, the steel sleeve was removed and aluminum end-caps were welded. From 1954 to 1964, a new lead dip process was substituted. In this process, the U rods were first immersed in a duplex bath of molten lead topped by a molten Al-Si layer followed by dipping in a molten bath of Al-Si mixture. The dissolved cladding from both these processes was sent to the tanks as cladding waste (CW).

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[2] A list of abbreviations is provided in the front matter of this report.

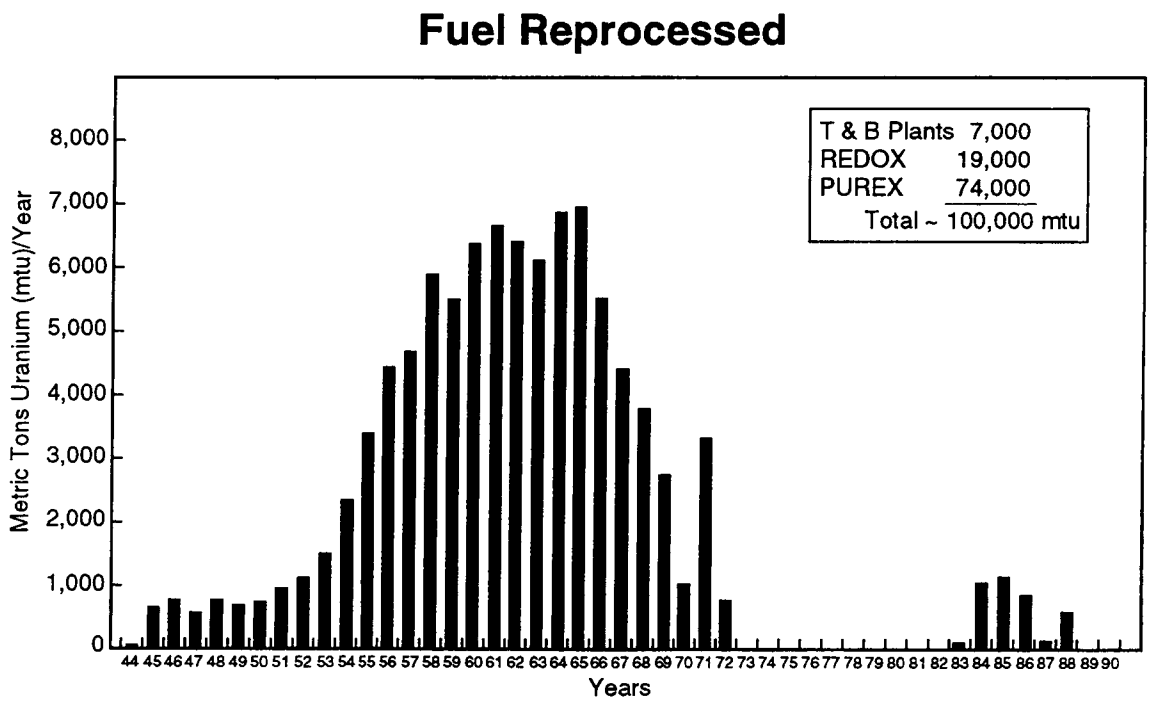


Figure 2-7. Annual estimates of fuel processed at the Hanford site using various processes (Wodrich, 1996)

2.5.2 Bismuth Phosphate Process

The history of the process chemistry development and details of the chemistry have been described by Thompson and Seaborg (1956). The Bismuth Phosphate (BP) process utilized the ability of bismuth to coprecipitate Pu in the +4 state in phosphoric acid [referred to as Pu (IV)] with bismuth phosphate ($BiPO_4$ referred to as BP), while U and other fission products did not coprecipitate to such a high degree. The separation was further enhanced when it was recognized that coprecipitation of Pu occurred only in the Pu (IV) state and not in the Pu (VI) state, whereas BP could be precipitated by controlling the acidity of the solution. A synopsis of the process is shown in figure 2-9 (Agnew, 1997). The fuel, containing U, Pu and fission products, is dissolved in nitric acid. Phosphoric acid and bismuth are added to the dissolved fuel solution and the Pu(IV) in the solution is precipitated as $Bi(Pu)PO_4$, while

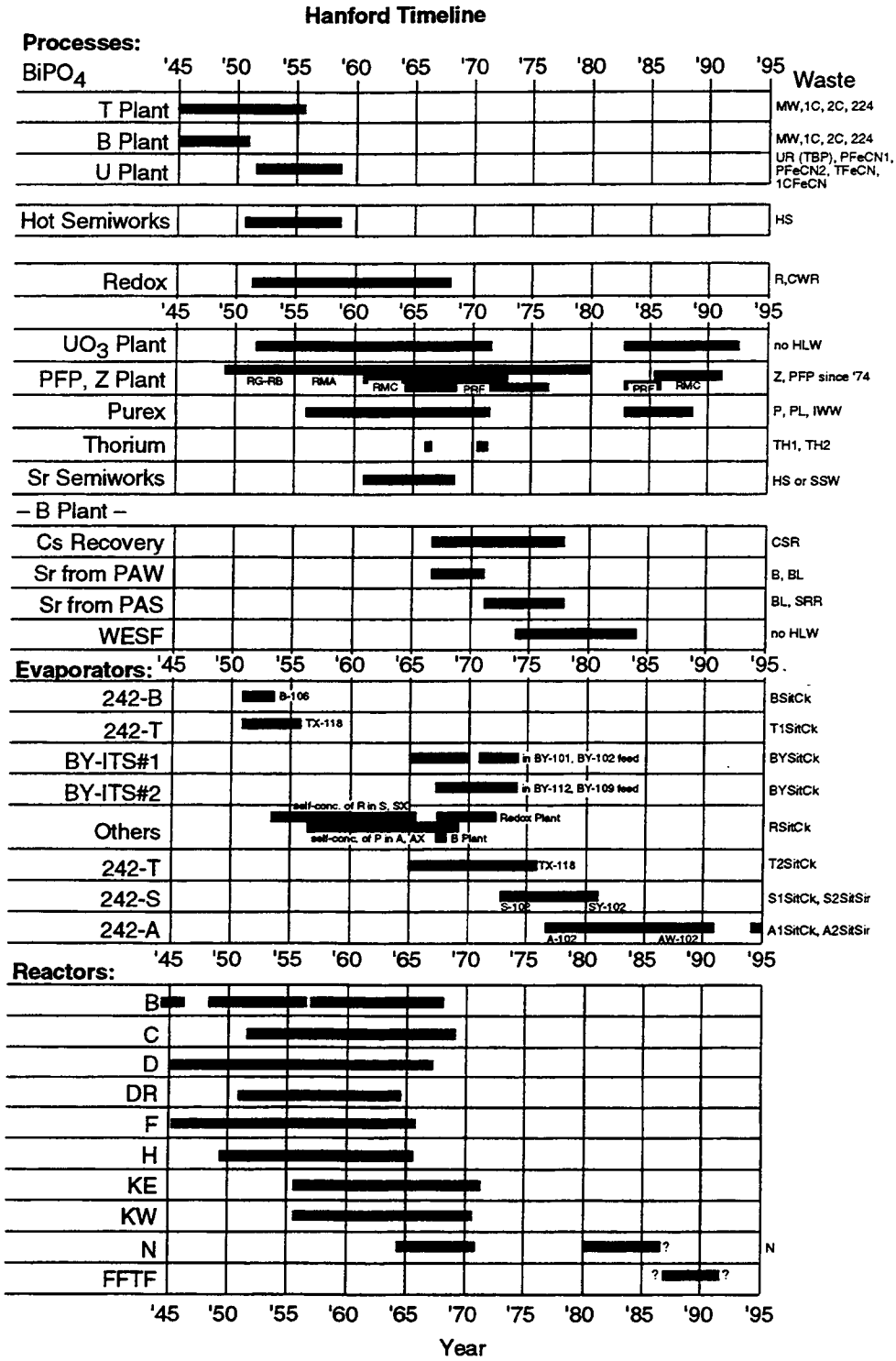


Figure 2-8. The timeline for various processes at the Hanford site and their associated wastes (Agnew, 1994). (The abbreviations for the wastes are indicated in the front matter of the report.)

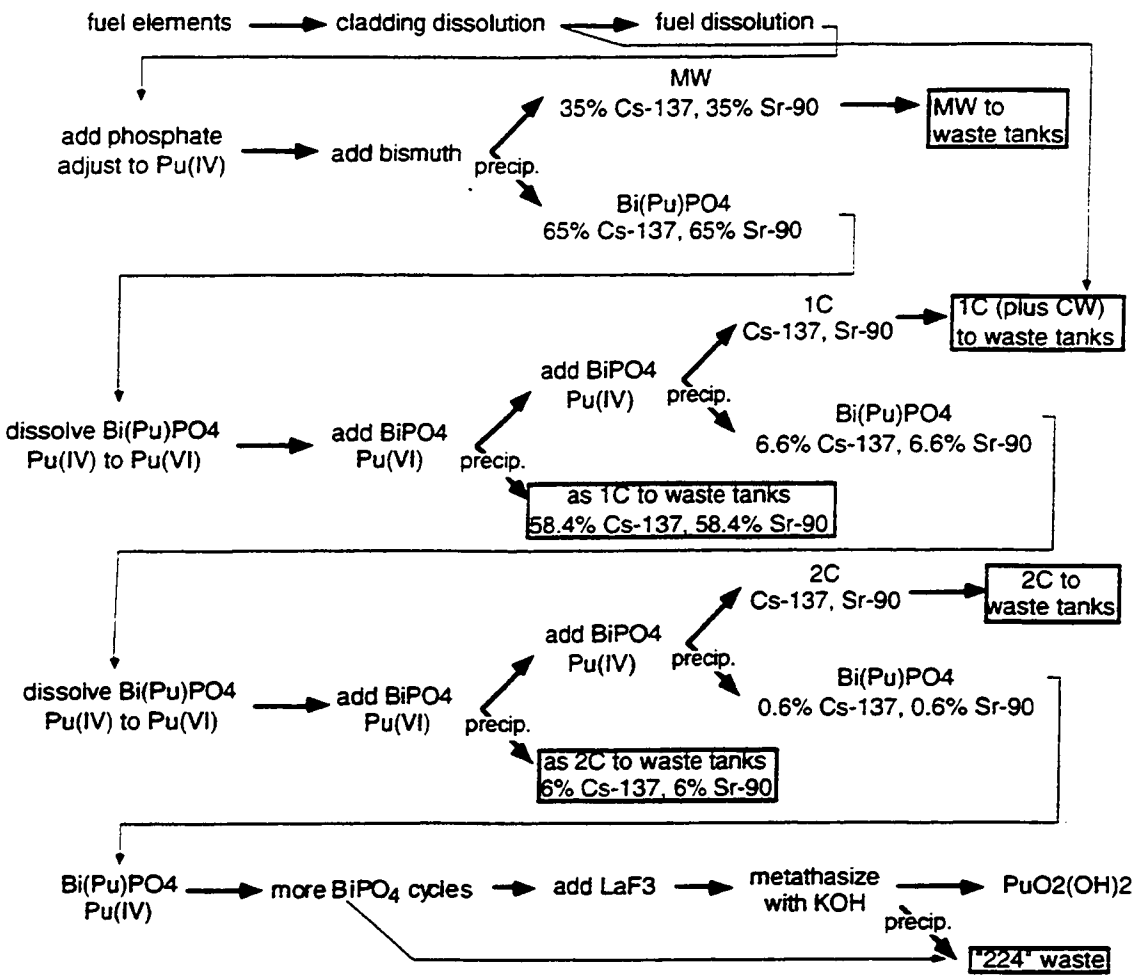


Figure 2-9. A synopsis of the BP process and associated waste streams (Agnew, 1997)

most of the U and fission products [labeled metal waste (MW)] are carried in solution. The $Bi(Pu)PO_4$ is dissolved again in nitric acid and the Pu(IV) oxidized to Pu(VI) using sodium bismuthate. When this solution is diluted or BP is added, the U and fission products precipitate and are sent to the waste tanks as First Cycle Waste (1C Waste), but the Pu(VI) remains in solution. Addition of ferrous ions to the supernate again reduces the Pu(VI) to Pu(IV) and the cycle is repeated. In the final stage, further purification of the Pu is achieved by coprecipitating the Pu(IV) with a small concentration of lanthanum fluoride.

The T, B, and U plants (or canyons) were constructed in 1944 to employ the BP process. However, because the B and T plants were sufficient to meet the demand, the U plant was never utilized for production using this process. Until 1952, the U plant was used to train the B and T plant operators. This process ran until 1952 in the B plant and 1956 in the T plant and generated some 370,000 m^3 (98,000 kgal) of MW, 1C, 2C, and 224 wastes (see glossary section for definition of these terms). The

1C, 2C, and 224 wastes referred to in figure 2-9 are from the first cycle, second cycle, and Pu finishing operation, respectively. The tank farms T, TX, and TY were used for wastes from the T plant and tank farms B, BX, and BY were used for wastes from the B plant. The discharges to the ground through trenches, cribs, and tank leaks from this process are given in the 200-West and -East Groundwater Aggregate Area Management Study reports (U.S. Department of Energy, 1992a, 1992b).

2.5.3 Uranium Recovery Process

In order to recover the U MW generated in the waste stream by the BP process, the U plant (221-U building) was converted to a U recovery plant and began operation in 1954 (Gerber, 1992b; Agnew, 1997) and ended in 1958. The wastes from this process included process waste and waste water sent to cribs, french drains, ponds, and ditches, and spent solvents and carbonate scrub solution sent to cribs (U.S. Department of Energy, 1992a). In 1955, the 224-U building, adjoining the U plant, was used to support the PUREX operation in the production of UO_3 powder.

The U recovery process at the Hanford site involved sluicing the tank wastes in the B, C, BX, BY, T, TX, and U tank farms using either water, a caustic or a carbonate solution (the latter two could have been used if sluicing was unsuccessful in removing all the sludge), dissolving the leachate in acid, complexing the U as U(VI) with nitric acid, and solvent extraction of U(VI) in a mixture of tributyl phosphate (TBP) and kerosene. A synopsis of the process is shown in figure 2-10. The U was recovered in the organic phase from which it was stripped by repeated carbonate wash and organic extraction. The U recovery process took advantage of the fact that the actinides, notably U and Pu, formed strong nitrato complexes in the hexavalent state whereas other fission products such as Cs, Sr, and Ru formed weak nitrato complexes (Fletcher, 1956). The nitrato complexes are quite soluble in organic solvents such as TBP or methyl isobutyl ketone (MIBK). When an aqueous nitrate solution was brought into intimate contact with an organic solvent such as TBP, the actinide nitrato complexes partitioned to the organic phase, while the fission products remained in the aqueous phase. Partitioning of the actinides to the organic phase was further enhanced by the presence of metal nitrates in the aqueous phase such as aluminum nitrate, called salting out agents. Because TBP was highly viscous and had a density close to that of water, it was diluted by other organic media such as normal paraffinic hydrocarbons (NPH) or kerosene. The actinides were then stripped from the organic phase using either dilute nitric acid solution or carbonate solution to recover the actinides. The carbonate wash shown in figure 2-10 is probably for washing the TBP/NPH phase after removal of U. Washing with carbonate removes residual waste from TBP/NPH and the organic phase is then recycled to the process.

The process produced about 2 m^3 of aqueous waste for each cubic meter of MW processed. Because the process produced more waste than could be accommodated by the tanks, concentrating the waste stream was performed by scavenging the supernatants (containing mostly Cs) with ferrocyanide [$Fe(CN)_6^{-4}$ also referred to as FeCN] to coprecipitate the Cs-137 with $Na_2NiFe(CN)_6$. The sludge from this process was returned to the tanks and the supernatant was placed in cribs. These tanks also contain remnants (heel) due to incomplete sluicing (ranging from 15 to 20 volume percent of the total MW) of original BP wastes, and these are suspected to be mainly a hard U carbonate phase. Agnew (1997) assumes that 80 percent of the Pu and 95 percent of the Cs associated with the MW waste were removed during the U and Cs recovery processes and ended up in the waste streams, while the remainder of the Pu and Cs ended up in the heel.

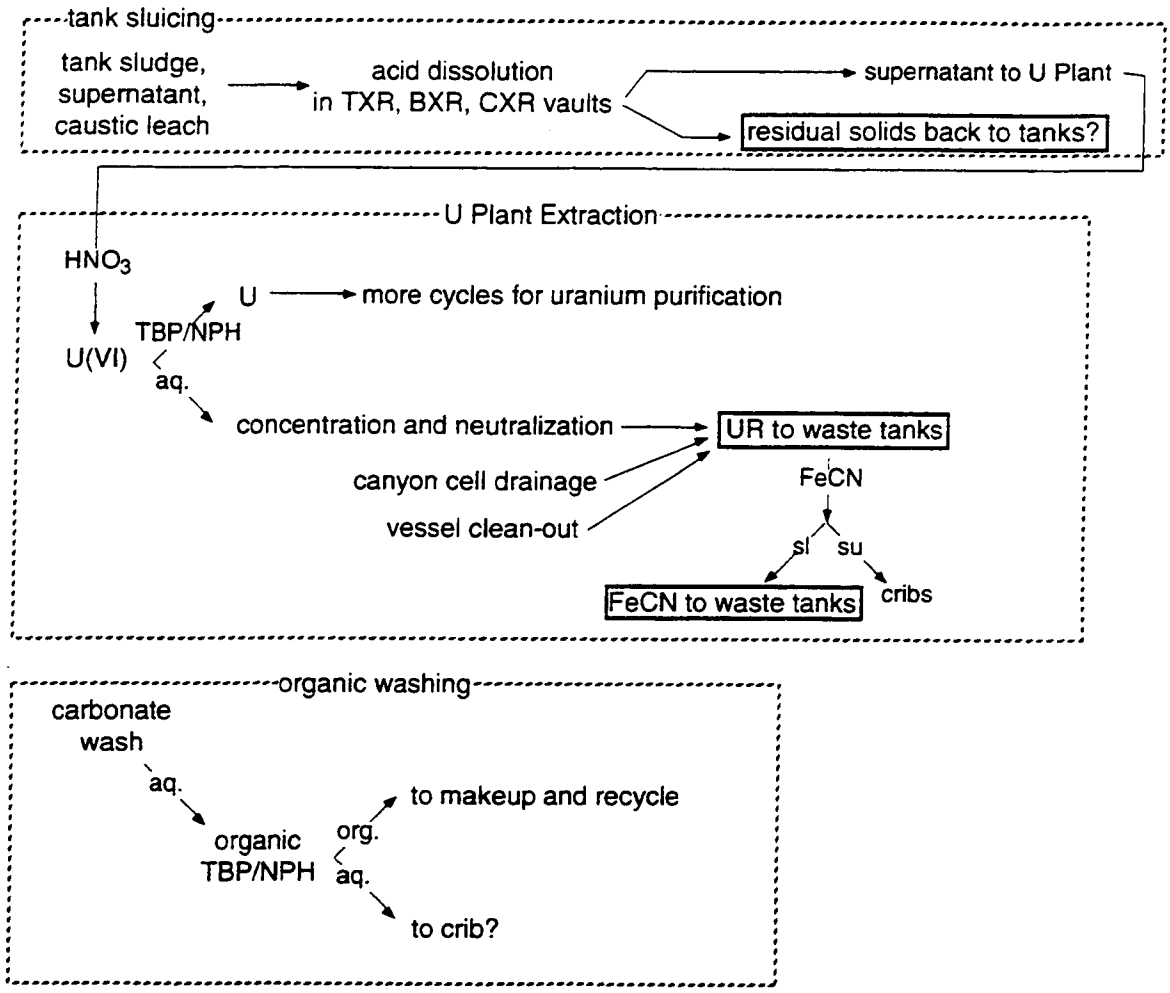


Figure 2-10. A synopsis of the uranium recovery process and associated waste streams (Agnew, 1997)

2.5.4 REDOX Process

The REDOX process began in January 1952 at the S or REDOX plant (202-S building) and was also based on continuous solvent extraction of Pu and U from an aqueous nitrate solution into methyl isobutyl ketone, also known as hexone. The synopsis of the process is shown in figure 2-11. Cladding was dissolved in caustic and separated from the fuel as cladding waste (CWR). While most of the fuel received for reprocessing in the S plant was Al-Si clad fuel, towards the end of the S plant operations in 1966, a small quantity of Zr-clad fuel was processed (Agnew, 1997). Following cladding removal, the fuel was dissolved in nitric acid and the solution composition was adjusted with $Al(NO_3)_3$ as a salting out agent, $Na_2Cr_2O_7$, NH_2SO_3H, and $Fe(NO_3)_3$ to control the REDOX condition such that U was present as U(VI) and Pu was present as Pu(IV). Intimate mixing with hexone extracted the actinides into the

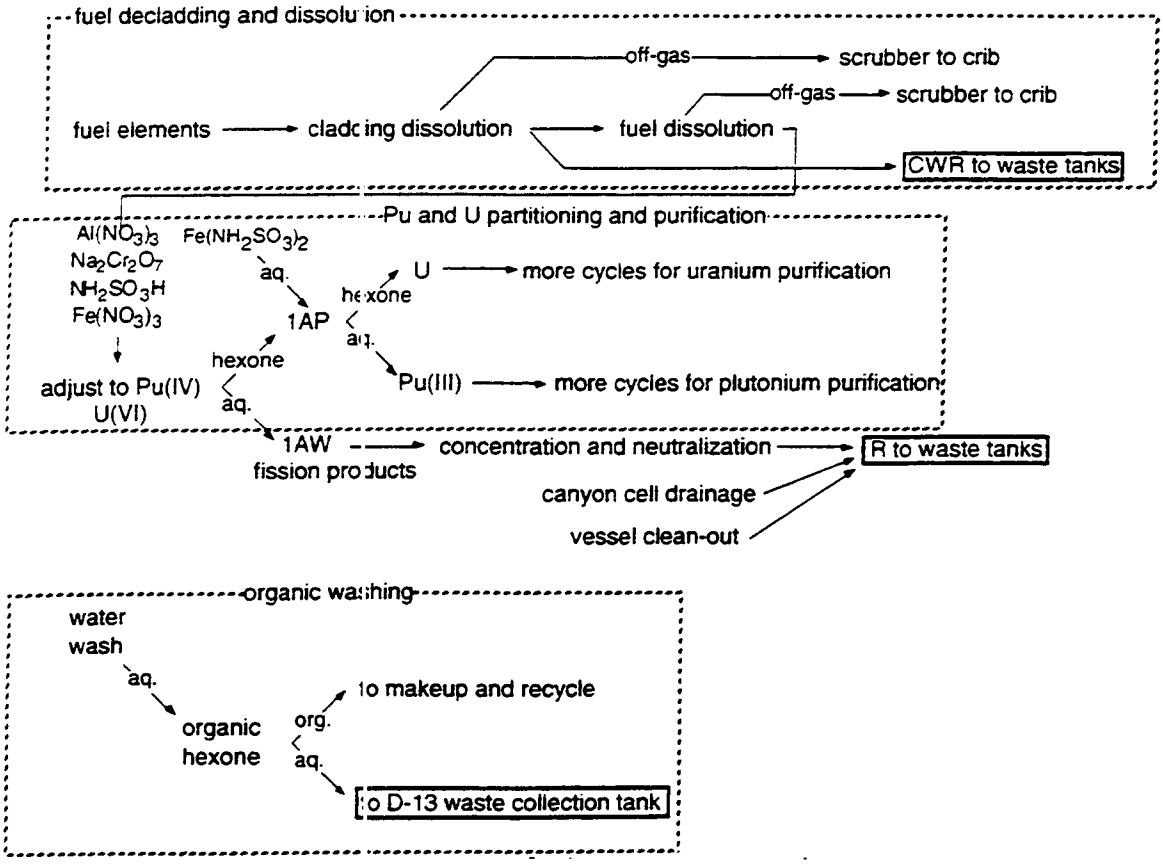


Figure 2-11. A synopsis of the REDOX process and associated waste streams (Agnew, 1997)

organic phase. The wastes, which were in the aqueous phase, went primarily to the S and SX farms. The organic phase was further washed with aqueous Fe(II) solution to reduce the Pu to Pu(III) which then partitioned to the aqueous phase. The Pu can be oxidized again to the tetravalent state to separate it from other actinides such as americium (Am). After removal of U from the organic phase, the organic medium was washed with water to remove the residual radionuclides and then recycled. The aqueous waste was sent to the tanks.

2.5.5 PUREX Process

The PUREX process started as a pilot plant in the Hot Semiworks (C plant) and became a production process in January 1956 in the PUREX or A plant. Al and Al-Si cladding was dissolved using caustic solution which does not affect the fuel. From 1968 to 1972, Zr clad was treated to dissolve the Zr cladding using a process called Zirflex process, presumably using hydrofluoric acid. Following cladding dissolution, the fuel was dissolved in nitric acid. After cladding and fuel dissolution, the aqueous Pu and U were complexed in a nitric acid solution and extracted into a TBP/NPH (kerosene) organic phase. The separation process chemistry is similar to that in the REDOX process, as shown by the process synopsis in figure 2-12. The REDOX condition prior to solvent extraction of U and Pu is adjusted using ferric nitrate instead of a mixture of nitrates, bisulfites, and dichromates as in the case of the

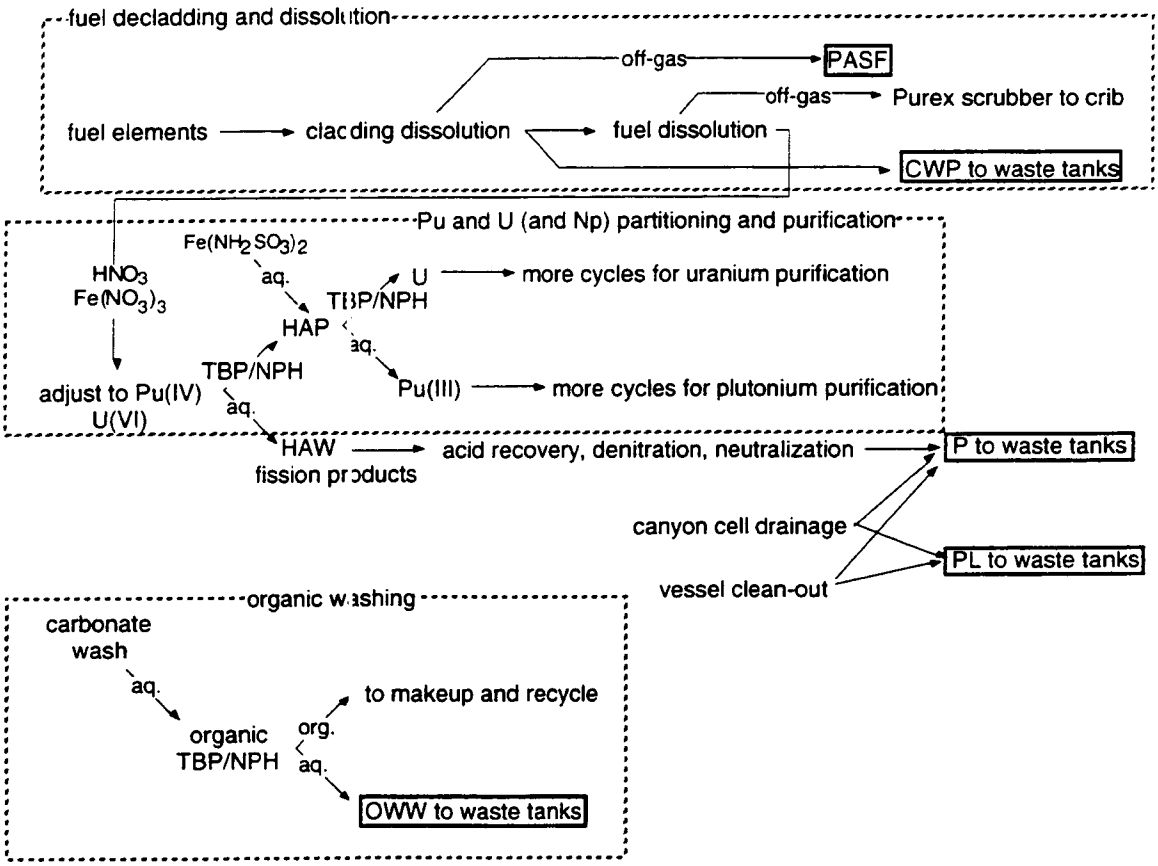


Figure 2-12. A synopsis of the PUREX process and associated waste streams (Agnew, 1997)

REDOX process. The ferric nitrate also acts as a salting agent to enhance the partitioning of the actinides to the organic phase. The organic solvent is finally washed with carbonate solution to remove radionuclide impurities and recycle the solvent to the solvent extraction process. From 1959 to 1961, the PUREX wastes were sent to the A and AX tank farms. The high activity waste (HAW) obtained by the separation of the agneous phase from TBP/NPH was denitrated using sugar to reduce the amount of caustic needed for neutralization.

2.5.6 Cesium and Strontium Recovery

The B and C plants were used to recover Cs and Sr, respectively, from the tank wastes, because the decay heat from these radionuclides was causing boiling in the tanks (Agnew, 1997). From 1962 forward, the Sr semiworks or C plant started processing the PUREX wastes to remove Sr-90, which was producing sufficient decay heat to cause boiling in the tanks (Agnew, 1997). The wastes from this operation were sent to the C tank farm. From 1968 to 1976 the B plant removed Cs from the neutralized supernatants taken from the A and AX tank farms which contained PUREX wastes and Sr from the PUREX acid waste from the PUREX plant and sludge sluiced from the tank farms. The supernatants from tanks for the Cs recovery were fed into the AR vault located close to the C plant through the C-105 tank as the staging tank and washed with caustic. The caustic solution was then sent to the B plant for Cs

recovery. The acid PUREX wastes were sent directly to the B plant. The waste from the B plant after Cs and Sr recovery was then directed to the B and BL tank farms.

The Cs and Sr recovery process synopsis is shown in figure 2-13. For the caustic Cs wastes, zeolites were used to extract Cs. For the acidic wastes, phosphotungstic acid was added to precipitate Cs. The supernatant from this process was treated with nitric acid and the Sr was recovered using solvent extraction into an organic phase containing TBP. The organic phase was washed as described before for the Redox process to recover the organic solvent and recycle to the solvent extraction process. The Cs was converted to a Cs chloride (CsCl), melted, and stored in double-walled capsules made of Type 316L stainless steel. The Sr was converted to a strontium fluoride (SrF_2) in a powder form, compacted, and stored in capsules of similar design to the Cs capsules. However, for the Sr capsules, the inner wall was made of a Ni-base alloy, Alloy C-276, and the outer wall was made of Type 316L stainless steel. A schematic of the capsule design is shown in figure 2-14. The centerline and surface temperatures calculated for air (figure 2-14) are presumably relevant to open, still-air conditions, although the assumptions in this calculation are not shown in the Environmental Impact Statement (EIS). There are at present 601 Sr and 1,328 Cs capsules with a total radioactivity of 76.3 MCi as of 1994. The capsules are stored under water in the Waste Encapsulation and Storage Facility (WESF) located close to the B plant. Monitoring and maintenance activities of the capsules involve calculating annual inventory, physically verifying that the inner capsule has not bulged (for Cs capsules only), and monitoring pool cell water contamination. The Cs capsules are "clunk tested" on a quarterly basis to determine if bulging of the inner canister has occurred. This is done in the pool itself by grasping one end of the capsule with the pool tong and moving it rapidly vertically by about 15 cm. This allows the inner canister to slide down within the outer capsule, making a clunking sound. If the capsule fails the clunk sound, it is removed to the hot cell for additional evaluation. Various alternatives for the long-term storage and disposal of these capsules are being pursued (U.S. Department of Energy, 1996b). The WESF is scheduled to be decontaminated and decommissioned within the next 10 years.

2.5.7 Other Processes

Various other processes were initiated in the production of Pu in the Z plant [also known as the Plutonium Finishing Plant, (PFP)], located in 200-West. The plant started by concentrating the Pu nitrate from the B and T plants into a paste, which took place from 1945 to 1949. In 1949, production of Pu metal was started and continued with some hiatus until 1988. This process used carbon tetrachloride, nitric and hydrofluoric acids, and various oils and degreasers. The wastes from these operations were sent to tanks TX-118 and SY-102 (Agnew, 1997). The RECUPLEX process started in 1955 to recover Pu from the Z plant waste stream and, during the operation, generated various organic wastes. Due to a criticality event, the RECUPLEX facility had to be shut down in 1962 (U.S. Department of Energy, 1992a). This was replaced by the Plutonium Reclamation Facility (PRF) which operated along the same principles until 1987. Another operation that took place in the Z plant was the recovery of Am from the PFP waste stream using an ion-exchange process. This process was stopped in 1976 after an explosion in one of the recovery units (U.S. Department of Energy, 1992a). A review of reports regarding the analyses of the causes of the explosion has not been performed.

2.5.8 Solidification Technologies

The history of various solidification processes at the Hanford site and other DOE sites has been described by McElroy and Platt (1996). Prior to 1965, solidification experiments were carried out in the

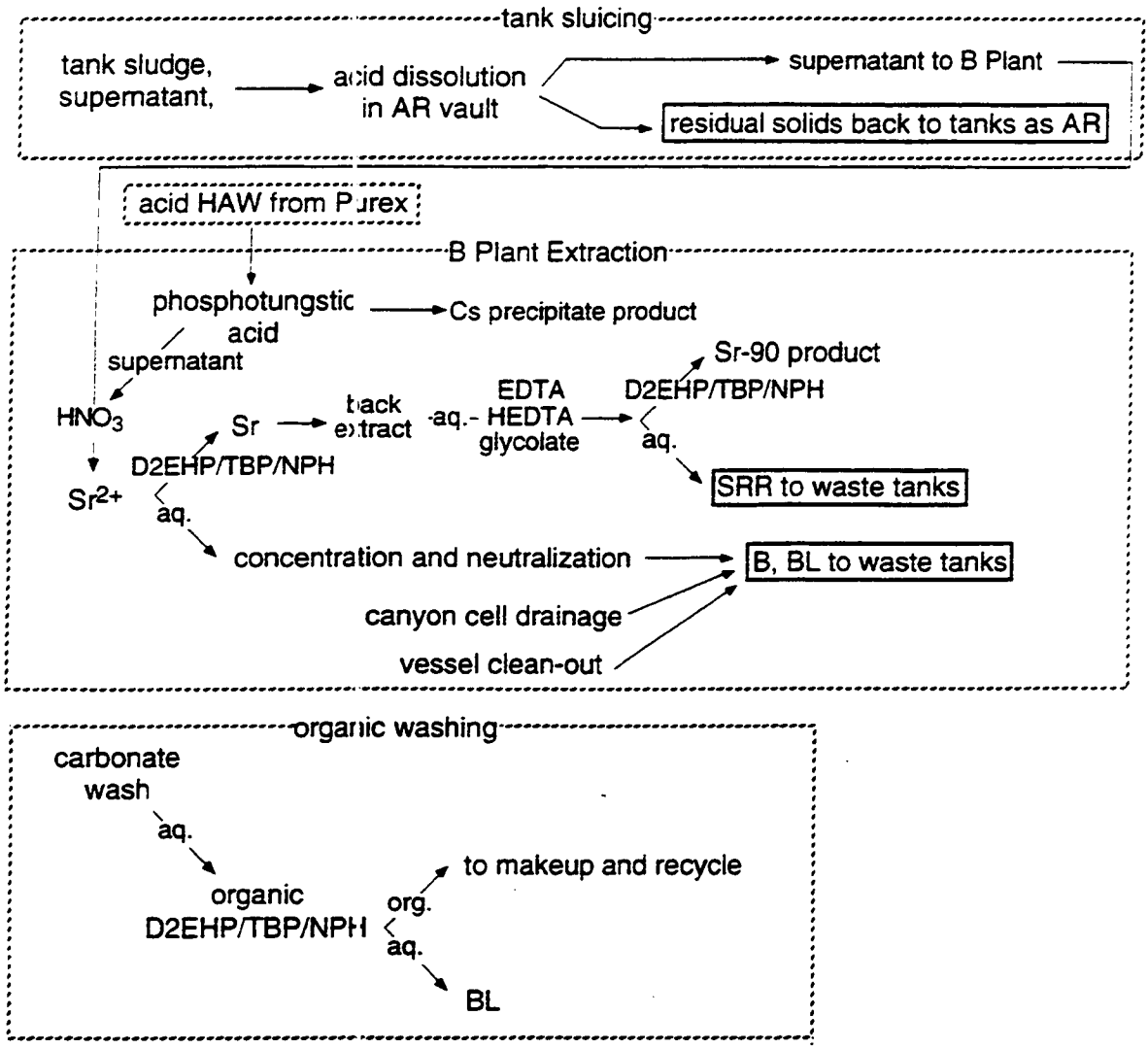
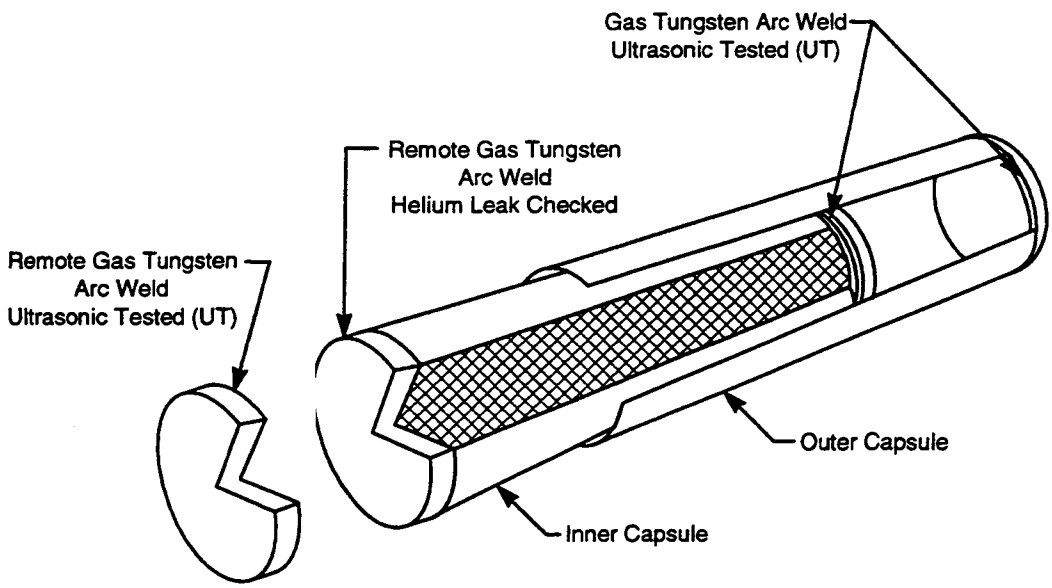


Figure 2-13. A synopsis of the strontium recovery process and associated waste streams. Cesium recovery from acidic waste is also shown (Agnew, 1997).

321 building using spray calcination to convert waste to a glass/ceramic waste form. Between 1965 and 1971, the Waste Solidification Engineering Prototypes (WSEP) program was conducted by PNNL in the 324 building. In the following 5 years, over 50 MCi were processed. Various solidification processes were tried including the Oak Ridge National Laboratory pot calciner, phosphate glass process, and spray calciner/melter process. The equipment was mounted on modular units and located in a single hot cell. Waste feed from the Hanford 200 Areas B plant was brought in and stored in vault tanks prior to solidification. A total of 33 solidification demonstrations were completed corresponding to the solidification of 104 metric tons of original fuel. Later in 1975, a small engineering scale vitrification facility was built in the 324 building along with engineering scale reprocessing facility. Spent fuel from the West Valley pool was obtained, reprocessed, and vitrified in this facility. The quantities and disposition of the solidified waste are not discussed by these authors.

Capsule Details							
Chemical Form	Physical Form	Curie Loading	Percent of Theoretical Density Based on Total Void Space of Capsule	Capsule Temperature			
				In Air		In Water	
				Center Line	Surface	Center Line	Surface
Strontium Fluoride	Compacted Powder	150 kCi (max)	68	860°C	430°C	660°C	71°C
Cesium Chloride	Melt-Cast	70 kCi (max)	65	450°C	200°C	327°C	58°C

Note: The curie loading for the capsules followed a broad nearly normal distribution.



	Capsule									
	Inner					Outer				
	Material	Wall[1] Thickness	Outside Diameter	Total Length	Total Cap Thickness	Material	Wall[1] Thickness	Outside Diameter	Total Length	Total Cap Thickness
Strontium Fluoride	Hastelloy C-276 (UT)	0.305 (UT)	5.72	48.39	1.02	Stainless Steel 316-L (UT)	0.277 (UT)	6.67	51.05	1.02
Cesium Chloride	Stainless Steel 316-L (UT)	0.241 (UT)	5.72	50.10	1.02	Stainless Steel 316-L (UT)	0.277 (UT)	6.67	52.77	1.02

Note: All dimensions are in cm.
[1]Wall thicknesses shown represent original design values.

Figure 2-14. A schematic view of the cesium and strontium capsules (U.S. Department of Energy, 1996b)

2.6 DESCRIPTION OF OPERATING FACILITIES

2.6.1 Overview of TWRS Facilities and Components

The TWRS facilities consist of waste tanks, evaporators, transfer piping, and processing vaults. Additionally, the privatization contractors are expected to construct the solidification facilities and waste handling systems. In evaluating the hazards associated with TWRS operations, it is important to obtain information on the materials of construction of various components. An overview of the materials of construction is provided in table 2-2 (Edgemon and Anantatmula, 1995). It must be noted that discrepancies can be found in the description of materials of construction and corrosion protection methods between various Hanford site reports. Where possible, these differences are pointed out. As further information becomes available, a resolution of these discrepancies may be attained.

2.6.2 Waste Tank Operations

Approximately 99 percent of the total radioactive waste volume at the Hanford site is stored in underground tanks. The tanks are grouped into tank farms and buried approximately 6 to 8 feet below ground in the 200-East and 200-West Areas (figure 2-15). In addition to the tank farms, there are Miscellaneous Underground Storage Tanks (MUSTs), most of which are inactive.

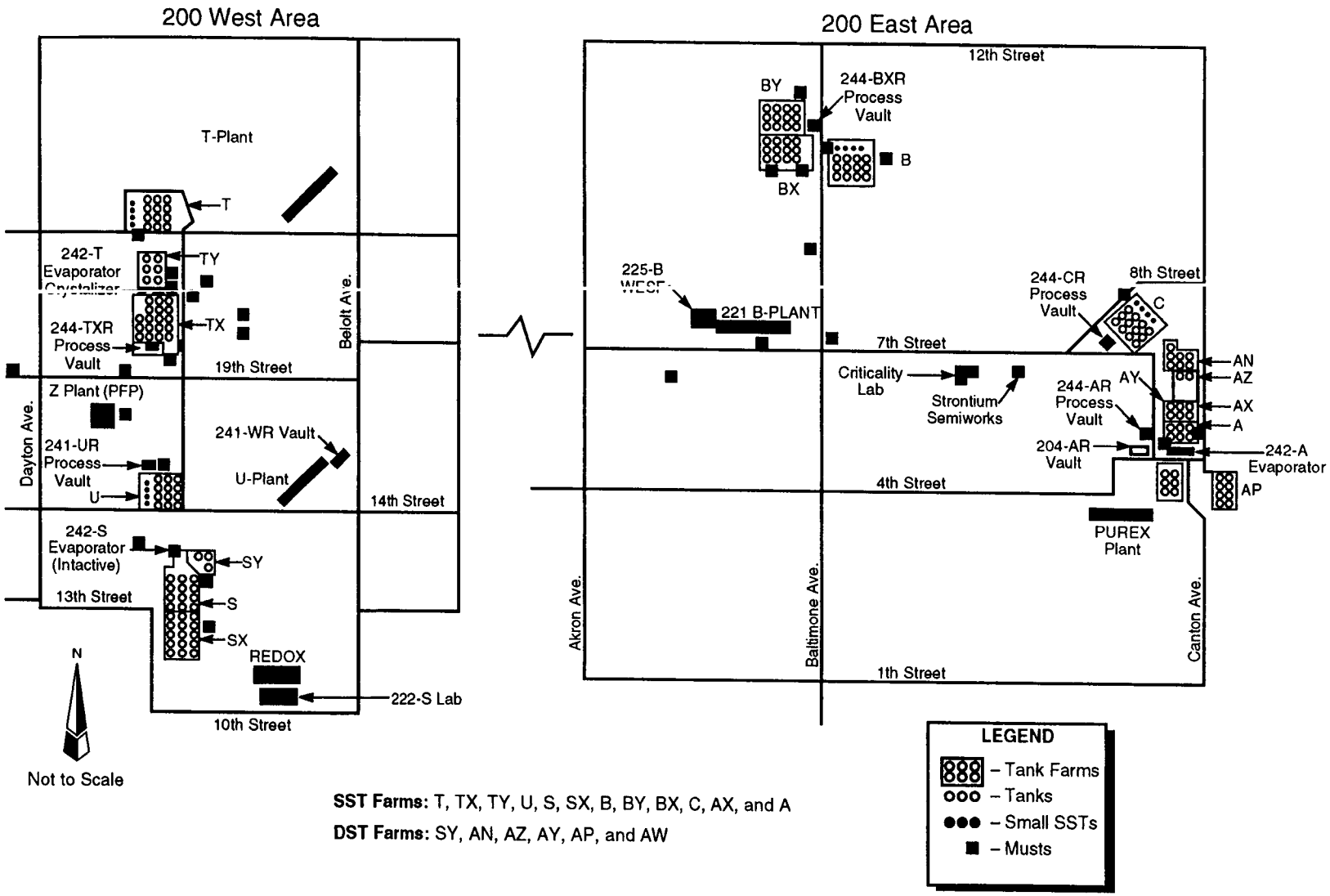
The first 149 tanks constructed at the Hanford site, starting in 1943, were made of a single carbon steel wall and floor in the form of an open container encased in an outer shell and dome of reinforced concrete. There are four basic designs of these single-shell tanks (SST), as shown in figure 2-16, with capacities ranging from 200 to 2,000 m^3 (55,000 to 1,000,000 gal). Construction of these SSTs was discontinued after 1964.

The tanks have two primary functions: (i) confinement—the tank shells and liners provide confinement barriers for liquid and solid wastes, and (ii) structural stability—the reinforced concrete structure and the steel liners of tanks provide acceptable safety margins for continued operation under normal and abnormal loads (Ohl et al., 1994). Table 2-3 provides details of the construction of the 149 SSTs including information on year of construction, location, farm, number of tanks in farm, capacity, steel grade, and condition of the steel plate. The SSTs were built by welding steel plates using flux- and later gas-covered electrodes, but none of the tanks were subjected to the stress relief post-weld heat treatment (PWHT) that is used in most recent designs. Changes in the specification of the steel were due to the introduction of new steel grades reflecting improvements in steel manufacturing practices and the development of tighter specifications by the American Society for Testing and Materials (ASTM) and American Society of Mechanical Engineers (ASME). Nominal design lives are not available in the SST design archives but an intended use of 20 to 40 yr temporary storage is generally accepted by the current Hanford site engineering staff (Ohl et al., 1994). All the SSTs have exceeded their intended life and 67 of them are known or assumed to have leaked radioactive waste to the surrounding soil (see chapter 4).

It is considered (Anantatmula et al., 1995) that the leakages experienced by the SSTs are the result of the initiation and propagation of cracks in the proximity of the welds due to stress corrosion cracking (SCC). This failure mechanism was confirmed for non-stress-relieved waste tanks at the Savannah River Site (Poe, 1974) and it has been observed in laboratory tests simulating the chemistry of the waste (Ondrejcin, 1978; Kirch, 1984). SCC of carbon steels in hot alkaline nitrate solutions within the range of concentrations typical of high-level radioactive wastes resulting from the reprocessing of

Table 2-2. Tank Waste Remediation System facilities and components

Facility	Component and Materials	Functions
DST	Primary tank (carbon steel)	Structural stability, primary containment
	Secondary liner (carbon steel)	Secondary containment, leak detection in annulus
	Concrete vault (side walls, dome, and base)	Structural stability, radiation protection
SST	Liner (carbon steel)	Primary containment
	Concrete vault (side walls, dome, and base)	Structural stability, radiation protection
Evaporator	Evaporator vessel (austenitic stainless steel)	Structural stability, containment
	Evaporator coils (austenitic stainless steel)	Primary containment
Transfer pipes (pipe-in-pipe)	Primary pipe (carbon or stainless steel)	Structural stability, containment
	Secondary pipe (carbon steel)	Structural stability, secondary containment
Transfer pipes (pipe in concrete)	Primary pipe (carbon or stainless steel)	Structural stability, containment
	Concrete trench	Structural stability, radiation shielding
Transfer pipes (direct buried pipe)	Primary pipe (carbon steel)	Structural stability, containment
Double contained receiver tanks	Storage tank (temporary)	Structural stability, containment
	Concrete vault	Structural stability, radiation shield
	Liner for concrete vault (carbon or stainless steel)	Secondary containment
Catch tanks	Storage tank (carbon steel)	Structural stability, containment
AR and CR vaults	Storage tank (carbon steel)	Structural stability, containment
	Concrete vault	Structural stability, radiation shielding



SST Farms: T, TX, TY, U, S, SX, B, BY, BX, C, AX, and A

DST Farms: SY, AN, AZ, AY, AP, and AW

Figure 2-15. A map of the tank farms in the 200 Areas, other facilities, and the approximate locations of the inactive miscellaneous underground storage tanks (U.S. Department of Energy, 1996a)

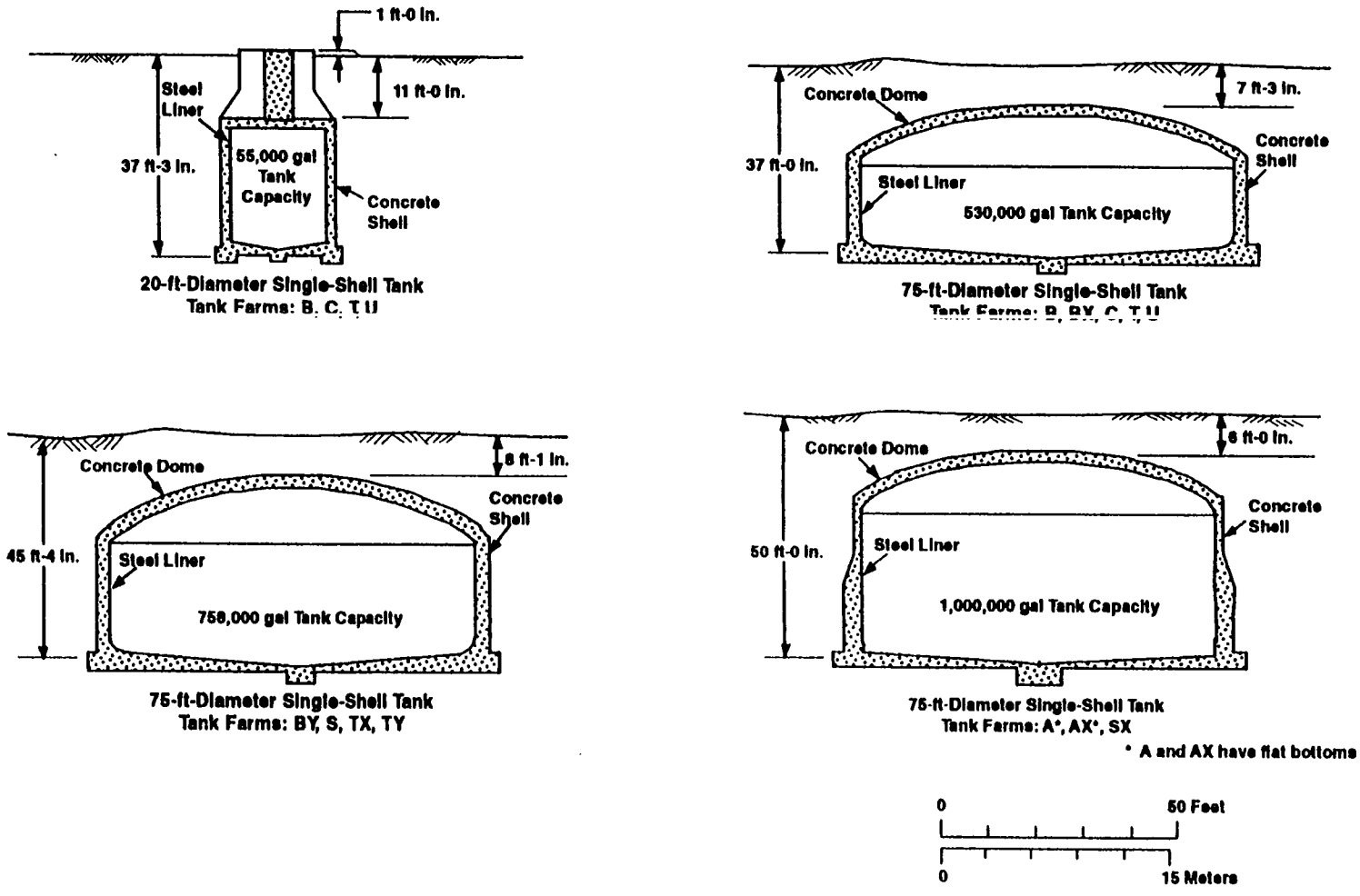


Figure 2-16. Schematic cross-sections of various types of single-shell tanks

spent fuel is a well recognized phenomenon (Donovan, 1977; Ondrejcin et al. 1979; Cragnolino, 1993). The occurrence of SCC can be inhibited, however, at high $[NO_2^-]/[NO_3^-]$ and $[OH^-]/[NO_3^-]$ ratios (Ondrejcin et al., 1979). Therefore, it may be possible to avoid SCC, even in tanks with relatively high residual stresses along the welds, by controlling the concentration of these anions in the waste streams entering the tanks or by pumping out of the tanks the supernatant and the interstitial liquids. These approaches have been adopted at the Hanford site in the process of stabilizing the waste in specific SSTs, an operation designated as tank stabilization.

As part of the resolution of waste tank safety issues at the Hanford site, other failure mechanisms and corrosion control options have been identified to minimize further degradation of the SSTs (Ohl et al., 1994). Localized (pitting and/or crevice) corrosion is another potential failure mode for SSTs (Anantatmula et al., 1995) A corrosivity factor (CF) has been defined as the ratio of the molar concentration of NO_3^- to the combined molar concentration of NO_2^- and OH^- to evaluate the propensity to localized corrosion of the waste contained in a tank. The critical CF above which the waste promotes localized corrosion is estimated to be 2.5. Different actions are recommended and eventually adopted for each tank, including pumping of liquid, addition of NaOH, and corrosion monitoring depending upon the estimated value of CF. Other failure modes, such as uniform corrosion, microbially influenced corrosion (MIC), concentration cell corrosion, erosion corrosion, hydrogen embrittlement, thermal embrittlement, radiation damage, fatigue, creep/stress relaxation, mechanical wear, and environmental degradation of the reinforced concrete are not expected as generic problems under the conditions prevailing in the tanks, although isolated instances of failure due to some of these processes may be plausible (Ohl et al., 1994, Anantatmula et al., 1995; Edgemon and Anantatmula, 1995).

Over the years, the design of the SSTs changed to better accommodate the waste being stored and to reduce the occurrence of corrosion. Alterations include adding equipment to handle self boiling waste, increasing size and changing the bottom to a flat surface instead of a bowl shape. Another change was the addition of a grid of drain slots beneath the steel liner. The grids were designed to collect leakage and divert it to a leak detection well. Another design difference is that several SST were built in cascades of three or four tanks connected with piping at different levels. Thus, when a tank filled to the level of the pipe, waste would flow through the pipe to the next tank. This construction allows the contents of the tank to settle to the bottom and therefore, the waste that went to the next tank had less solid and less radioactivity (mostly in the form of Cs, since Sr had settled out in the solids). This design also allowed the waste to be pumped into one location until all the tanks were full, reducing the amount of waste rerouting to fill the tanks in a particular cascade group.

Figure 2-17 shows the configuration of the instrumentation currently available in SSTs. All SSTs have measuring devices to monitor the surface level of the waste, including manual tape, automatic FIC, which is a device manufactured by the Food Instrument Company, and/or ENRAF, which is a gauge fabricated by ENRAF Incorporated. These tanks have thermocouples and a camera observation port for taking in-tank photographs and videos. Drywells are located around the SSTs to allow monitoring by gamma radiation or neutron-moisture sensor of any tank leakage. However, only two SSTs are currently monitored monthly by gamma radiation sensor. The remaining drywells are monitored upon request as is the case of monitoring by neutron-moisture sensors.

Starting in 1968, 28 double-shell tanks (DSTs) were built with a capacity of approximately 3,780 m^3 (1,000,000 gallons) each. They are composed of an inner, freestanding, completely enclosed carbon steel tank which is referred to as the primary tank. The primary tank is located inside a reinforced concrete shell and dome with the walls covered with a steel liner, as shown in figure 2-18. The liner is

Table 2-3. Years of construction of single-shell tanks, location, associated tank farms, and capacity. Also indicated are the steel specification and the plate condition for the tank walls (Larrick et al., 1995; Edgemon and Anantatmula, 1995).

Year	Area	Tank Farm	Number of SST	Capacity m^3 (gal.)	Steel Specification	Plate Condition
1943–44	200E	B	4	208 (55,000)	A7-1939[a]	A-R
1943–44	200E	C	4	208 (55,000)	A7-1939	A-R
1943–44	200W	T	4	208 (55,000)	A7-1939	A-R
1943–44	200W	U	4	208 (55,000)	A7-1939	A-R
1943–44	200E	B	12	2,006 (530,000)	A7-1939	A-R
1943–44	200E	C	12	2,006 (530,000)	A7-1939	A-R
1943–44	200W	T	12	2,006 (530,000)	A7-1939	A-R
1944	200W	U	12	2,006 (530,000)	A7-1939	A-R
1946–47	200E	BX	12	2,006 (530,000)	A7-1939	A-R
1947–48	200W	TX	18	2,839 (750,000)	A283-1946T, Gr C[b]	A-R
1948–49	200E	BY	12	2,839 (750,000)	A285-1946T, Gr B & C	A-R
1950–51	200W	S	12	2,839 (750,000)	A283-1946T, Gr B	A-R
1951–52	200W	TY	6	2,839 (750,000)	A283-1949T, Gr B	A-R
1953–54	200W	SX	15	3,785 (1,000,000)	A283-1952T, Gr A or B	A-R
1954–55	200E	A	6	3,785 (1,000,000)	A285-1952aT, Gr B & C	A-R
1963–64	200E	AX	4	3,785 (1,000,000)	A201-1961T, Gr A[c]	A-R

A-R as rolled
a A7 introduced in 1939 (American Water Works Association Code) and replaced by A36 in 1960
b A283 introduced in 1946; it was ASME code in 1967 and 1971; currently not an ASME material
c A201 introduced in 1949 and replaced by A515 and A516

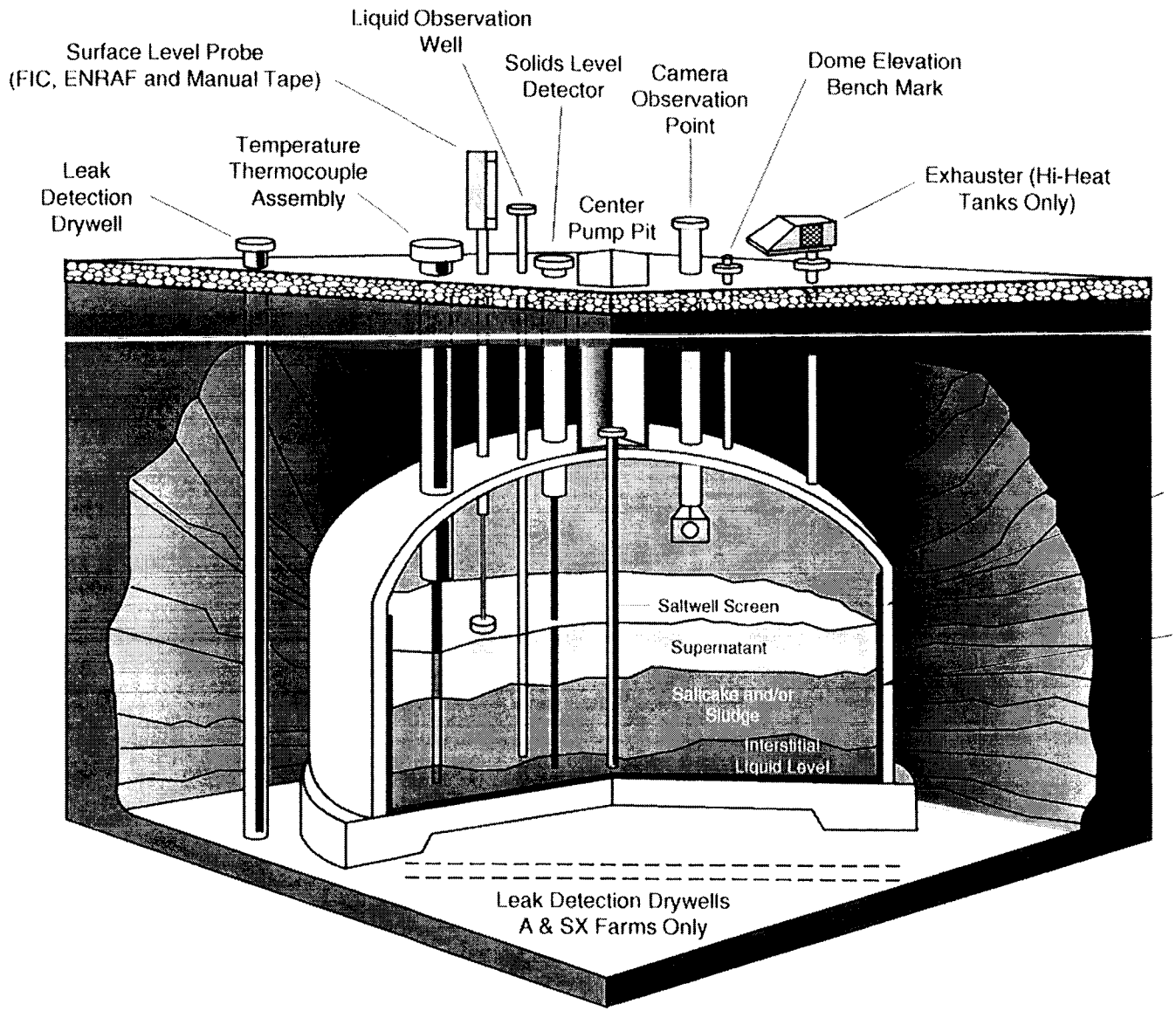


Figure 2-17. Single-shell tank instrumentation configuration

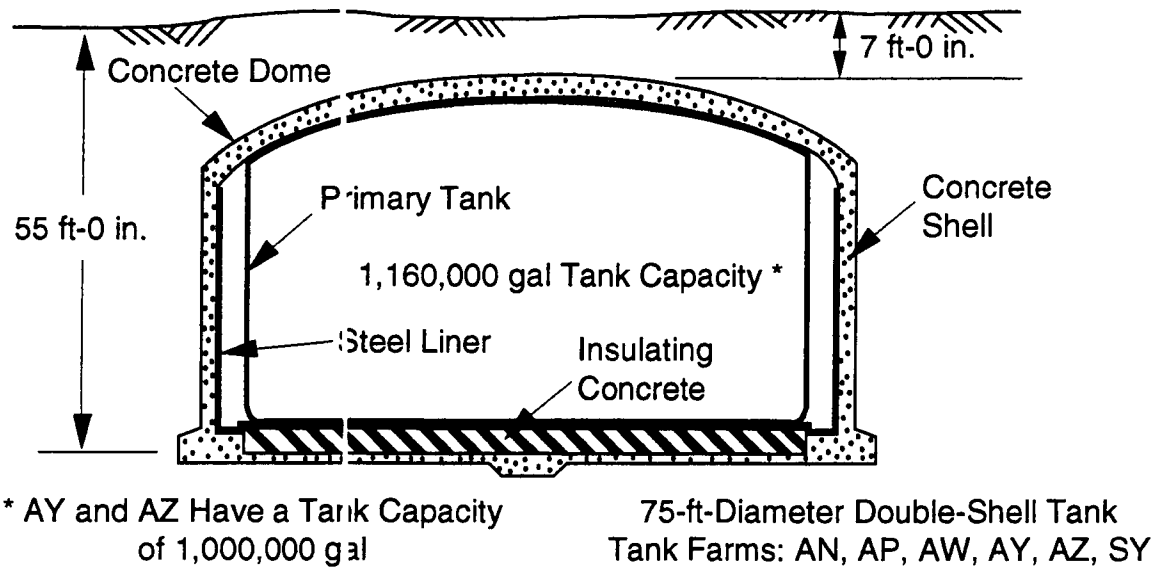


Figure 2-18. Schematic cross-section of a double-shell tank showing the inner (primary) tank that is a completely enclosed steel tank surrounded by an open topped steel liner and encased in concrete

usually referred to as the secondary steel tank and its purpose is to contain any liquid leakage from the primary tank. The space between the two steel tanks, the annulus, is monitored for leaks using radiation detector and conductivity probes Schematic drawings in different publications (Gephart and Lundgren, 1995; Hanlon, 1996) differ slightly, and may lead to the mistaken impression that the primary tank is an open container without the steel dome.

Table 2-4 provides information on the DSTs, including year of construction, location, farm, number of tanks in each farm, capacity, steel grade, and condition of the steel plate. All butt-welded joints between plates were executed with full penetration and the primary tanks were stress relieved by a post-weld heat treatment (PWHT) following modern practices. The purpose of the PWHT is to reduce residual stresses along the welds to a level low enough to avoid the occurrence of SCC. None of these tanks have leaked.

The current schedule for the disposal of the radioactive waste contained in SSTs and DSTs will require operation of the DSTs through the year 2028. This schedule requires a service life of 40 to 60 yr depending upon the closure sequence of the tanks. An analysis of useful life of DSTs has been conducted assessing the failure modes limiting the service life of the tanks (Ohl et al., 1996). The failure modes considered to be potentially limiting of the life are: (i) primary tank breach by pitting corrosion; (ii) primary tank breach by SCC; (iii) exceeding allowable stress for primary tank as a result of uniform corrosion; and (iv) occurrence of a beyond-design-basis accident. Eight additional failure modes, as reviewed by Edgemon and Anantatmula (1995) and listed above for the SSTs, were analyzed and discounted as life-limiting modes in terms of DST failure. DST failure is defined for this purpose as a physical change in tank geometry or material properties that could cause the removal of the tank from

Table 2-4. Years of construction of double-shell tanks, location, associated tank farms, and capacity. Also indicated are the steel specification and the plate condition for the primary tank (Larrick et al., 1995; Edgemon and Anantatmula, 1995).

Year	Area	Tank Farm	Number of DST	Capacity m^3 (gal)	Steel Specification	Plate Condition
1968–70	200E	AY	2	3,785 (1,000,000)	A515-1965, Gr 60	N
1971–77	200E	AZ	2	3,785 (1,000,000)	A515-1969, Gr 65	N
1974–78	200W	SY	3	4,391 (1,160,000)	A516-1972, Gr 65	N
1978–80	200E	AW	6	4,391 (1,160,000)	A537-1974a, Cl 1	N
1980–81	200E	AN	7	4,391 (1,160,000)	A537-1975, Cl 1	N
1983–86	200E	AP	8	4,391 (1,160,000)	A537-1979, Cl 1	N

N normalized

service. Through the useful life analysis it was concluded that the rate controlling mechanism for DST failure is primary tank breach by pitting corrosion in the vapor phase. The probability of this type of failure was estimated to range from 0.4 to 0.6 for the expected 40 to 60 yr of service life. In order to relate pit propagation with a parameter associated to tank operation, the following equation was derived to relate pit propagation rate (PPR) with CF with a correlation coefficient $r^2 = 0.94$.

$$PPR\ (mils/yr) = 3.28(CF)^{0.23} \tag{2-1}$$

The expression was derived from a limited set of experimental data obtained with steel coupons exposed to the liquid phase, the vapor phase, and the interface between these phases of various waste types, including PUREX, REDOX, and $BiPO_4$, using both tank samples or laboratory simulated wastes (Ohl et al., 1996).

As a first level screening process to guide the integrity inspection and the corrosion monitoring of the tank, the DSTs were grouped into different categories (Ohl et al., 1996) according to their potential propensity to pitting corrosion and SCC. The CF was used to classify the DSTs in two groups according to their susceptibility to pitting corrosion. On the basis of values of CF greater than 2.5, calculated from the estimated concentrations of NO_3^-, NO_2^-, and OH^-, either for the supernatant or the sludge, only three DSTs (AN 107, AP 107, and AW 104) were considered to be susceptible to pitting corrosion. In terms of the susceptibility to SCC, the DSTs were classified in three groups, using a criterion developed by Ondrejcin (1978). On the basis of statistically designed slow strain rate tests conducted in solutions containing a range of concentrations of NO_3^- (1.5 to 5.5 mol/L), NO_2^- (0 to 3.5 mol/L), and OH^- (0 to 5.0 mol/L) at temperatures ranging from 50 to 100 °C, Ondrejcin determined environmental domains of SCC at 50, 60, 70, 80, and 100 °C in terms of the concentrations of these three anions. An elongation to fracture lower than 13 percent was selected as indicative of SCC susceptibility and found to be consistent with the results of SCC tests using a fracture mechanics approach. Environment compositions, including the effect of temperature, that may lead to elongation to failure greater than 13 percent, were estimated by Ohl et al. (1996) for the majority of the DSTs, which were therefore classified as having a low susceptibility to SCC (Group I). A second group (Group II), which includes three DSTs (AW 104, SY 101, and SY 102), was considered to be potentially susceptible to SCC because the elongation to failure for the composition of their waste was estimated to be lower than 13 percent. A third group was defined for tanks exhibiting temperatures above 100 °C, because no determination could be made regarding their SCC susceptibility due to the lack of data at temperatures above 100 °C. Group III is composed of Tanks AY 101, AZ 101, and AZ 102. In summary, six tanks were evaluated as being potentially susceptible to SCC, but only Tank AW 104 was found to be susceptible to both pitting and SCC. As noted by Ohl et al. (1996), the screening process needs to be verified through inspections, because it is based on current estimates of the bulk waste solution, without considering local concentrations in crevices or other localized areas, nor potentially adverse conditions that may have existed in the past.

Figure 2-19 shows the configuration of the instrumentation used in DSTs. The main difference with respect to the SSTs is the existence of the annulus. Monitoring leakages in the DSTs can be easily accomplished by continuous air monitoring in the annulus using radiation detectors or by conductivity probes that are activated in the presence of an electrolytic conductor. In DSTs, there are usually one or more thermocouple trees in risers in the primary tank.

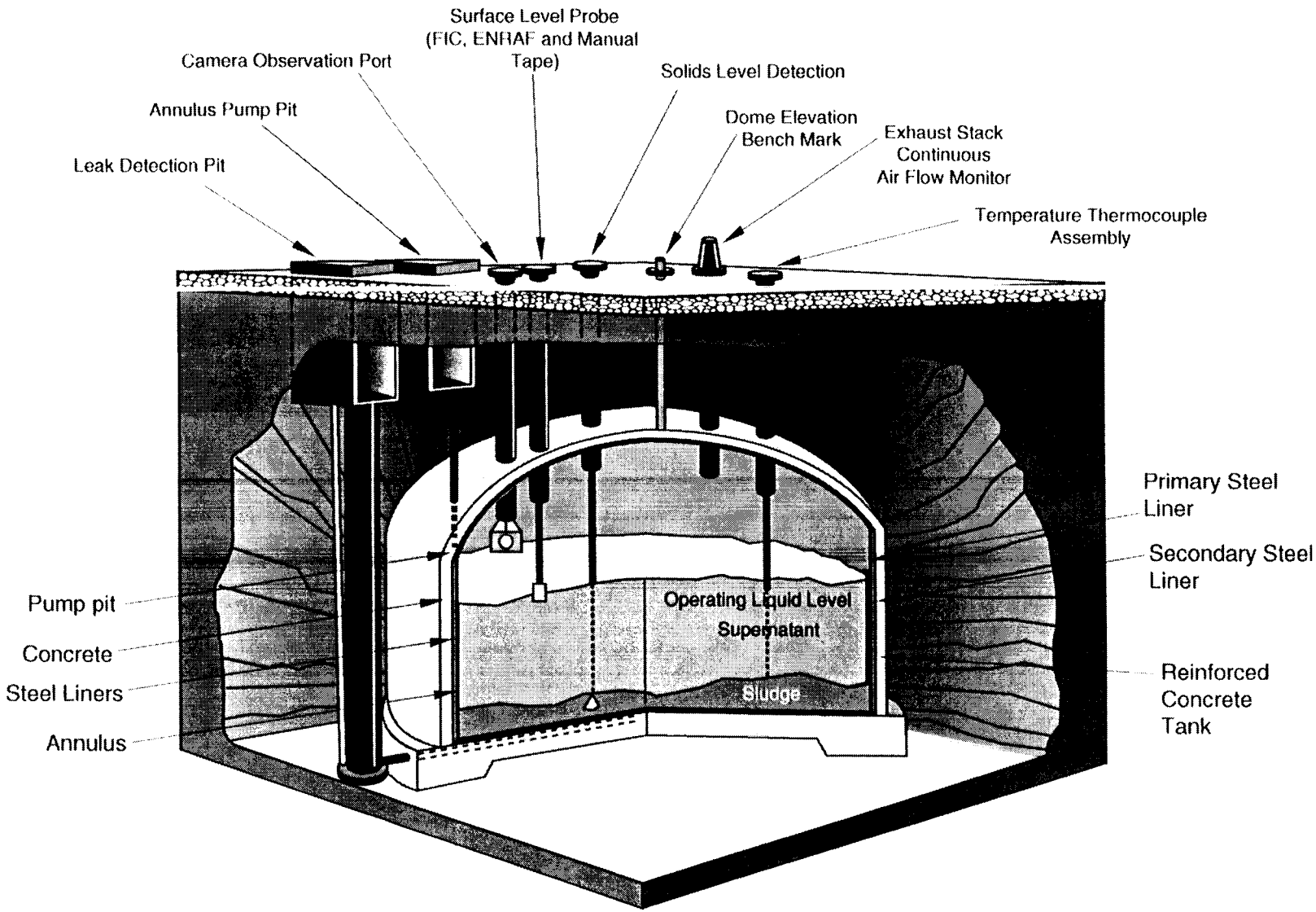


Figure 2-19. Double-shell tank instrumentation configuration

2.6.3 Waste Transfer System

The waste is transferred between storage tanks and from storage tanks to waste processing facilities through a complex network of underground piping with a total length of over 80 km. An example of the complex network of transfer piping within the 200-E Area is shown in figure 2-20. It must be noted that figure 2-20 does not show all the pipes in this area (Gephart and Lundgren, 1995). The underground transfer system consists of process piping, catch tanks, lift tanks, diversion boxes, pump pits, valves, and jumpers. Corrosion of the process piping as a result of contact with the soil is the primary concern regarding the integrity of the transfer system. Other transfer system components are made of corrosion resistant alloys or are isolated from the underground environment.

Corrosion control of the underground transfer system is accomplished by an impressed-current cathodic protection system (Haberman, 1995). Cathodic protection was first installed at the Hanford site in the 1940's following premature failure of the 300 series stainless steel transfer lines from external corrosion arising from direct contact with the soil (Jaske, 1954). The original cathodic protection system was shut down in 1980 and replaced later in many stages with one of modern design (Haberman, 1995). Anodes made of high-silicon cast iron were introduced and current was provided with 3-phase 480 V input rectifiers with silicon diode circuitry. Special design considerations were employed to minimize stray currents. Since 1985, all new transfer lines installed at the Hanford site are required to have cathodic protection.

Despite the significant improvement represented by installation of the new cathodic protection system, the complexity of the pipe network and the coexistence of different materials, soil environments, coatings, and variations in temperature make effective corrosion control challenging. Adequate monitoring and frequent surveys of the performance are required to avoid detrimental effects associated to stray currents that may affect the integrity of the tanks. Between April and June of 1994 the entire cathodic protection system was surveyed and in general was found to operate as intended (Haberman, 1995). However, rectifier adjustments were required and stray current was detected affecting several lines which require bonding with protected piping. No negative effect on the tanks was found.

Liquid waste has been transferred between the 200-West Area and 200-East Area facilities for approximately 30 yr, using a cross-site transfer system connecting the SY tank farm in the 200-West Area with tank farms in the 200-East Area (Brantley, 1996). The piping system has been installed in the past 7 to 40 yr through a combination of many projects. The portion of the system that lies between the 200-West and 200-East Areas is referred to as the cross-country transfer system and consists of six 3-in. Schedule 10 stainless steel pipelines in a reinforced concrete encasement. This segment was built in 1950. Four of the six pipes have plugged during transfers and at least one ruptured during attempts to clear the blockage (Brantley, 1996). The current cross-country transfer system and three additional segments will be removed from service and replaced by a new piping system, currently under construction, through a project designated as Replacement of Cross-Site Transfer System (RCSTS). The trace of the RCSTS is schematically shown in figure 2-21.

The RCSTS consists of a buried pipe-in-pipe system approximately 10.5 km long with two lines connecting the 241-SY-A and 241-SY-B valve pits in the 200-West Area with the 244-A lift station in the 200-East Area (Kidder, 1996) Liquid waste will be transferred in either direction through one line, whereas the other one will be used to transfer wastes with as much as 30 percent solids from the 200-West Area to the 200-East Area using a booster pump to allow pumping of liquids with higher viscosities and solid contents. The pipe-in-pipe design is schematically shown in figure 2-22. The transfer piping is made of a 8.62-cm (3-in) Schedule 40 AISI 304L stainless steel primary pipe encased in a

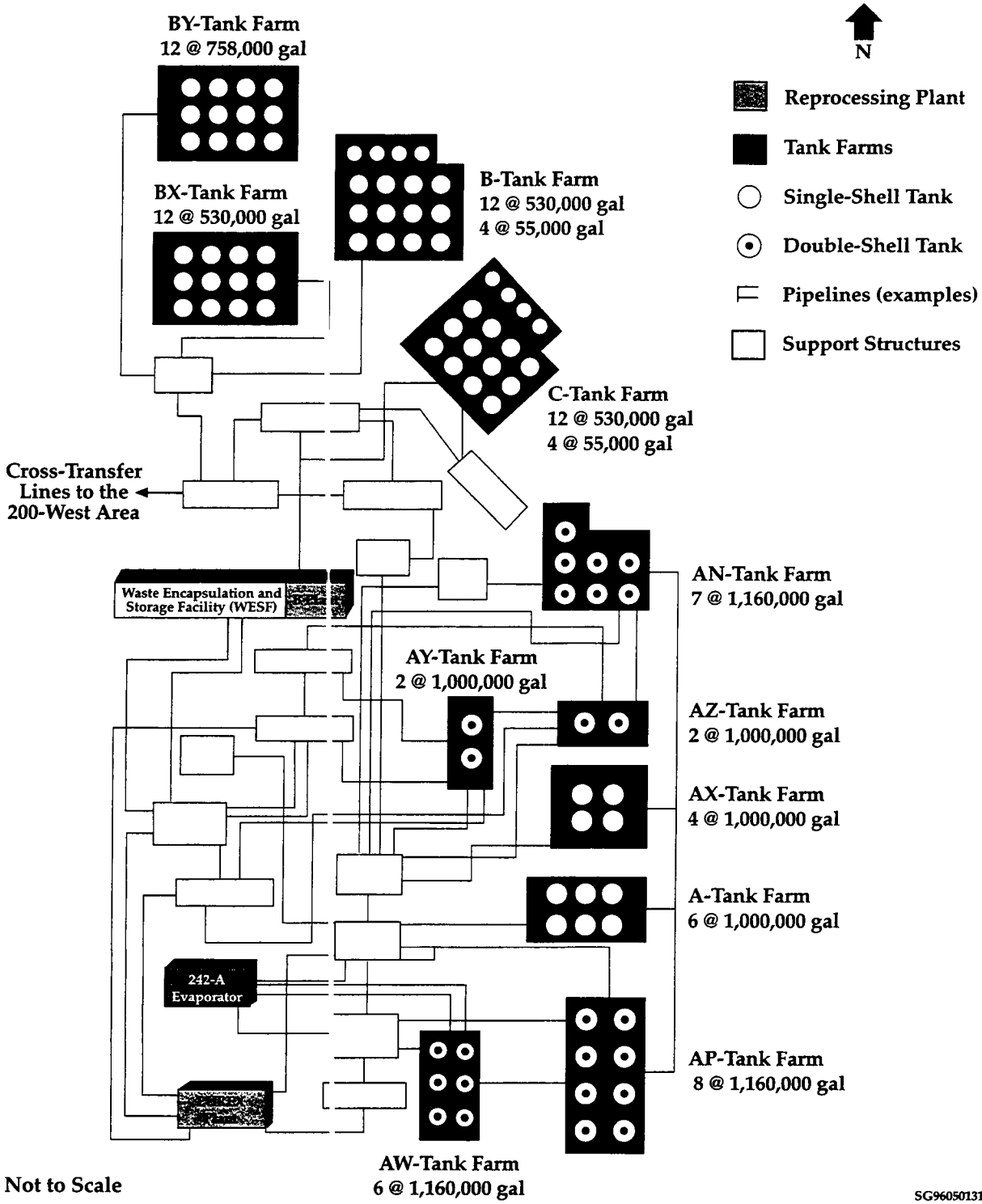


Figure 2-20. A schematic descri ɔtion of tank farms, processing facilities and the interconnecting pipelines in the 200-East Area Not all the pipelines are shown in this figure (Gephart and Lundgren, 1995).

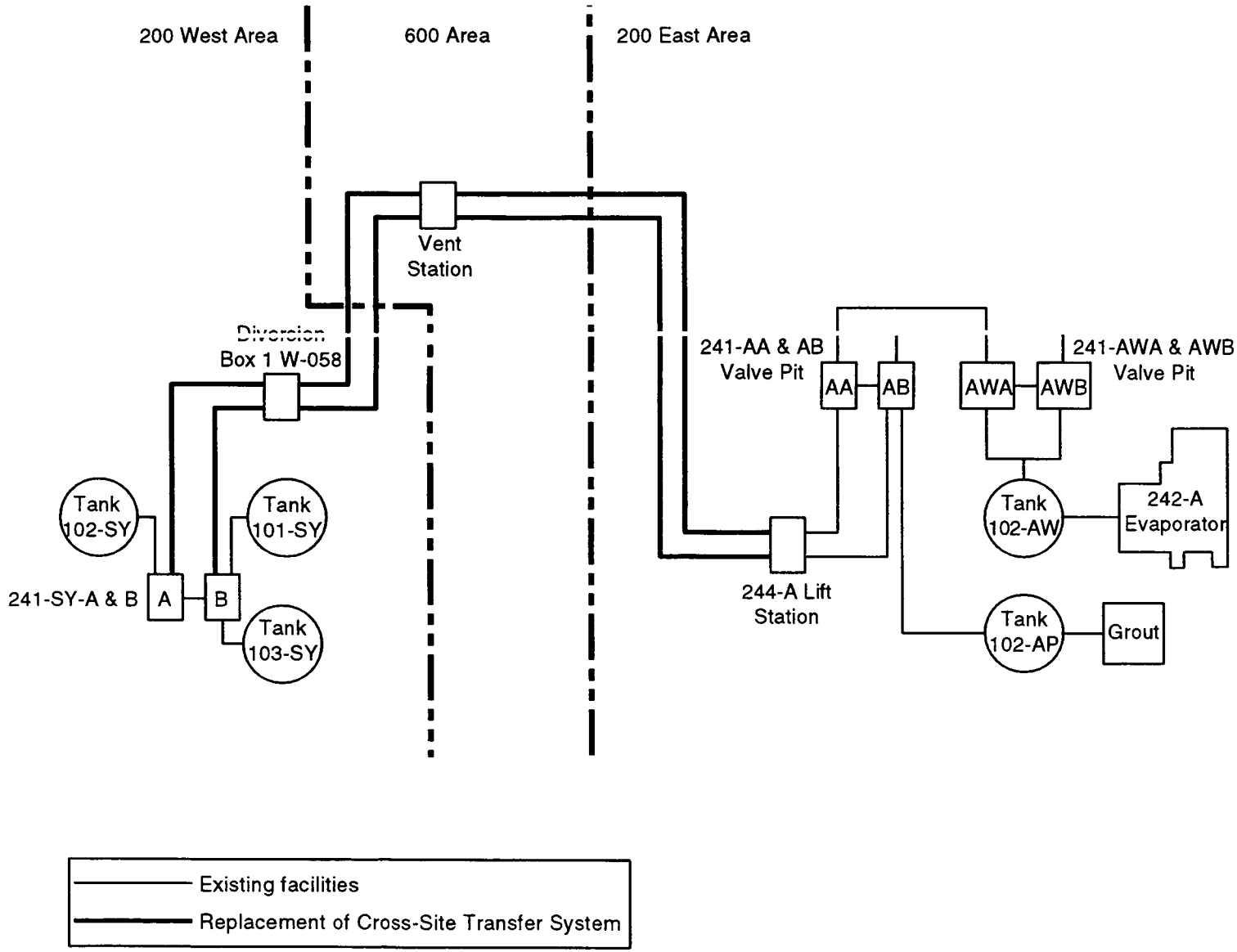


Figure 2-21. Trace of the replacement cross-site transfer system (Brantley, 1996)

15.24 cm (6-in.), Schedule 40 ASTM A53 grade B carbon steel pipe. The encasement pipe will be 30.48 cm (12 in.) diameter at the expansion loops. Both the primary and encasement pipe sections are joined by welding (no jumpers are used). The carbon steel pipe is protected with an epoxy coating to minimize external corrosion, although the use of galvanized steel was indicated in the Preliminary Safety Analysis Report (Kidder, 1996). The encasement pipe is surrounded by polyurethane foam insulation and a fiberglass reinforced plastic jacket to reduce the temperature drop during waste transfer to a maximum of 10°C (20 °F). As shown in figure 2-22, the pipe-in-pipe system rests on a low-density concrete bedding material. Cathodic protection of the encasement pipe was not recommended (Anantatmula and Ohl, 1996) due to the high costs (approximately $1.5 M) of an impressed current cathodic protection system.

The design parameters of the RCSTS are provided in table 2-5 (Kidder, 1996). The RCSTS was designed following the requirements of American National Standard Institute (ANSI)/ASME B31.3-1993 Chemical Plant and Petroleum Refinery Piping with an expected service life of 40 yr. The justification for the selection of the piping materials for transferring alkaline radioactive mixed waste has been provided in a material of construction position paper (Parsons, 1994). For leak detection of the primary line, a continuous coaxial cable will be run in the annular region between the primary and the encasement pipe, as shown in figure 2-22. This annular region will be filled with dry air or an inert gas to minimize corrosion and spurious leak detection alarms. In the diversion box and vent station, simple conductivity or thermal anemometer-type leak detectors will provide indication of a leak. Additional details are provided in the Preliminary Safety Analysis report (Kidder, 1996).

The inner surfaces of the transfer lines in contact with tank waste may be susceptible to similar modes of corrosion as those affecting the tanks. A large number of waste transfer line failures has been recorded (Edgemon and Anantatmula, 1995). Although no detailed information of these failures was available for the preparation of this report, a table provided by Edgemon and Anantatmula (1995) lists the corrosion processes that are expected using a qualitative ranking based on historical data, literature review, and their own opinion. Table 2-6 reveals that, in addition to pitting corrosion, erosion corrosion associated with the flow of water slurries is a matter of concern. It can be seen that the third most important failure mode is related to malfunctioning of the cathodic protection system.

2.6.4 Evaporator and Effluent Treatment Facilities

Evaporators were used to concentrate waste streams associated with the T, REDOX, B, and PUREX plants in order to maximize the use of available tank space. With the exception of the 242-A evaporator crystallizer in the 200-East Area, the other evaporators have been shutdown, but not decontaminated. This section will focus on the 242-A evaporator crystallizer since this is an operating system that will be used in future volume reductions of wastes from the SSTs and DSTs and laboratory facilities. Detailed discussion of the evaporator design and operations can be found in the safety analysis and integrity assessment reports (Westinghouse Hanford Company, 1992; 1993). The materials of construction of the 242-A facility are shown in table 2-7.

The corrosion performance of the materials of construction is described by Ohl and Carlos (1994). The most severe corrosion occurred in the EC1 condenser which has tubes made of carbon steel. With the current materials, 8–10 yr of life is expected after each replacement of materials and renewal of operations. The localized corrosion is due to the presence of unfiltered river water in the shell side of the tube bundles. However, for the stainless steel vessels and components, no significant degradation was found after 7 yr of operation.

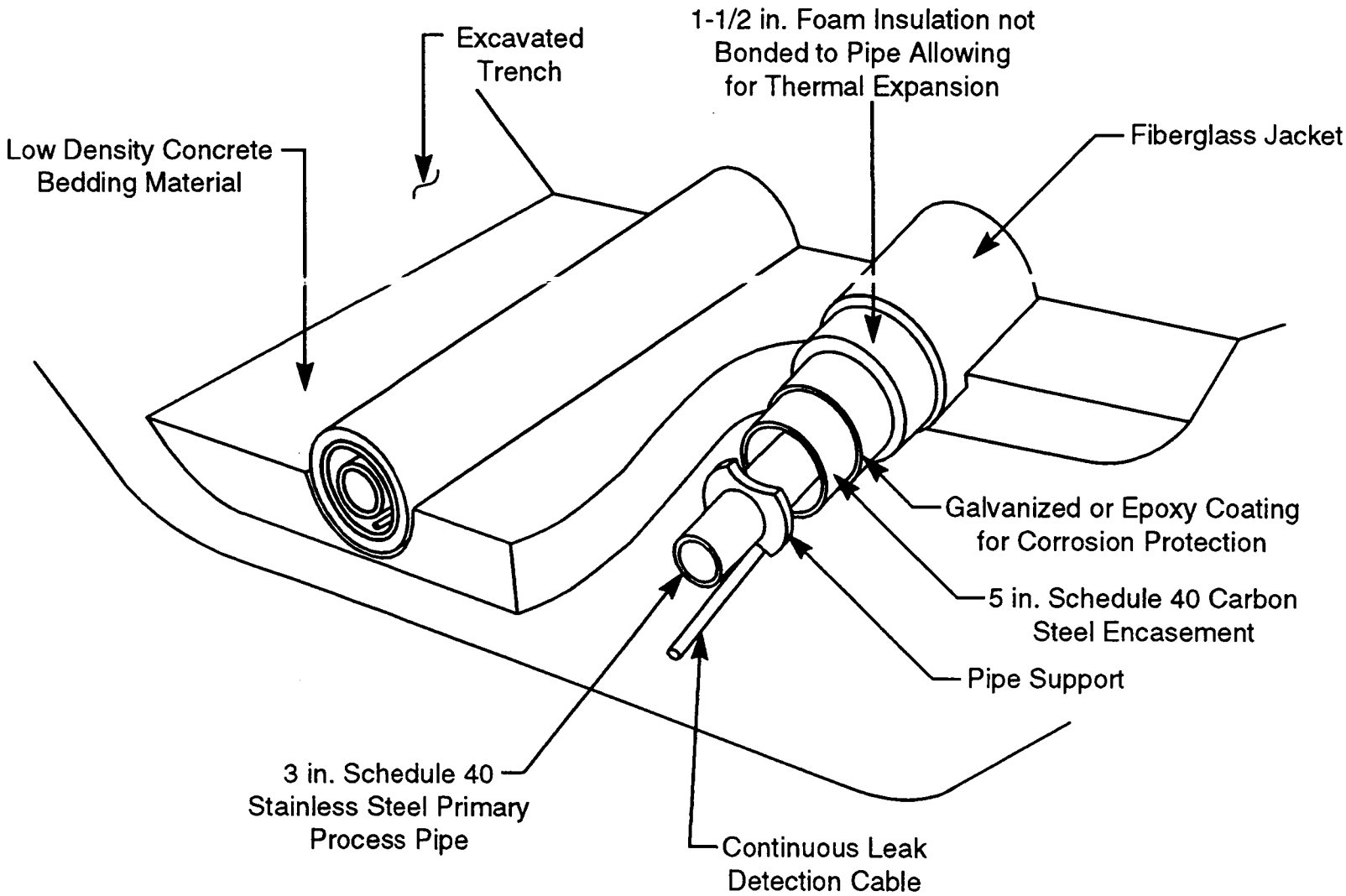


Figure 2-22. Schematic diagram showing the components of the cross-site transfer piping (Kidder, 1996)

Table 2-5. Design parameters for the cross-site transfer system (Kidder, 1996)

Achievable Design Velocity	4.5 ft/s	6.0 ft/s
Specific gravity	1.5 g/cm^3	1.25 g/cm^3
Viscosity	30.0 cP	10 cP
Solid content	30.0 displacement vol%	20.0 displacement vol%
Miller number	<100	<100
Minimum pH (transfers/flushes)	11.0	11.0
Temperature (transfers/flushes)	35 to 200 °F	35 to 200 °F
Insulation	Required	Required
Particle size	0.5 to 4,000 μm	0.5 to 4,000 μm
Friction factor	0.0404	Newtonian flow

The Liquid Effluent Retention Facility (LERF) treats the condensate from the 242-A evaporator and consists of three RCRA compliant surface impoundments or basins. This facility provides equalization of flow and chemistry (essentially pH) to the Effluent Treatment Facilities (ETF). Each of the three basins in the LERF has a capacity of 24.6 million liters (6.5 million gallons). The basins are constructed of two flexible polyethylene membrane liners. Beneath the secondary liner is a 1-m thick/soil/bentonite barrier. The basins have a low-density polyethylene cover to minimize evaporation and ingress of water.

The ETF has a treatment system to reduce concentrations of radioactive and hazardous waste constituents, tanks for verifying treated effluent characteristics before discharging, and State-approved land disposal area for the effluents. The treatment processes include ultraviolet/peroxide destruction of organics, reverse osmosis for removing dissolved solids, and ion exchange to remove some contaminants. The effluents are analyzed for verification of acceptable levels of radioactive and hazardous contaminants and then discharged.

The Effluent Disposal Facility is a collection and disposal system for non-RCRA waste streams that already meet discharge requirements. The waste streams originate from Z plant, 222-S laboratory, T plant, B plant, and PUREX plant.

Table 2-6. Relative ranking of degradation mechanisms for transfer lines (Edgemon and Anantatmula, 1995)

Priority	Mechanism	Relative Probability of Occurrence	Relative Probability of Causing Failure	Risk Factor
1	Pitting	8	7	56
2	Erosion/erosion corrosion	5	7	35
3	Improper/ malfunctioning cathodic protection system	8	4	32
4	Uniform corrosion from interior	7	3	14
4	Galvanic coupling	7	3	14
4	MIC	2	7	14

2.6.5 Canister Storage Building

Approximately 2100 metric tons of spent nuclear fuel are currently located in two storage basins, K-East (KE) and K-West (KW) attached to the retired KE and KW reactors in the 100 Area. Most of this fuel is from the retired N reactor, but some fuels from older reactors are also stored here. These fuels consist of unprocessed metallic U or Pu and have been stored for periods ranging from 8 to 24 yr (U.S. Department of Energy, 1995). The KE and KW basin are located as close as 420 m from the Columbia River. The basins are unlined concrete pools with asphaltic membranes beneath the pools. The interior of the KW basin has been coated with epoxy, although the status of this epoxy is at present unknown. The KE basin has leaked water in the past and may be continuing to leak radionuclides. This condition, coupled with seismic vulnerabilities (e.g., possible breaching and draining of water leading to criticality) has resulted in a recent decision to remove the fuel from these basins and place it in dry interim storage. Towards this end, a Canister Storage Building (CSB) is being constructed in the 200-East Area at the site where the vitrification facility was originally planned to be constructed (Daily et al., 1995).

Half of the fuel is stored in open-top aluminum and stainless steel canisters (in KE basin) and the other half is in sealed vented canisters (in KW basin) (Lawrence et al., 1996). Each water-filled canister is 0.71 m tall and contains up to 14 fuel assemblies. Examination of corroded fuel while in the KW basin and after removal into a hot cell showed extensive corrosion and accumulation of U oxide particles in the sludge in the canisters as well as the basin floors. The fuel that was removed was subjected to a variety of thermal cycles to determine whether it can be dewatered and transported in a dry-storage cask. These investigations (Lawrence et al., 1996) showed that the fuel could be dried and passivated to form an oxide film. The ignition temperature of the uncorroded part of the fuel was about 650 °C whereas the corroded fuel had an ignition temperature of 300 °C. Passivating the fuel through

Table 2-7. 242-A Evaporator Crystallizer facility and component materials of construction

Item	Material Specifications
C-A-1 evaporator	ASTM A240, Type 304L Stainless steel (SS)
De-entrainment pads	AISI 304L SS
P-B-1 recirculation pump	ASTM A240, Type 304L and 316L SS
E-A-1 reboiler	ASTM A240, Type 304L SS
P-B-2 bottoms pump	ASTM A240, Type 304L and 316L SS
E-C-1 condenser	Shell: ASTM A285, Grade C Carbon Steel (CS) Tube Sheet: ASTM A516, Grade 70 CS Tubing: ASTM A53, Type E or S, Grade A or B CS
E-C-2 condenser	Shell: ASTM A53, Grade B CS Head: ASTM A515, Grade 300, CS Tubing: ASTM A53, Type E or S, Grade A or B CS
E-C-3 condenser	Shell: ASTM A53, Grade B CS Head: ASTM A515, Grade 300, CS Tubing: ASTM A53, Type E or S, Grade A or B CS
TK-C-100 condensate catch tank	ASTM A167, Type 347 SS (Modification of ASTM A 312, Type 304L SS)
X-D-1 ion exchange column	ASTM A36 CS
TK-C-103 tank	ASTM SA36 CS
Piping (water and steam)	ASTM A53, Type E or S, Grade A or B CS or ASTM A 106, Grade A or B CS
General chemical and air piping	ASTM A312, Type 304L SS
Building/secondary containment	ACI 301-72 structural concrete, coated on the inside walls of the building with acrylic coating

treatment in a 2 percent oxygen +98 percent argon mixture at 150 to 250 °C improved the ignition temperature to 650 °C. It must be noted that the proposed drying temperature of the fuels prior to placing them in dry storage canisters is 300 °C. Considerable amounts of sludge, up to 79 cm deep in basin pits, up to 19 cm on the floor, and over 30.5 cm in some canisters, have been found. These sludges contain fission products, U oxides, and wind-blown debris (mostly sand). At present, investigations are ongoing to determine their disposition and compatibility with DST wastes (Lawrence et al., 1996). The fuel in the CSB will be stored in vertical tubes made of carbon steel. The CSB can accommodate 400 tubes with three canisters in each tube.

2.6.6 Proposed Privatization Operations

In the phased alternative, which is the preferred alternative for TWRS in the DOE EIS (U.S. Department of Energy, 1996a), readily retrievable, well-characterized waste from the DSTs would be processed in two demonstration-scale plants. At present, one of the privatization contractors has proposed converting both the Low Activity Waste (LAW) and High-Level Waste (HLW) into solidified waste forms to meet the performance requirements specified for borosilicate glass in the DOE contract and the other privatization contractor has proposed solidifying only the LAW as glass. The HLW and LLW vitrification facilities will be located east of the 200-East Area within the area previously constructed for grout disposal. A possible layout of the Phase II implementation facility is shown in figure 2-23 (U.S. Department of Energy, 1996a). The waste feed will be staged into tanks AP-102 and AP-104. The contents will be analyzed to determine whether they meet the process envelopes identified for meeting waste form, productivity, and process safety requirements. The wastes will then be transferred to tanks AP-106 and AP-108 for retrieval by the privatization contractors.

2.7 ONGOING ACTIVITIES

A number of RCRA and CERCLA related activities are under way at Hanford site (U.S. Department of Energy, 1995). The ongoing activities in the 200 Areas include the TWRS and the Remedial Investigation/Feasibility Study. This report focuses on activities pertinent to the TWRS. Other activities, when they are of interest to understanding and assessing the risk related to the TWRS activities, have been mentioned throughout the other sections. A list of ongoing activities at the Hanford site pertaining to the TWRS is shown in table 2-8 (U.S. Department of Energy, 1996b). The table also identifies potential areas of interest for the NRC that will be addressed by a review of these activities. Some of these activities are described in greater detail in this section and in subsequent chapters. The details pertinent to other activities in table 2-8 may be found in the TWRS EIS (U.S. Department of Energy, 1996b,c). Activities related to waste characterization are described in greater detail in chapter 3. The watch-list tank activities are described in greater detail in chapter 4.

2.7.1 Vadose Zone Characterization

Vadose zone characterization was initiated in 1995 (U.S. Department of Energy, 1996c) to provide baseline data on soil contamination around the SSTs, with a particular focus on the SX tank farm. Characterization consists of gamma spectroscopy in the dry wells beneath the SX tanks. Ten of the fifteen tanks in the SX farm are assumed or verified to be leaking, with the most abundant radionuclide detected being Cs-137 at depths up to 38 m (125 ft). Other radionuclides detected include Co-60, Eu-152, and Eu-154. These surveys do not address site contamination from the LAWs sent to the cribs but do provide some idea of the transport mechanisms resulting in groundwater contamination. In terms of potential interest to the NRC regulatory development, such information is essential, for example, in estimating potential hazards due to pipe leakage. Details of site contamination and current site characterization activities are provided in sections 2.2 and 2.3.

2.7.2 Watch-List Tanks

As shown in figure 2-24, watch-list tanks belong to four categories: (i) flammable gas [Hanlon (1996) reports that a total of 56 tanks are on the flammable gas list], (ii) ferrocyanide (14 tanks), (iii) high organic (20 tanks), and (iv) high heat (1 tank). Knowledge of current actions in this program

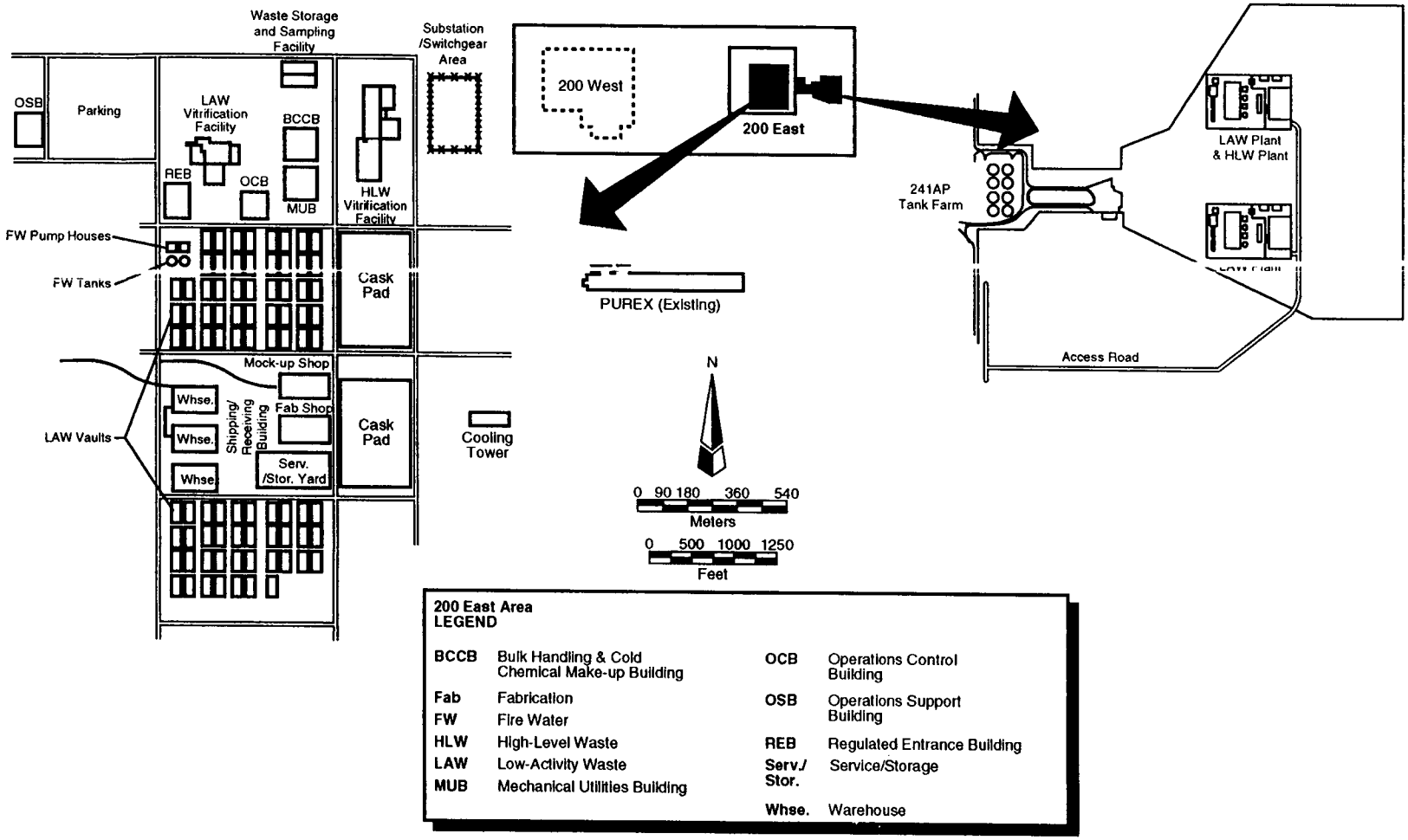


Figure 2-23. Planned location of the vitrification/solidification facilities in the phased implementation approach of the Tank Waste Remediation System. The AP-241 tank farm and the PUREX facility are the only existing facilities. (U.S. Department of Energy, 1996a)

Table 2-8. Ongoing and planned programs related to the Hanford Tank Waste Remediation System

Program	Description	Potential Areas of Interest for NRC
Vadose zone characterization	Initiated in April 1995 to provide baseline data on potential contamination distribution beneath SST (SX tank farm)	Baseline risk evaluation, groundwater contamination due to transfer pipe leaks
Waste characterization	Initiated to better define the tank contents through analyses of samples	Safety issues with respect to waste mixing and feed quality before solidification
Watch-list tanks	Establish operating parameters and develop mitigating measures	Consequence criteria development, risk evaluation during TWRS operation
Unreviewed safety questions	Review of known or suspected conditions that fall outside the authorization bases; need to be completed by September 1998	Consequence criteria development
Continued operation of tank farms	Monitoring of liquid levels, corrosion, and drywells; calculating operational waste volumes and waste minimization; isolating and removing pumpable liquids from SST; operating 242-A evaporator, and treating evaporator effluents	Radiological releases from various TWRS operations such as retrieval, evaporation, and from the heels in the tanks—consequence criteria development
Cross-transfer piping	Construction of a safe, regulatory-compliant cross-transfer piping to replace existing lines between 200 East and 200 West	Plugging can lead to criticality, pipe leaks to radionuclide release—consequence criteria development
Tank farm upgrades	Instrumentation for automatic tank data gathering, improved tank ventilation systems, increased electrical power, and upgraded tank waste transfer facility within tank farms	Radionuclide release from improperly designed ventilation or transfer piping
Initial tank retrieval system	Consolidation of compatible wastes in the DST to increase room in existing DST for waste from SSTs	Radionuclide release from transfer piping, chemical compatibility of wastes
Cs and Sr capsules	Currently listed as waste by-product, however, needs consultation with NRC on final classification of wastes	Classification of wastes and determining treatment options
Hanford tank initiative	Obtain information with respect to tank closure; determine residual waste volumes after retrieval, sampling of residuals, and waste contamination around tanks	Determination of potential hazards from residuals and closure operations

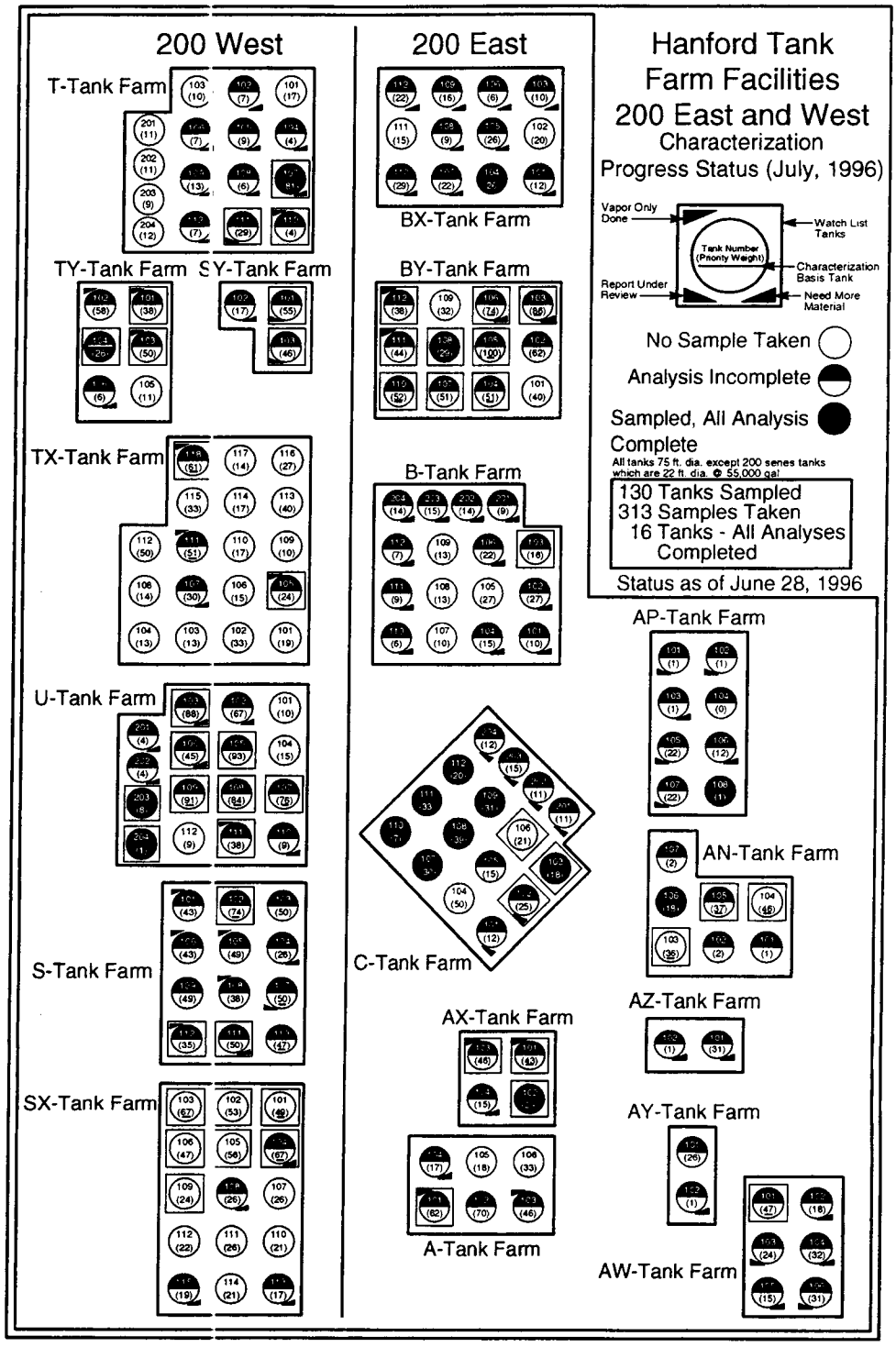


Figure 2-24. Characterization status of all the underground storage tanks in the 200-East and -West Areas (Hanlon, 1996)

is necessary to determine the effect of various TWRS design decisions on consequences, including selection of tanks for mixing prior to solidification. The details of the watch-list tanks are provided in chapter 4.

2.7.3 Unreviewed Safety Questions

The Unreviewed Safety Questions (USQ) program is a formal administrative program that aims to identify known or suspected operating conditions outside established safe limits. These limits form the authorization bases for continued operation of the tank farms. Some of the watch-list tanks were under this category until the safety issues associated with their operation were identified and they were placed under a specific watch-list category. Criticality with respect to the tank contents was originally an unreviewed safety question, but the criticality issue was closed in 1994. Currently, there are no tanks in the criticality watch-list. However, criticality during tank waste retrieval will be addressed on a tank-by-tank basis during remediation. Details of the watch-list categories are provided in chapter 4. The TPA requires that all unreviewed safety questions be resolved by September 1998. Recently, some tanks containing dry organic nitrates were placed under the USQ Program because methods of analyzing accident scenarios have become available for these (Hanlon, 1996).

2.7.4 Continued Operation of Tank Farms

In addition to routine operations, such as maintenance of facilities and equipment, a number of safety management activities are being conducted. Among these activities, those that may influence the NRC review of TWRS activities include: (i) combining compatible tank waste types through existing cross-transfer piping in order to provide tank space and address safety issues, (ii) screening and characterizing waste on a tank-by-tank basis for remedial actions, (iii) isolating and removing pumpable liquids from SSTs, and (iv) operating the 242-A evaporator to concentrate wastes and remove contaminants from residual liquids. These activities are not likely to fall within the Phase I remediation program but may be important in hazard analyses related to Phase II activities.

In addition to screening and characterizing waste on a tank-by-tank basis, monitoring of the effect of waste additions on the corrosion of the tanks has been initiated using electrochemical noise (EN) probes (Edgemon and Bell, 1996). Using these probes, the initiation and growth of pits was detected on prototype electrode probes placed in tank 241-AZ-101 following raw water additions (Edgemon et al., 1996; 1997). However, current transients related to pitting decreased in magnitude and frequency with increasing times after the water addition, suggesting that conditions leading to uniform corrosion were reestablished. Recommendations for improvements in the EN probes have been developed with an aim to extend monitoring to other tanks (Edgemon et al., 1996).

Details of the tank and evaporator designs are provided in section 2.5. Projections for future tank waste additions are shown in table 2-9 (U.S. Department of Energy, 1996b). This waste is expected to be added to the DSTs after being processed in the 242-A evaporator. The majority of the future waste additions would come from D&D activities at inactive facilities at the Hanford site and would be classified as dilute, noncomplexed wastes (meaning that they do not contain significant quantities of complexing organic chemicals). The 100 Area cleanout waste is classified as double-shell slurry feed waste. This is the waste that is concentrated in the evaporator to a point just below the sodium aluminate saturation boundary. Cleanout of the K Basins would result in the addition of approximately 54 m^3 of sludge from spent nuclear fuel, corrosion products, iron and aluminum oxides, concrete, fission and

Table 2-9. Projected future waste additions to double-shell tanks after processing in the 242-A evaporator (U.S. Department of Energy, 1996b)

Source	Waste Type	Volume (m^3)	Duration of Accumulation
PUREX: Deactivation waste	DN	5,700	FY94-97
B Plant: Terminal cleanout waste (concentrated)	DN	2,100	FY97-01
100 Area:Terminal cleanout waste (concentrated)	DSSF	2,200	FY95-99
100 Area: Sulfate waste	DN	140	Not reported
300 Area: Fuel supply cleanout	DN	45	Not reported
105-F, 105-H: Basin cleanout	DN	850	Not reported
Tank 107-AN: Caustic addition	DN	190	Not reported
100-KE, KW: Basin cleanout	DN	1,200	Not reported
TOTAL		12,400	

DN: Dilute noncomplexed waste
DSSF: Double shell slurry feed

activation products and sand from the outside environment. The sludge waste would add about 11,000 Ci to the DSTs. This would include about 5,200 Ci of Pu-241, 260 Ci of Pu-239, 1,280 Ci of Sr-90, and 970 Ci of Cs-137. Following cleanout, the sludge would be transported in about 1200 m^3 of water to the DSTs.

2.7.5 Cross-Transfer Piping

Since the solidification plants are planned to be constructed in the 200-East Area, wastes have to be transported from 200-West to 200-East. The existing cross-transfer piping is nearing the end of the 40-yr design life. Currently, four of the existing six lines are out of service due to plugging, and the two remaining lines do not meet engineering requirements such as double containment and leakage detection. Hence, the construction of regulatory-compliant cross-transfer piping has begun and is expected to be operational by 1998. The causes of plugging may vary, including fluid flow, thermal, and chemical factors. Additional information on the causes of plugging and the nature of precipitates in these pipes will benefit future safety analyses of existing and newly constructed cross-transfer piping systems. Details of the transfer piping are provided in section 2.6.3.

2.7.6 Tank Farm Upgrades

Upgrades to the tank farms are undertaken to improve the reliability of safety related systems, upgrade the regulatory compliance status, and stabilize the tanks until completion of TWRS. Several upgrades to the tank farms have been recently planned. First, installation of 300-HP mixer pumps in SY-102, AW-105, and AZ-102 tanks will enhance sludge removal from the bottom of the tanks. These pumps are twice the size of the pump installed in tank 101-SY, dubbed the burping tank. Second, the addition of instrumentation including an automatic tank data gathering and management control system is planned. Third, improvements will be made to the tank ventilation system. Finally, the power capacity of the electrical system will be increased and brought into compliance with existing codes.

2.7.7 Initial Tank Retrieval System

This initial tank retrieval system would provide means for enhanced retrieval of waste from up to 10 DSTs. The initial tank retrieval capabilities would allow consolidation of compatible tank wastes to create additional DST storage space and support passive mitigation such as diluting gas generation wastes.

2.7.8 Cesium and Strontium Capsules

The design of the Cs and Sr capsules and the origin of wastes in these capsules are discussed in section 2.5.6. These capsules are stored in the WESF in 200-East in five of the eight pools. The pools are filled with water to a depth of 4 m and house metal storage racks for placing the capsules. The capsule characterization is indicated in figure 2-14. Cs is primarily present as Cs-137, which has a half life of 30.17 yr and decays to barium (Ba-137). Sr is present mainly as Sr-90, which has a half life of 28.6 yr and decays to Y-90, which then decays to the stable Zr-90. The TWRS EIS does not propose any activities for the disposition of these capsules. These capsules are considered as by-product materials. Originally, the Sr capsules were used as heat sources and the Cs capsules were used in strengthening wood products, and sterilizing medical products and saline solutions. Plans call for all capsules to be returned to the Hanford site by the end of 1997 (U.S. Department of Energy, 1996a).

2.7.9 Hanford Tank Initiative

The Hanford Tank Initiative program includes several activities described in the TWRS EIS. One objective is to reduce uncertainties in waste retrieval by developing and demonstrating waste retrieval technologies, which is the primary objective of Phase I of the TWRS program. Additional activities would involve development of technologies for removal of tank heels after sluicing of the waste for initial retrieval and planned activities related to tank closure (U.S. Department of Energy, 1996a). Tank closure is not included in the TWRS activities, and the details of tank closure methods have not been defined at this time.

3 DESCRIPTION OF TANK CONTENTS

3.1 NATURE OF TANK WASTES

Hanford Tank Wastes may be considered in four categories: SSTs, DSTs, MUSTs, and future tank waste additions. The discussions of this chapter emphasize the inventory of SSTs and DSTs, which together comprise greater than 99 percent of the total waste volume and a majority of total radionuclide activity at the Hanford site (U.S. Department of Energy, 1996b). The other major contributors to radioactivity in Hanford wastes are the Cs and Sr capsules, which are beyond the scope of this report. The total MUST waste volume is minor and the MUST inventory, while not yet well documented, is expected to differ little in character from the SST and DST inventories (U.S. Department of Energy, 1996b).

The tanks contain complex mixtures of solids and liquids. Liquids are either supernatant—easily pumped and floating above settled solids—or interstitial—confined to pore spaces of the solids. Solids are classified as sludge or saltcake (Gephart and Lundgren, 1995). Sludge is a thick, wet layer of settled and precipitated water insoluble solids at the tank bottom, with small pore spaces that do not allow removal of liquids. Saltcake is dryer with larger pore spaces, being a residue after evaporation of supernatant liquid; saltcake components are typically water soluble. Slurry is a water/liquid mixture that can be pumped. Figure 3-1 is a photograph of the interior of an SST, showing a variegated solid crust forming on the top of the waste.

The wastes have been produced over a long period of time by a variety of processes, as summarized in chapter 2; records on the contents and volumes of wastes transferred to the tanks are typically incomplete or nonexistent. Chemical and radiological characterization is therefore a challenging task, complicated by the inherent difficulties of sampling heterogeneous tank contents. In this section, the general characteristics of the wastes are described, while section 3.2 addresses the inventories of chemical and radionuclide components of the wastes. Detailed inventories of the tanks are presented in appendix A. Unless otherwise noted, the following references were the sources for the information contained in this section: (Gephart and Lundgren, 1995; Golberg and Guberski, 1995; Agnew, 1997; U.S. Department of Energy, 1996b).

3.1.1 Single-Shell Tanks

As shown in table 2-3, the 149 SSTs were built from 1943 to 1964 and hold from 55,000 to 1,000,000 gal. each. Of the combined 35 million gallons of waste, 66 percent is wet saltcake, predominantly sodium nitrate, and 34 percent is sludge, defined as a mixture of water and insoluble salts and salt-containing liquids. Nearly all separable liquids have evaporated or been transferred from the SSTs to DSTs, but about 6 million gal. of liquid are not easily pumped and will remain in the tanks. The solids and dissolved constituents of the SSTs are 90 percent sodium nitrates and nitrites, with the remainder consisting mostly of phosphates, carbonates, hydroxides, and sulfates. Radioactivity in the SSTs is dominated by Sr-90 (75 percent) and Cs-137 (24 percent); Sr is concentrated in the sludge, while Cs is located chiefly in the saltcake and interstitial liquids.

Figure 3-1. Photograph of the interior of tank 241-AX-101, from the web page at http://www.hanford.gov/twrs/char.pub/ax101big.gif

3.1.2 Double-Shell Tanks

The 28 DSTs are newer and larger than the SSTs, having been built between 1968 and 1986 and ranging in capacity from 1 to 1.16 million gal. (table 2-4). Because they are volumetrically dominated by supernatant liquids transferred from SSTs, the 20 million gal. of DST waste are 85 percent water. The waste is thus dominated by liquids and slurries, sometimes with a bottom layer of sludge. DST waste types have been delineated in greater detail than SSTs. Eight types have been defined, listed here in decreasing order of volume (Gephart and Lundgren, 1995; Hanlon, 1996):

- **Double-shell slurry and double-shell slurry feed (31 percent of total DST waste volume)**—suspension-rich, high-salt solutions from evaporation of SST and reprocessing plant wastes; includes solids comprising 19 percent of this waste type

- **Concentrated complexant (23 percent)**—liquid and solid alkaline waste with high organic and transuranic contents, resulting from evaporation of dilute complexed waste; includes solids comprising 17 percent of this waste type

- **Dilute noncomplexed waste (21 percent)**—low radioactivity liquid waste from a variety of processing operations; includes solids comprising 9 percent of this waste type

- **Neutralized current acid waste (9 percent)**—93 percent liquid waste generated since 1983 from solvent extraction at the PUREX plant

- **Concentrated phosphate waste (6 percent)**—from decontamination of N Reactor; confined to tank AP-102

- **Dilute complexed waste (5 percent)**—high-organic liquids from the SSTs; includes solids comprising 10 percent of this waste type

- **Neutralized cladding removal waste (4 percent)**—thick alkaline sludge, chiefly zirconium hydroxide, from the PUREX plant

- **PFP sludge wash (0.7 percent)**—sludge from PFP recovery operations; confined to tank SY-102

According to the Westinghouse Hanford Company (WHC) Waste Tank Summary (Hanlon, 1996), most tanks contain only one of these waste types. Exceptions are: AW-103, AW-105, and SY-102, which contain neutralized cladding removal waste solids or PFP solids in addition to dilute noncomplexed waste; and SY-101 and SY-103, with both concentrated complexant and double-shell slurry.

The chemistry of the solids and dissolved constituents of the DSTs is, like the SSTs, dominated by sodium nitrates and nitrites, with additionally 20 percent metal hydroxides and 10 percent phosphates, carbonates, oxides, and sulfates. Cs-137 comprises 72 percent of the DST waste radioactivity, while 27 percent is from Sr-90; this contrast with the SST proportions is due to the tendency for Sr to have settled out in the SST solids before waste transfer to the DSTs.

3.2 INVENTORY

As mentioned above, characterization of chemical and radionuclide inventories of the tank wastes is not a straightforward task. Two approaches to this question have been employed, each complementing the other: direct sample measurement (or assay) and estimation based on facility records. The former is limited by the extreme physical and chemical heterogeneity of the tank contents, while the latter may be unreliable due to incomplete or inaccurate documentation of waste transfer transactions. Furthermore, inventories may change due to additions, transfers, and radioactive decay.

The ongoing Hanford tank waste inventory effort combines both approaches: (i) analytical characterization work is being reported in a Tank Characterization Report (TCR) for each tank (e.g., Benar and Amato, 1996)—these reports include estimations of total tank inventories based on an informed combination of individual sample results; and (ii) historical characterization is reported in documents termed Historical Tank Content Estimates (HTCE), which are released for quadrant groupings of tank farms (e.g., Brevick et al., 1996) with reference to supporting summaries for each farm (e.g., Brevick and Newell, 1996). The HTCE reports summarize all available historical data on processing and waste transfers, and present the waste inventories based on those data.

The complex computational basis for HTCE inventories is being executed at Los Alamos National Laboratory (LANL). This effort, using what is termed the Hanford Defined Waste (HDW) model (Agnew, 1997), compiles historical process and waste transaction records in order to construct spreadsheets delineating time-dependent inventories of solid and liquid chemical inventories for each tank. In the HDW model, all possible sources of tank contents are classified among 48 different waste types, each with a given chemical/radionuclide profile based on knowledge of the processing from which it originated. Tank contents are then calculated from combinations of these waste types consistent with the historical records. The HDW estimation model for solids compositions is termed the Tank Layer Model (TLM) and that for liquids is called the Supernatant Mixing Model (SMM). The HDW model compiles estimates for 33 nonradioactive chemical species, 46 radionuclides (decayed to 1994), and four other properties (density, water weight percent, total organic carbon, and sludge void fraction). The radionuclide estimates are based on ORIGEN2 calculations for all the nuclear fuel batches processed at Hanford, with modifications for extraction and other processing.

The HDW total site inventories are shown in table A-1. Because the set of tables illustrating individual tank inventories would constitute 354 pages, we report here only a few selected tanks as examples. These examples are shown in tables A-2 to A-7, which are reproductions from Agnew (1997). The example tanks were selected on the basis of the following (see chapters 2 and 4):

- A-101 is on both the Organic and Flammable Gas Watch-lists
- AW-104 has nitrate, nitrite, and hydroxide concentrations that make it particularly susceptible to pitting corrosion and stress corrosion cracking
- BY-106 is on the Ferrocyanide Watch-list
- C-106 is on the High-Heat Watch-list due to high fission product content
- SY-101 is a "burping" tank and is on the Flammable Gas Watch-list
- SY-102 is particularly high in Pu

In terms of inventory characterization, the goal of Hanford's overall effort is to produce a unified "best-basis" inventory drawing on all available estimation and assay results. This work is still in progress, and the most recent results may be viewed on line at the PNNL Tank Waste Information Systems (TWINS) web site at

http://twins.pnl.gov:8001/TCD/main.html

(Permission for access to this database must be obtained from PNNL). This database also has all available assay data on tank waste samples, and should prove to be a valuable resource for ongoing tank waste familiarization.

The TWRS EIS (U.S. Department of Energy, 1996) used a different, preliminary set of data in reporting overall chemical and radionuclide inventories for SST and DST tanks. The EIS approach (Golberg and Guberski, 1995) was to use historical process records for estimation of SST inventories and measurement data augmented by historical data for the DSTs. Therefore, the methods employed for the EIS inventory were not fundamentally different from those in current use; the more recent historically based inventories are the products of further records research and more sophisticated modeling techniques, and their results are being critically compared with analytical data from all tanks. The EIS total inventories, not broken down by individual tank, are provided for comparative purposes in tables A-8 and A-9.[1] In the EIS (U.S. Department of Energy, 1996a), the argument is made that these total inventories, while not accounting for the considerable variations among tanks, are adequate for conceptual design of waste treatment options.

The current Hanford inventory approach is compared with that utilized in the EIS in table 3-1. Comparison of inventory values is briefly discussed later in this chapter.

Table 3-1. Comparison of inventory approaches for the TWRS Environmental Impact Statement and the ongoing inventory characterization effort ("Hanford Best-Basis")

Inventory	EIS	Hanford Best-Basis	
Coverage	site-wide only	Individual tank	
Approach	assay and records—DST records—SST	1. Tank Characterization Reports—sample assay ↓	2. Historical Tank Content Estimates—records; includes Hanford Defined Waste Model ↓
		Best-Basis Inventory	

↓ The arrows signify that the Best-basis inventory is based on a comparative analysis of results of both Tank Characterization Reports and Historical Tank Content Estimates.

[1]Note that there is a traceable discrepancy in DST soluble chemical components between the versions of table A-8 in the Golberg and Guberski report and the EIS itself; we report here the former, primary source. In EIS table A.2.1.2, values in the DSTs Soluble column from CrO_4^{2-} down to Zr^{4+} were erroneously shifted up one row.

3.2.1 Inorganic chemicals

Table A-1 shows that, by far, the most abundant cation in the tank wastes is sodium; Na^+ comprises around 80 percent of the cationic content by weight. Figure 3-2 shows the range of variation in Na^+ concentrations across all 177 tanks, based on the Revision 3 HDW model. [Note that revision 3 data are used in the histogram plots of figures 3-2, 3-3, and 3-4 because of the existence of the CNWRA database derived from revision 3 (Agnew, 1996). Electronic files of revision 4 concentration data are not easily available; the online TWINS database lists only total amounts in kg or Ci, rather than in concentrations. The differences between revisions 3 and 4 are not important for the purposes of these illustrative plots.] The next most abundant cation overall is aluminum, with approximately 5 weight percent of the cationic inventory. Clearly, sodium is the major cationic species in any chemical processes/reactions involving tank waste. There are relatively large concentrations of cations derived from construction materials: Fe^{3+}, Ni^{2+}, and Cr^{3+} and fuel claddings: Zr^{4+} and Al^{3+} [also presented as $Al(OH)_4^-$].

The anionic waste contents are not so dominated by a single constituent. The dominant anion, by weight, is nitrate (NO_3^-) at about 62 percent, and other abundant anions include hydroxide (OH^-), nitrite (NO_2^-), and carbonate (CO_3^{2-}). However, a number of other anions such as phosphate (PO_4^{3-}), Cl^-, F^-, SiO_3^{2-}, SO_4^{2-} (table 3-1) have significant concentrations and are important to waste chemistry. The EIS designates nitrate as the chief inorganic anion of significance to risk (U.S. Department of Energy, 1996b), because of its potential to oxidize ferrocyanide as well as organics in the tank, leading to explosion and radionuclide release. The range of variation in nitrate concentration among tanks based on the HDW revision 3 model is shown in figure 3-3.

3.2.2 Organic Chemicals

Interest in organic waste constituents arises from two considerations (Gephart and Lundgren, 1995; Turner et al., 1995). First, at elevated temperatures, organic compounds can combine with the abundant oxidizing materials in the waste, chiefly nitrates and nitrites, in exothermic reactions that pose risks of fire and/or explosion. (This issue is discussed in more detail in chapter 4.) Second, organic complexants can bind with waste constituents (e.g., radionuclides) and affect their chemical behavior during waste treatment processes. The overall EIS inventories (table A-8) report organic components only as total organic carbon (TOC). Ongoing individual tank inventory efforts such as HDW provide more detailed delineation of organic compound contents by tank (e.g., tables A-2 to A-7) and overall for the Hanford site (table A-1). The overall site inventories (table A-1) show that, on a molar basis, glycolate is the predominant organic complexant. The other listed organic anions—citrate, Ethylenediaminetetra-acetic acid (EDTA), N-(2-hydroxyethyl)ethylenediaminetetra-acetate (HEDTA), acetate, oxalate, DBP, and butane—all have similarly low molar concentrations, ranging from approximately 1/20 to 1/4 of the total site glycolate value. On a weight basis, glycolate is rivaled in abundance by HEDTA. There are no major differences in organic inventories between SSTs and DSTs.

3.2.3 Radionuclides

The key radionuclides for risk assessment at Hanford site are C-14, Sr-90, Tc-99, I-129, Cs-137, and U (U.S. Department of Energy, 1996b). As mentioned above, Sr-90 and Cs-137 are by far the most abundant radionuclides on an activity basis (tables A-1 and A-9). The daughters of Sr-90 and Cs-137—Y-90 and Ba-137m, respectively—are at or near a state of transient equilibrium, that is, equal

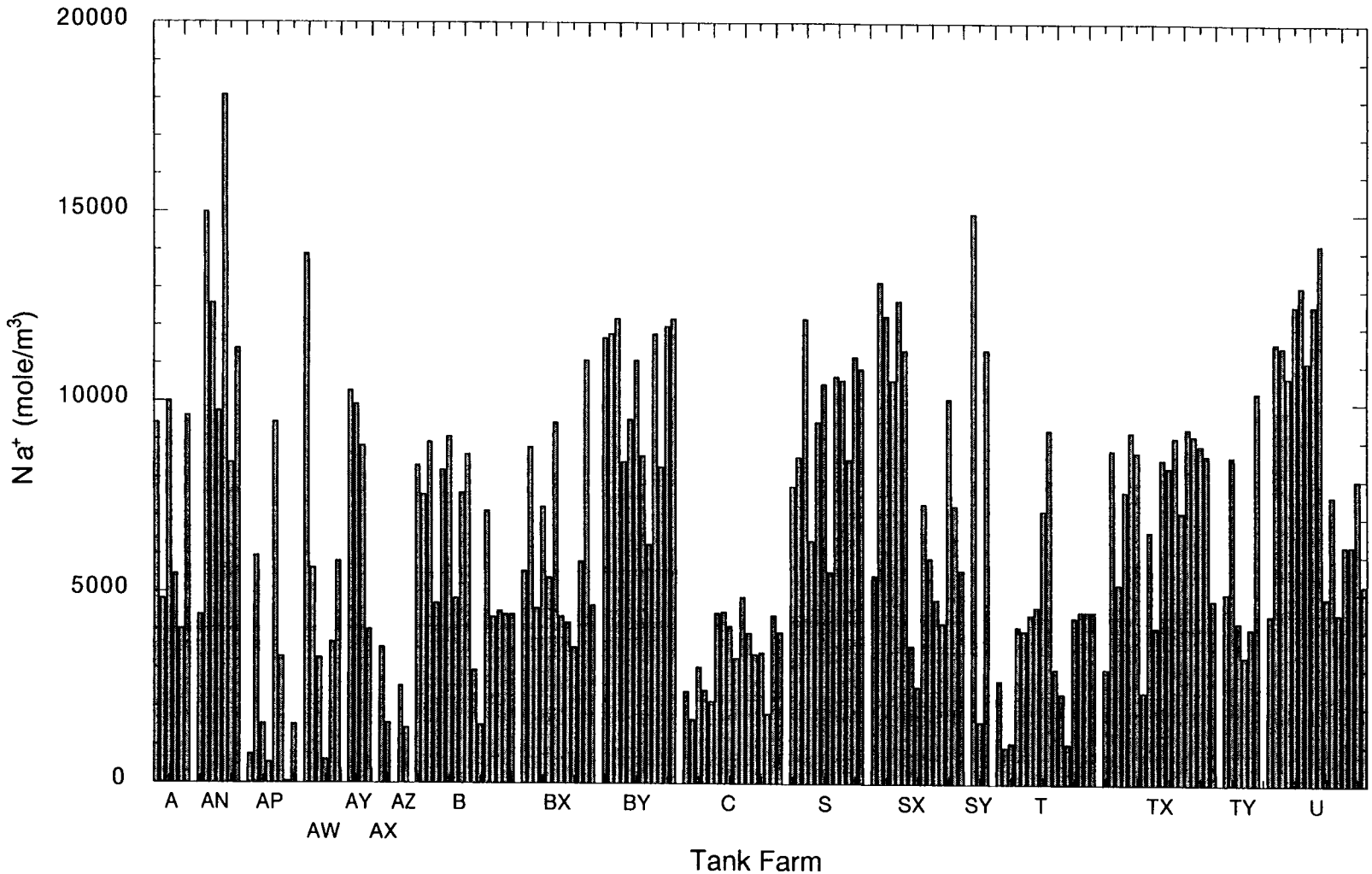


Figure 3-2. Histogram of moles/m^3 Na^+ in Hanford tanks from the Hanford Defined Waste model, revision 3 (Agnew, 1996). Tank farms are separated by blank spaces along the x axis.

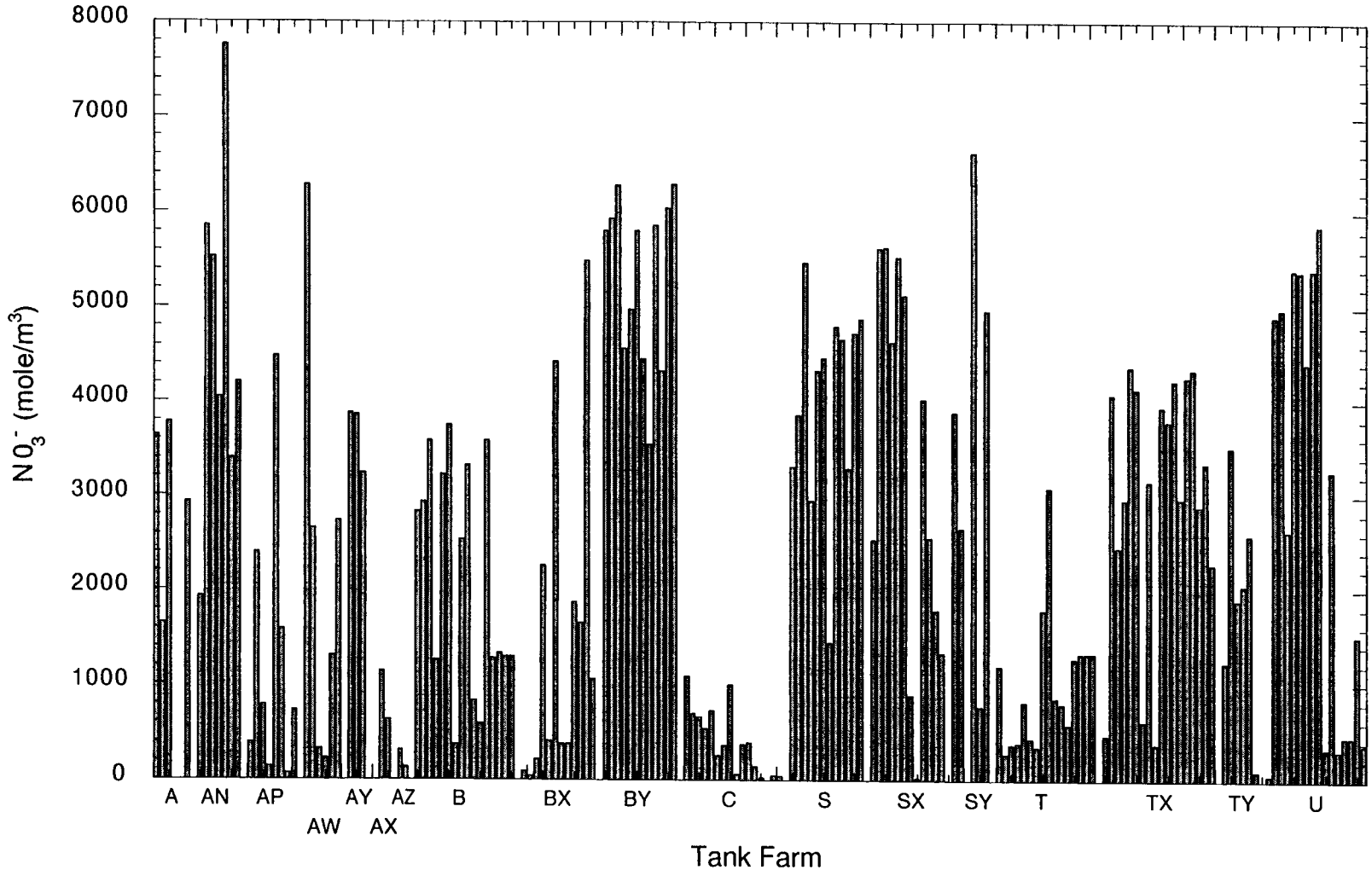


Figure 3-3. Histogram of moles/m^3 NO_3^- in Hanford tanks from the Hanford Defined Waste model, revision 3 (Agnew, 1996)

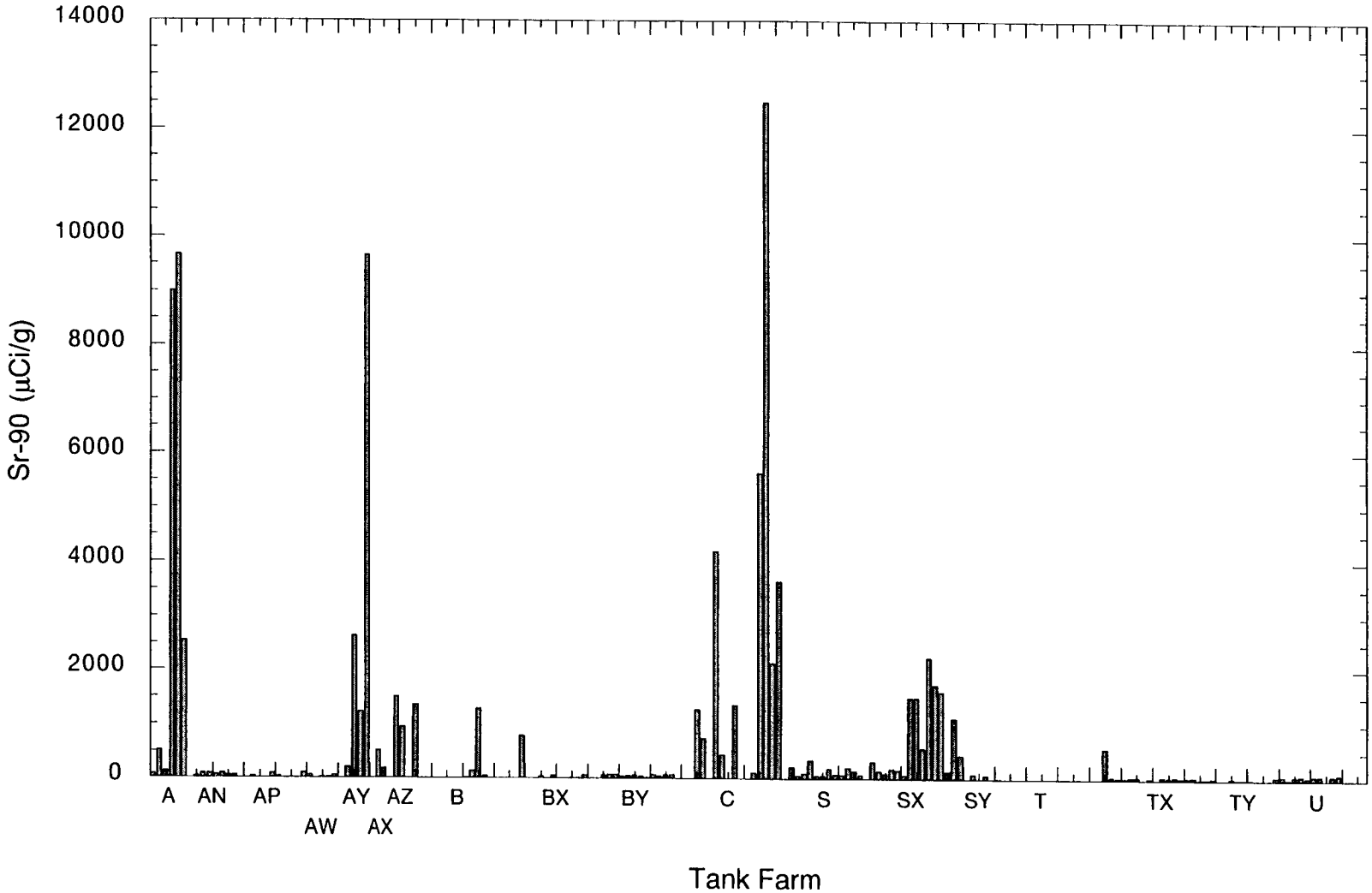


Figure 3-4. Histogram of μCi/g Sr-90 in Hanford tanks from the Hanford Defined Waste model, revision 3 (Agnew, 1996). Many values are too small to be visible.

radioactivity, with their parents and should be included in the inventory. However, both of these daughters are short-lived enough that they decay away in a matter of days when separated from their parents. Figure 3-4 is a histogram of Sr-90 concentrations in the tanks; note the wide variability. Such large inter-tank variability is also noted in other tabulated radionuclides (tables A-2 to A-7).

3.2.4 Discussion

The nature of the tank waste inventories—chiefly their derivation in large part from reconstructions of waste histories—precludes attaching a large degree of certainty to any particular inventory estimation scheme without consideration of the times considered and the methods employed. For example, distribution of Cs-137 between SSTs and DSTs can be appreciably affected by pumping liquids from the former into the latter, which is an ongoing activity. Furthermore, it is projected that the 74,200 m^3 of waste in the DSTs will be augmented by another 12,400 m^3 during future waste transfers; no calculations of the effects on tank inventories were noted in the literature. The EIS (U.S. Department of Energy, 1996b) does note that the added wastes will be dominated by dilute noncomplexed waste types (see above). Note also that accurate radionuclide inventories require dates of calculation to account for decay; however, the five-year spread in dates used in the studies cited herein results in less than a 13 percent difference in Sr-90 and Cs-137 contents.

It has been noted by nearly all studies cited in this chapter that individual tank inventories have the highest degree of uncertainty. Agnew (1997) calculated estimated uncertainties in concentrations based on variability in knowledge of process and solubilities. The resultant variabilities are shown for individual tanks in tables A-2 to A-7. There is a wide range in relative variabilities, ranging up to nearly 100 percent of reported concentrations, but most appear to be in the range of 10 to 50 percent. A higher degree of confidence in individual tank inventories is the goal of the Hanford "best-basis" effort, which as noted is still incomplete. This effort will unify results from the HTCE/HDW estimation scheme with analytical data on the wastes themselves. See table 3-2 for a "grab bag" example of how divergent analytical data may be from inventory estimation for tank contents of major constituents. Note the rather good agreement for sodium and Cs-137, but the factor of two difference in nitrate and factor of five difference in Sr-90. For study of individual tanks, in lieu of a "best-basis" estimate for a given constituent, it would seem conservative to choose the larger of the TCR and HTCE values. Furthermore, best-basis values must also be critically reviewed when they are finalized.[2]

Table 3-2. Comparison of assay or Tank Characterization Report and records or Historical Tank Content Estimate (which incorporates Hanford Defined Waste results) inventory approaches for selected constituents in Tank SY-101. Data from TWINS online database and table A-6.

Constituent	HTCE/HDW	TCR
Na^+ (kg)	1.77×10^6	1.39×10^6
NO_3^- (kg)	1.69×10^6	8.50×10^5
Sr-90 (Ci)	6.83×10^5	1.31×10^5
Cs-137 (Ci)	1.54×10^6	2.31×10^6

[2]Agnew (1997) notes that direct comparison of HDW values with assays for a given tank are not generally likely to be useful. He says instead that the comparison should be made among groups of tanks with similar waste histories (he does not, however, provide a list of such groups).

While the overall site tank waste inventories for constituents are subject to less uncertainty, significant differences emerge from one estimation scheme to another. (Note that TCR total site inventories are not yet available.) A comparison is made in the EIS (U.S. Department of Energy, 1996b) using an earlier HDW which does not generally differ markedly with the revision 4 version cited here. It is noted there that some constituents are listed at contents several times higher in the HDW than in the Golberg and Guberski (1995) WHC report. The EIS authors state that it is not possible, considering model complexities, to easily explain the source of these differences. It would seem, then, that use of the generally higher HDW inventories would be more conservative. An important exception, noted in the EIS, is nitrate, which is about twice as high in the Hanford overall inventory as in the HDW, and is potentially significant as a post-remediation pollutant (U.S. Department of Energy, 1996b). Table 3-3 compares the total site tank EIS values for selected major constituents with those from the more recent HDW revision 4 model (Agnew, 1997). Agreement is quite good for three of the four constituents, but the large difference in nitrate estimates persists.

In summary, the best tank waste inventory (i.e., the "best-basis" model currently under development) is not yet complete. Preliminary results are available at the online TWINS database site. Until completion of this inventory, use of the HDW model (Agnew, 1997) is generally preferred for constituents listed therein (table A-1 and example tables A-2 to A-7).

3.3 GEOGRAPHIC INFORMATION SYSTEM DATABASE OF TANKS AND TANK WASTES

A computerized database for the Hanford tanks and tank wastes project was constructed using the ARC/INFO Geographic Information System (GIS) developed by Environmental Systems Research Institute, Inc. (ESRI). The purpose of the GIS is to provide a computer-based information source on data related to underground storage tanks and tank wastes located within the 200 Areas at the Hanford site. The GIS currently contains information on waste tank status, characteristics, and waste chemistry. The information within the database was collected from reports prepared for the DOE by contractors and laboratories. The GIS provides an avenue for rapid retrieval and evaluation of this data. Display, examination, and analysis of the data contained in the GIS are best achieved using the ArcView desktop mapping software package also developed by ESRI. Following are brief descriptions of the ARC/INFO GIS system, the data collected and entered into the GIS database to date, the ARC/INFO coverages specifically constructed for the project, and the ArcView desktop mapping software.

Table 3-3. Comparison of total site tank inventories as determined (Golberg and Guberski, 1995) for the Environmental Impact Statement (EIS) and in the HDW revision 4 (Agnew, 1997) for selected constituents. EIS values are from tables A-8 and A-9, with values from the former converted from metric tons to kg. HTCE/HDW values are the "All Tanks" values in table A-1.

Constituent	EIS	HTCE/HDW
Na^+ (kg)	6.91×10^7	4.92×10^7
NO_3^- (kg)	1.07×10^8	5.04×10^7
Sr-90 (Ci)	5.37×10^7	6.16×10^7
Cs-137 (Ci)	3.49×10^7	4.71×10^7

The ARC/INFO GIS system is designed to link quantitative and qualitative data contained within a database to a common spatial reference or geographic location. In the ARC/INFO environment, discrete data types intrinsically tied to geographic locations are separated into layers or coverages. Coverages usually consist of a single data format: points, lines, or areas. Points, lines, or areas can be digitized or edited into coverages. When a coverage is created, ARC/INFO builds an associated attribute table which is linked to the coverage. Spatial information about each point, line, or area added to the coverage is automatically entered into the attribute table by ARC/INFO. Data items and associated data are then added to the attribute table to complete the coverage. In short, an ARC/INFO coverage is linked to a table which contains spatial data and associated attribute data for each point, line, or area in the coverage.

The GIS for the Hanford tanks and tank wastes project contains information on the configuration, status, surveillance, liquid and solid contents, and chemical and radionuclide composition of each of the existing 177 large underground storage tanks in the 200 Areas at the Hanford site. Coverages for the GIS are composed of line and area data types which represent streets, buildings, tank farms, and underground storage tanks within the 200 Areas at the Hanford site. The geographic locations of streets, buildings, tank farms, and storage tanks at the site were digitized directly from an existing map of the 200 Areas (figure 3.2.3; U.S. Department of Energy, 1996b). Data on tank status, characteristics, and contents (e.g., shell type, total capacity, liquid and solid waste volumes) were manually entered into the GIS from charts and tables in a waste tank summary report prepared for the DOE by WHC (Hanlon, 1996). An electronic version of the HDW report (Agnew, 1996) was obtained and used to input the estimated chemical and radionuclide inventories of tanks into the GIS. The chemical and radiological constituents contained in the GIS are listed in appendix A. Development of the database accessed by the GIS [e.g., incorporation of data on radionuclides not addressed by the Agnew model (see above)] will continue.

The GIS is currently composed of six coverages (coverage name is in parentheses): streets (HANSTREETS), buildings (HANBLDGS), tank farms (HANFARMS), underground storage tanks (HANTANKS), a summary of storage tank status and characteristics (TANKSUMM), and a chemical and radionuclide inventory (TANKCHEM). A schematic diagram of the GIS showing the coverages and data items contained within each coverage is shown in figure 3-5. Notice that information on tank status, characteristics, and chemistry are contained in the TANKSUMM and TANKCHEM coverages; the other coverages provide data about the site infrastructure (e.g., street and building names). Data can be added to these existing coverages as additional information concerning the site geography or tanks if needed or requested. As waste is retrieved from the tanks for processing, information on the status, content, and chemistry of the tanks can be modified. New coverages can also be constructed and added to the GIS. For example, a coverage is planned which will show the location and describe the characteristics of cross-transfer piping for the retrieval and transport of tank wastes to staging, sampling, and treatment facilities.

Although coverages can be displayed and examined using the ARC/INFO system, its data management and analysis features are limited. ArcView is a sophisticated desktop mapping software package which has extremely flexible data management, analysis, and reporting features. ArcView can read ARC/INFO coverages without translation or recompilation. A major advantage of ArcView is that it permits access to spatial data in ARC/INFO format to users not directly associated with an ARC/INFO site. In addition, unlike the UNIX-based ARC/INFO, ArcView can be installed and executed on either Windows or UNIX platforms.

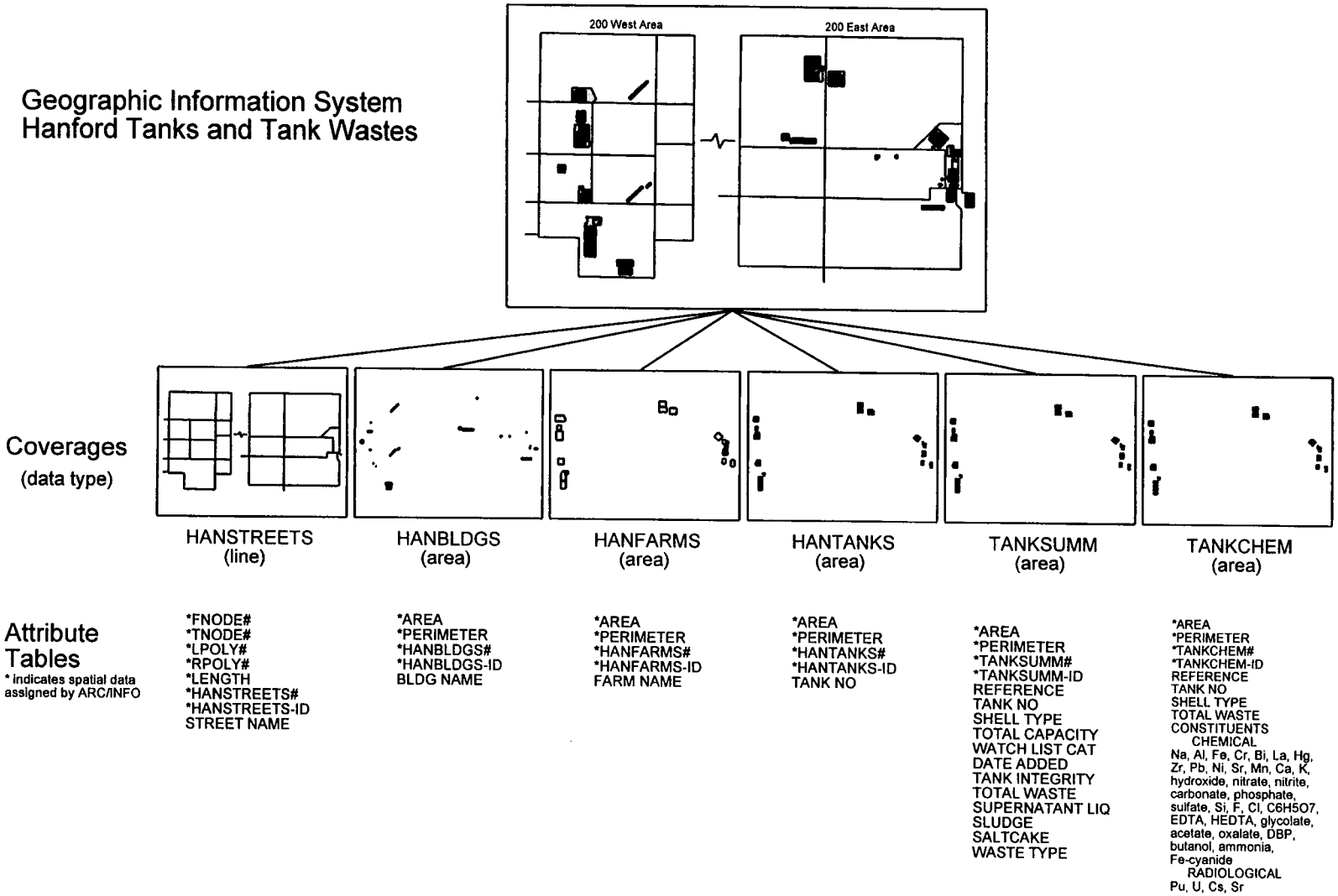


Figure 3-5. Schematic diagram of the Hanford tanks and tank wastes Geographic Information System showing the coverages, their data types, and the data items contained within each coverage

The ArcView graphical user interface allows users to quickly display coverages, dynamically examine data, perform spatial and logical data queries, and create maps. A map of the site constructed with ArcView using the Hanford tanks coverages is shown in figure 3-6. ArcView is an excellent tool for performing spatial analyses and presenting information graphically (in charts, tables, and maps). For the Hanford tanks and tank wastes GIS, waste tanks with certain characteristics or waste contents and tank wastes with certain chemistries can be identified using query operations. To demonstrate, a simple example is presented. A logical query was performed to identify waste tanks in the 200-East Area with a Pu-239 concentration greater than 1.0 μCi/g. The information resulting from this query operation is presented graphically in figure 3-7. In this figure, the tanks with Pu-239 concentration greater than 1.0 μCi/g are highlighted on a map of the 200-East Area. The figure also includes a table which lists the tank numbers and estimated Pu-239 concentrations of the highlighted tanks.

Further work in this area was halted in January 1997, due to resource constraints.

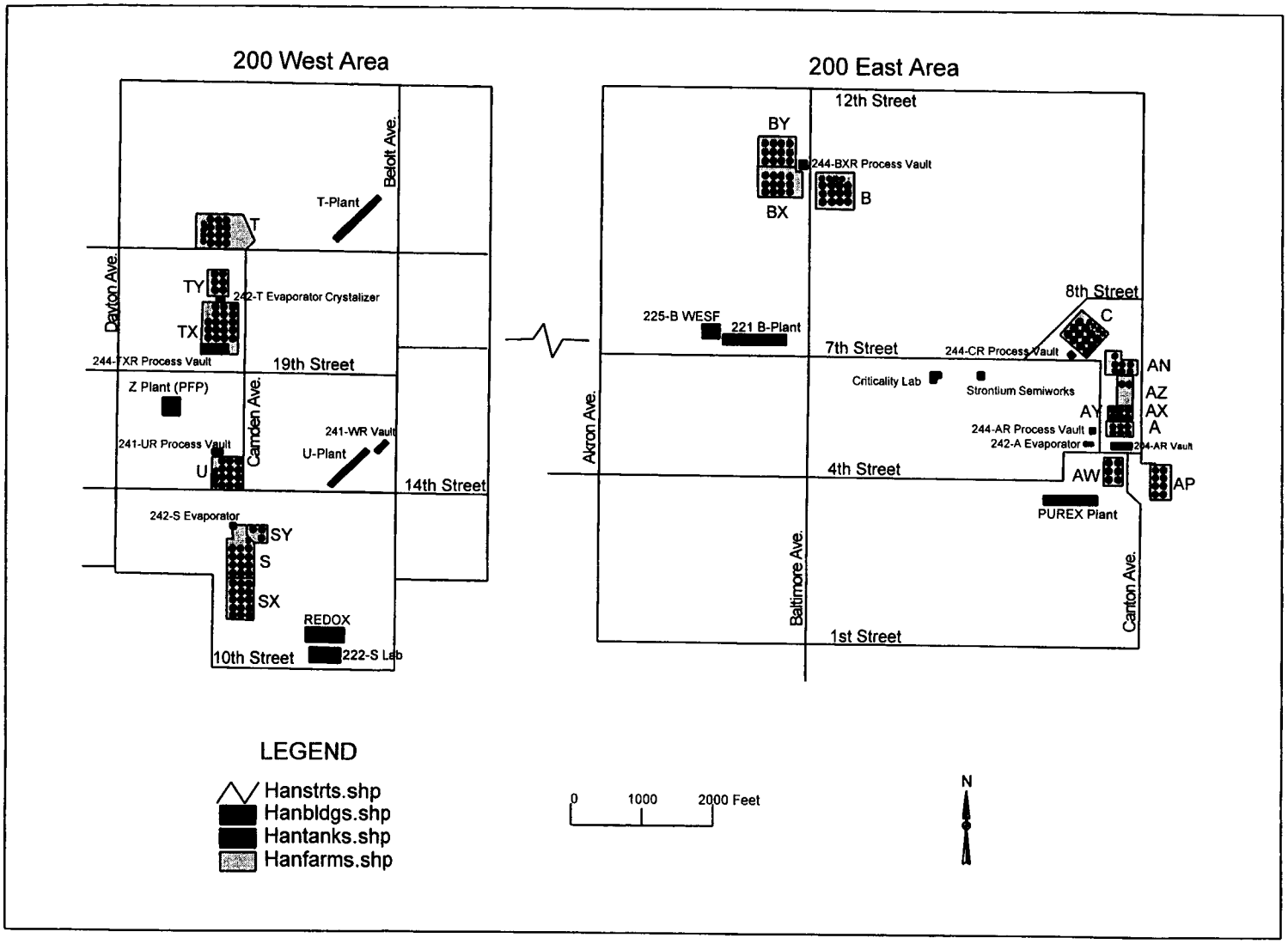
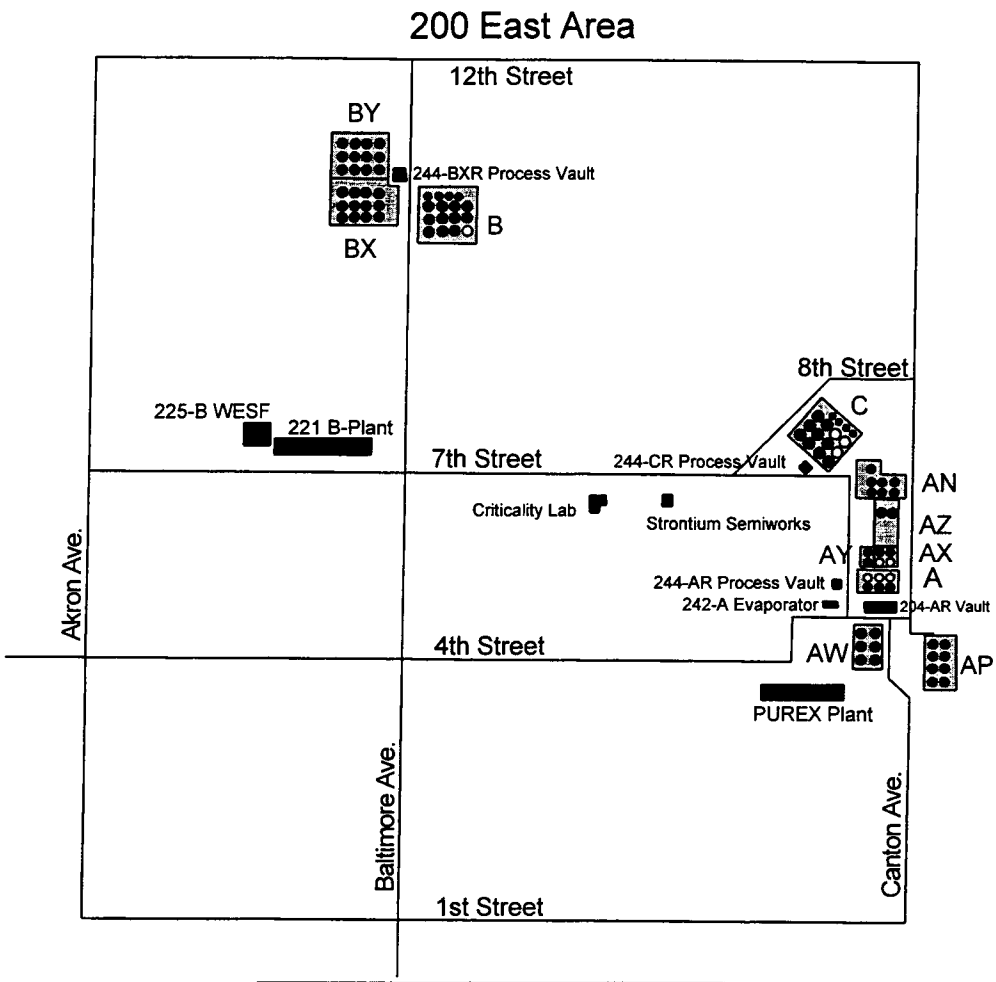


Figure 3-6. Map of the 200 Areas at the Hanford site constructed with ArcView using the Hanford tanks ARC/INFO coverages



Tank Number	Pu (µCi/g)
B-101	1.14
C-106	3.67
C-103	1.15
C-102	1.02
AX-102	1.87
AX-104	1.04
A-106	1.62
A-105	1.04
A-104	7.03

Figure 3-7. Map of the 200-East Area at the Hanford site highlighting tanks (open circles) with a Pu-239 concentration greater than 1.0 μCi/g. The tank numbers and estimated Pu-239 concentrations of the highlighted tanks are listed in the table at the bottom.

4 HAZARDS POSED BY WASTE TANKS AND TANK WASTE REMEDIATION SYSTEM

4.1 PRIMARY HAZARDS ASSOCIATED WITH HANFORD WASTE TANKS

A number of safety issues associated with Hanford waste tanks have been identified by the DOE. Of primary importance, particularly with respect to the regulatory role of the NRC, are those having the potential for releasing radioactivity to the environment. The DOE developed a set of criteria to identify tanks with potential safety concerns as Watch-list tanks.[1] The four different Watch-list categories are flammable gas, ferrocyanide, high organic content, and high-heat generation. Information indicates that there are 50 tanks (44 SSTs, 6 DSTs) on the Watch-list (Hanlon, 1996), with 10 tanks listed in more than one of four different Watch-list categories. The safety issues associated with these Watch-list categories are discussed in the following sections, and the Hanford waste tanks identified for each Watch-list are given in table 4-1.

4.1.1 Flammable Gas Safety Issue

The risk associated with the release of flammable gases into the dome space of waste tanks at the Hanford site is a top priority safety issue (McDuffie, 1995). Although flammable gas production from radiolysis is always a concern for high-level radioactive waste storage, a special problem developed at the Hanford site when wastes were concentrated by evaporation to generate additional storage space in the million-gallon waste tanks. The volume of the slurry concentrate slowly increased due to retention of generated gases after being pumped into the tanks, which defeated the purpose of volume reduction. The real problem became evident when some tanks began to have rather large surface level drops accompanied by release of gas mixtures containing both fuel (hydrogen) and oxidant (nitrous oxide). These gas mixtures are flammable and potentially explosive even if not mixed with the oxygen in the ambient air. Tank SY-101, prior to installation of a mixer pump, exhibited the largest cyclic releases (as indicated by tank surface level drop and increase in tank pressure), and hydrogen concentrations in the tank dome space and ventilation header have exceeded the lower flammability limit (LFL)[2] for short periods of time (McDuffie, 1994). The presence of flammable concentrations of gases and an ignition source could lead to reactions that could cause a radioactive release or provide an energy source which

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[1]A separate but related formal administrative DOE program is in place to identify as an USQ known or suspected operating conditions that have not been analyzed or that fall outside of the established authorization bases. Following identification of a USQ, a review is conducted and corrective action is taken if applicable. The USQ may be closed from an administrative standpoint, which means that conditions surrounding the safety issue have been analyzed, although the safety issue may still exist and may require mitigation, controls, or corrective action. The safety issues that were identified under the Watchlist program were also previously analyzed as USQs. Technical evaluation has resulted in closing the USQs on ferrocyanide, floating organic layer, and criticality (U.S. Department of Energy, 1996a). There is a USQ associated with the Flammable Gas Watch-list tanks because of the potential consequences of a radiological release resulting from a flammable gas burn, an event not analyzed in the SST Safety Analysis Report. Hanlon (1996) reported that DOE declared a USQ on some tanks containing dry organic nitrate chemicals because methods for analyzing accident scenarios have become available for these.

[2]The lower and upper limits of flammability indicate the percentage of combustible gas in air below which and above which flame will not propagate. When flame is initiated in mixtures having compositions within these limits, it will propagate and therefore the mixtures are flammable (Avallone and Baumeister, 1996). Lower and upper limits of flammability for hydrogen are 4.0 and 75.0 vol.%, respectively. For ammonia, lower and upper limits are 15.0 and 28.0 vol.%, respectively. For methane, the lower and upper limits are 5.0 and 15.0 vol.%, respectively.

Table 4-1. Watch-list tanks (Hanlon, 1996)

Flammable Gas			Organics			Ferrocyanide[1]			High Heat		
Tank No.	Temp. (°F)	Total Waste (inches)	Tank No.	Temp. (°F)	Total Waste (inches)	Tank No.	Temp. (°F)	Total Waste (inches)	Tank No.	Temp. (°F)	Total Waste (inches)
A-101 (*)	151	347	A-101 (*)	151	347	BY-103	80	153	C-106	154	72
AX-101 (*)	133	272	AX-102 (*)	76	14	BY-104	122	155	**1 Tank**		
AX-103 (*)	108	40	B-103 (*)	64	17	BY-105	113	190			
S-102	110	207	C-102	82	149	BY-106	123	241			
S-111	92	224	C-103	115	66	BY-107	97	104			
S-112	85	239	S-102	110	207	BY-108	106	90			
SX-101	135	171	S-111	92	224	BY-110	115	152			
SX-102	147	203	SX-103	170	242	BY-111	87	174			
SX-103	170	243	SX-106	111	201	BY-112	88	113			
SX-104	165	229	T-111	63	158	T-107	65	61			
SX-105	179	254	TX-105 (*)	97	228	TX-118	75	122			
SX-106	111	201	TX-118	75	134	TY-101	64	50			
SX-109	148	96	TY-104	64	24	TY-103	69	66			
T-110	64	133	U-103	87	166	TY-104	64	24			
U-103	87	166	U-105	90	147	**14 Tanks**					

Table 4-1. Watch-list tanks (Hanlon, 1996) (cont'd)

Flammable Gas			Organics			Ferrocyanide[1]			High Heat		
Tank No.	Temp. (°F)	Total Waste (inches)	Tank No.	Temp. (°F)	Total Waste (inches)	Tank No.	Temp. (°F)	Total Waste (inches)	Tank No.	Temp. (°F)	Total Waste (inches)
U-105	90	147	U-106	79	78						
U-107	79	143	U-107	79	166						
U-108	88	166	U-111	79	115						
U-109	85	164	U-203	64	6						
AN-103	112		U-204	61	9						
AN-104	118		**20 Tanks**								
AN-105	106										
AW-101 (*)	104										
SY-101	120										
SY-103	98										
25 Tanks											

[1] The Ferrocyanide Safety Issue was considered officially closed and all tanks removed from the Ferrocyanide Watch-list as of October 1996 (J. Kinzer, U.S. Department of Energy. Reported in Tri-City Herald, October 31, 1996).

(*) All Watch-list tanks are monitored continuously for temperature, except for the eight tanks identified with an asterisk, which are measured manually on a weekly basis. Temperatures listed in the table are the highest temperatures recorded for the month of July, 1996 (Hanlon, 1996).

could facilitate other reactions within the tank. Subsequent analytical and experimental work has demonstrated that flammable gases other than hydrogen, such as ammonia and methane, must also be considered. Episodic venting of flammable gases is expected to recur until some form of mitigation or retrieval action is undertaken.

Twenty-five tanks are on the DOE Flammable Gas Safety Program Watch-list and are identified in table 4-1. The list includes tank SY-101 (the only one which had a gas release event resulting in flammable gas concentrations exceeding the LFL for hydrogen) and tanks containing materials related to contents of tank SY-101 or tanks that exhibited slurry growth, episodic level drops, or short-term releases of gases into the tank headspace. Analysis of DSTs SY-103, AW-101, AN-103, AN-104, and AN-105 indicated that these tanks contain sufficient stored gas such that, on a sudden release, the hydrogen concentration would exceed the safety criterion. For tank domes this criterion is 25 percent of the LFL, a value recommended by the National Fire Protection Association (NFPA). DOE Order 5480.4 requires that the NFPA guidelines be used for nuclear facilities. The above Watch-list is current as of July 31, 1996, but is subject to updating, especially during the current safety screening campaign being undertaken by the DOE[3].

Although there is still insufficient knowledge about processes occurring within the waste that generate, retain, and release the gas, it is well known that hydrogen, a very flammable gas, is produced by radiolysis of water or aqueous solutions. Thus, there are always concerns about hydrogen accumulation in vapor spaces of reactors, fuel storage systems, and radioactive waste storage tanks. Additional studies in various laboratories (e.g., Delegard, 1980; Jansky and Meissner, 1984; Bryan et al., 1992) using Hanford waste simulants show that it is possible to produce flammable gas mixtures even without the presence of radiation (McDuffie, 1994). For example, chemical degradation of organics producing hydrogen occurs under alkaline conditions (high hydroxide ion concentration) in the presence of some form of aluminate. Ammonia and nitrous oxide are produced by reduction of nitrite ion in the presence of organic compounds. Other chemical and radiolytic studies indicate that organic compounds such as some of the complexants present in Hanford tank wastes are active in producing gases, whereas more refractory organics such as formate and oxalate (the anions of formic acid and oxalic acid, respectively) are not effective hydrogen producers under tank conditions (McDuffie, 1995). A general conclusion from studies on Hanford radioactive wastes containing active organics, aluminum, and nitrite is that the potential exists for production of flammable mixtures of hydrogen, ammonia, and nitrous oxide, along with low concentrations of methane and carbon monoxide. However, the relative contribution of purely chemical production of gases as compared to radiolytic production has not yet been determined.

The physics of gas retention and gas release in Hanford tank wastes is not fully understood and studies of retention and release mechanisms are still under way. However, it is known that the relative densities of solid and liquid phases, as well as shear strength of gas-retaining layers, are important factors determining the relative amount of gas retained before gas release can occur. Several mechanisms for gas retention are possible including viscous trapping of bubbles, stabilization in three-phase foams at

[3]Tank safety screening is being conducted by DOE to ensure that appropriate safety issues have been/are identified for the Hanford Site SSTs, DSTs, double contained receiver tanks, catch tanks, and MUSTs that contain radioactive waste. These tanks are being screened for safety issues relevant to ferrocyanide, organics, flammable gas, and criticality (Dukelow et al., 1995), as well as for safety issues relevant to noxious vapors (Osborne et al., 1995). All tanks have been previously screened for high heat conditions (DeFigh-Price and Wang, 1993). The safety screening involves taking solid, liquid, and/or gas samples from waste tanks for chemical analysis.

hydrophobic surfaces, capillary channel gas accumulation, mechanical trapping of crystal clusters, and tight engulfment in bubbles attached to solid particles (McDuffie, 1995). Retention of gas within the waste appears to present a greater problem than gas generation, which would not be a problem if the tank ventilation can successfully remove the gases from the tank dome space. Gas retention or accumulation, on the other hand, can result in a serious situation if it leads to a sudden release of large inventories of gases, such as those which have occurred in tank SY-101 and, more recently, in tank SY-103 (Hanlon, 1996). In the latter case, hydrogen gas concentration increased from a 60 ppm baseline to 500 ppm over two days, then subsequently increased from 470 to 1720 ppm within one minute.

Because there is inadequate information regarding tank waste processes that generate, retain, and release flammable gases, efforts are ongoing at Hanford to collect information about the basic chemical and physical properties of the tank wastes. This information is needed to gain knowledge about the behavior of the waste so that effective mitigation methods can be developed and implemented. Mitigation methods may involve mechanical processes, chemical treatment, or a combination of both. Tank SY-101 is currently being mitigated by using a mixer pump to stir the waste and allow hydrogen gas to be released gradually and prevent episodic releases that are above the LFL. The pump is operated for 25 min three times a week.[4] Other tanks are being screened and evaluated to assess the magnitude of their risk from flammable gas generation, retention, and intermittent release. Gas monitoring systems are also being installed that will provide continuous monitoring of hydrogen and periodic monitoring of other gases. In addition, efforts are under way to upgrade instruments for surface level and temperature measurements.

Recently, all 177 tanks (Watch-list and non-Watch-list) were placed under flammable gas controls, which means that flammable gas may exist in all 177 tanks and special safety measures will be taken during maintenance, monitoring, and waste transfer activities (Hanlon, 1996; U.S. Department of Energy, 1996a). Final resolution of how many tanks present a risk due to flammable gas has not occurred.

4.1.2 Organics Safety Issue

A variety of organic compounds were used at the Hanford site during fuel reprocessing, metal recovery operations, and waste management operations. The principal sources for the majority of the organics were the solvent extraction processes that were used to recover Pu and U, which include Uranium Recovery, PUREX, and REDOX processes, and the waste management operations which involved removal of Cs-137 and Sr-90 from the wastes to improve the safety of radioactive waste storage. The major organics added to the tanks as a result of these operations include the solvent tributyl phosphate (TBP, 30 vol%) in a normal paraffin hydrocarbon (NPH) diluent, the radiolytic degradation products of TBP [dibutyl phosphate (DBP) and butanol], di-2-ethylhexyl phosphoric acid (D2EHPA), sodium ethylenediaminetetra-acetate (EDTA), sodium hydroxyethylenediaminetriacetate (HEDTA), glycolate, sodium citrate, sodium tartrate, and sodium hydroxyacetate. Estimated quantities of organic chemicals used at Hanford are listed in table 4-2.

In addition to the organics, wastes contain large amounts of sodium nitrate and nitrite, with the nitrite arising principally from radiolysis of nitrate. Since these organic-bearing wastes are mixtures of organic fuels, strong inorganic oxidants, and heat-producing radionuclides, the potential exists for rapid

[4] Wodrich, D. 1997. U.S. Department of Energy. Personal communication, January 14, 1997.

Table 4-2. Organic chemicals used at Hanford (Turner et al., 1995)

Process or Operation	Organic Chemical	Amounts Purchased or Used (times 1000)[1]
PUREX/B Plant	NPH/TBP[2]	140 kg (308 lb)
B Plant	TBP-NPH-D2EHPA	0.06 cubic meters (12.7 gal)
Z Plant	TBP-DBBP bottoms that contained some carbon tetrachloride	1.8 cubic meters (400 gal)
B Plant (strontium and cesium recovery)	Glycolic acid	694 kg (1,530 lb)
B Plant (strontium and cesium recovery)	Citric acid	633 kg (1,396 lb)
B Plant (strontium and cesium recovery)	HEDTA	745 kg (1,642 lb)
B Plant (strontium and cesium recovery)	EDTA	166 kg (366 lb)
N Reactor, T Plant	Turco[3] brand detergents	Unknown
PUREX, B Plant	Ion-exchange resins	Unknown

1 Quantities derived from Klem (1990) and Gerber (1992a).
2 These solvents degrade to alkali-soluble materials under tank conditions (Camaioni et al., 1994).
3 Turco (a trademark of Turco Products, Inc.) detergents, which are estimated to contain 5-10 wt% TOC, were used in decontamination procedures.

D2EHPA = Di-2-Ethylhexyl phosphoric acid
DBBP = Dibutyl-butyl phosphonate
EDTA = Ethylenediaminetetra-acetic acid
HEDTA = Hydroxyethylene(ethylenediamine)triacetic acid
NPH = Normal paraffin hydrocarbons
PUREX = Plutonium-Uranium Extraction
TBP = Tributyl phosphate

energetic reactions that could result in radioactive release to the environment. Such a reaction resulted in a major explosion in a radioactive waste tank in Kyshtym, Russia, in 1957 (Medvedev, 1979) resulting in radiation contamination of an estimated 23,000 sq km. The Kyshtym explosion occurred when the tank cooling system failed and the radioactive decay heat raised the temperature of a sodium acetate-sodium nitrate radioactive waste mixture to the point at which a thermal-runaway reaction occurred between acetate and nitrate. The organic chemical safety issue associated with the Hanford site is the possibility of exothermic reactions occurring due to the presence of heated organic waste components mixed with oxidizing salts (e.g., sodium nitrite and sodium nitrate) under conditions of low moisture.

Based on reviews of waste transfer records (Babad and Turner, 1993) and available sampling data (Webb et al., 1995), 36 tanks were considered to possibly contain greater than 3 wt% TOC on a dry-weight basis (or 480 J/g of exothermic energy), which is the minimum fuel concentration considered necessary to support a propagating reaction based on empirical data (Fisher, 1990). Those tanks had controls put in place to prevent propagating reactions (Westinghouse Hanford Company, 1995) and were placed under the scope of the DOE Data Quality Objectives[5] (DQO) to Support Resolution of the Organic Complexant Safety Issue (Turner et al., 1995). The tanks were evaluated using criteria described in the DQO to determine whether: (i) the wastes have enough fuel to support a propagating reaction when dried, (ii) enough moisture is present in the wastes to prevent a propagating reaction, and (iii) the wastes have the potential to dry during interim storage. Of the 36 tanks, only 20 are still in a recent (July 31, 1996) High Organic Watch-list (Hanlon, 1996). These tanks are listed in table 4-1.

The temperature of the waste in these tanks is either monitored continuously or measured manually on a weekly basis. The tanks are also checked for the presence of entrained or floating organic layers that might pose a risk from a slow pooled or wicked fuel burn. Studies are also under way to gain a better understanding of high organic safety issues. Current characterization efforts are focused on testing tank waste samples to confirm that the current safe storage criteria (i.e., fuel energy value, TOC, moisture content) for tank wastes are conservative for actual waste (U.S. Department of Energy, 1996c). Waste from selected tanks will be tested for reaction propagation using an adiabatic calorimeter.

4.1.3 Ferrocyanide Safety Issue

During the 1950s, additional tank storage space for high-level radioactive waste from defense operations was generated using precipitation processes for scavenging Cs and other soluble radionuclides from tank waste liquids. In the Cs-137 scavenging processes, waste solutions were adjusted to a pH between 8 and 10, and sodium or potassium ferrocyanide and nickel sulfate were added to coprecipitate Cs with the insoluble alkali-metal nickel ferrocyanide. Because the waste solutions had high nitrate and radiolytically produced nitrite concentrations, these ions became incorporated into the precipitates. After

[5] The DQO Process, defined by the EPA, is a series of planning steps to identify and design more efficient and timely data collection programs. It provides a systematic procedure for defining the criteria that a data collection design should satisfy, including when and where to collect samples, the tolerance level of decision errors for the study, and how many samples to collect. It is the policy of the DOE Office of Environmental Management (EM) to apply up-front planning, where practical, to ensure safer, better, faster, and cheaper environmental sampling and analysis programs for all EM projects and operations (memo from Thomas P. Grumbly, Assistant Secretary for Environmental Management, September 7, 1994). Specifically, it is EM policy that the DQO process be used in all environmental projects where there may be a need to collect significant environmental data. The EPA "Guidance for the Data Quality Objectives Process" (U.S. Environmental Protection Agency, 1994a,b) provides excellent guidance on the steps of the DQO process for developing data quality criteria and performance specifications for data operations.

allowing the radioactive precipitates to settle, the decontaminated solutions were pumped to disposal cribs, thereby providing additional tank storage volume. Later, some tanks were found to be leaking; pumpable liquids were removed from these tanks, leaving behind a wet solid (sludge) residue containing the ferrocyanide precipitates (Burger et al., 1991). In implementing the scavenging process, approximately 140 metric tons (154 tons) of ferrocyanide [calculated as $Fe(CN)_6^{4-}$] were added to waste that was later routed to 18 Hanford site SSTs.

The explosive nature of ferrocyanides in the presence of oxidizers has been known for decades, but the conditions under which impure mixtures of ferrocyanide, nitrate, and nitrite can undergo propagating reactions had not been thoroughly studied. The potential reactivity of these mixtures was first recognized at the Hanford site when the Cs-137 scavenging process using ferrocyanide was investigated for application to radioactive wastes produced by the next generation processing technology. The investigation found that cesium zinc ferrocyanide and nitrate exploded when heated (Hepworth et al., 1957). In the laboratory, mixtures of ferrocyanide and oxidants, such as nitrates and nitrites, have been shown to undergo energetic reactions when heated to high temperatures (above 250 °C) or exposed to an electrical spark of sufficient energy to heat the mixture (Cady, 1993; Epstein et al., 1994). Because the scavenging process precipitated ferrocyanide from solutions containing nitrate and nitrite, an intimate mixture of ferrocyanides and nitrates and/or nitrites is likely to exist in some regions of the ferrocyanide tanks. Despite the fact that the measured temperatures in the Hanford waste tanks continue to drop, there has been speculation as to the possibility of "hot spots" forming in the tanks from radiolytic heating.

Efforts have been under way since the mid-1980s to evaluate the potential for ferrocyanide reactions in Hanford site SSTs (Burger, 1984; Burger and Scheele, 1990; Meacham et al., 1995). The 1987 EIS (U.S. Department of Energy, 1987) included an environmental impact analysis of potential explosions involving ferrocyanide-nitrate mixtures. The EIS postulated that an explosion could occur during mechanical retrieval of saltcake or sludge from a ferrocyanide waste tank. The EIS concluded that this worst-case accident could create enough energy to release radioactive material to the atmosphere through ventilation openings, exposing persons offsite to a short-term radiation dose of approximately 200 mrem. A General Accounting Office study (Peach, 1990) postulated a greater worst-case accident, with independently calculated doses of one to two orders of magnitude greater than postulated in the DOE EIS.

Three different flowsheets (and variations of them) were used in ferrocyanide waste scavenging campaigns. Approximately 66 percent of the total ferrocyanide used at the Hanford site was used in the U-Plant flowsheet, which treated "metal waste" dissolved in nitric acid after the U had been recovered using the tributyl phosphate process. Simulant sludge produced by this flowsheet contained approximately 8.3 wt% sodium nickel ferrocyanide on a dry basis. The T-Plant flowsheet, used to treat first-cycle waste from the BP process, consumed approximately 8 percent of the ferrocyanide used at the Hanford site, and simulant sludge produced by this flowsheet contained 8.8 wt% sodium nickel ferrocyanide. The In-farm flowsheet, which treated the basic waste from recovery of U, consumed approximately 26 percent of the ferrocyanide used at Hanford and produced sludge containing up to 25.8 percent sodium nickel ferrocyanide (Postma and Dickinson, 1995). A more detailed review of ferrocyanide waste production is presented by Postma et al. (1994) and by Jeppson and Wong (1993).

Reviews of process flowsheets and waste transfer records (Borsheim and Simpson, 1991) indicated that eighteen tanks received ferrocyanide waste. These tanks were placed under the scope of the DQO on Ferrocyanide Safety Issue (Meacham et al., 1995) for further evaluation using criteria described in the DQO. The Ferrocyanide Safety Program was implemented in 1990 to address this safety issue

(Bryan et al., 1995) and comprised four major components. The first, tank monitoring, involves developing, deploying, and maintaining instrumentation for continuous monitoring of the tank contents. Specifically, waste temperatures in the tanks are being monitored continuously to detect increasing temperature trends. The second program component, modeling and analyzing existing tank data, allows predictive calculations of, for example, the existence of hot spots within the waste or concentrations of gases within the tank dome space. Ferrocyanide waste characterization using waste simulants and actual tank samples is the third program component and focuses on the chemical analysis (e.g., fuel, moisture, and nickel concentrations) of gas space, surface samples, and core samples from the ferrocyanide tanks. The fourth component is research and development designed to provide an understanding of potentially hazardous reactions of precipitated ferrocyanides and their aging products within the SST ferrocyanide waste.

Four of the 18 tanks that received ferrocyanide waste (tanks C-108, C-109, C-111, and C-112) were classified as safe based on criteria described in the DQO on Ferrocyanide Safety Issue and were removed from the Ferrocyanide Watch-list in June 1996 (Hanlon, 1996). As of July 31, 1996, fourteen tanks remained on the Ferrocyanide Watch-list (Hanlon, 1996) and are listed in table 4-1. These tanks contain >8 wt% sodium nickel ferrocyanide on an energy equivalent basis but meet conditionally safe criteria established in the DQO which preclude sustainable, rapid exothermic ferrocyanide reactions (Hanlon, 1996, table A-2 footnote). However, because the ferrocyanide sludge has been exposed for many years to other highly caustic wastes, as well as to elevated temperatures and both gamma and beta radiation, DOE investigators believe that ferrocyanide decomposition may have occurred in the tanks which would lead to ferrocyanide concentrations much less than that predicted by tank inventory records. Tank waste samples that have been analyzed to date support the conclusion that ferrocyanide decomposition has occurred and that the sludge in the Ferrocyanide Watch-list tanks is too dilute to support a sustained reaction, even if dried out and ignited (Postma and Dickinson, 1995). This conclusion has recently been accepted by the DOE.[6] All tanks have been removed from the Ferrocyanide Watch-list and the Ferrocyanide Safety Issue was officially closed as of October 1996.

4.1.4 High-Heat Safety Issue

Radioactive decay of stored waste can result in elevated temperatures of Hanford tanks. If waste tank structural damage occurs due to overheating of the waste tank concrete structure, release of high-level nuclear waste may occur. According to Hanlon (1996), 10 SSTs have high-heat loads [>42,000 kJ/h (>40,000 Btu/h)] namely: A-104, A-105, C-106, SX-107, SX-108, SX-109, SX-110, SX-111, SX-112, and SX-114. All of these tanks are on active ventilation except for A-104 and A-105. However, tank C-106 requires more than active ventilation to keep the temperature below 150 °C (300 °F), which is the maximum temperature limit established in the DOE Operating Safety Document (Wodrich, 1992). The rate of heat generation in tank C-106 is estimated at more than 105,000 kJ/h (100,000 Btu/h) and arises primarily from radioactive decay of Sr-90 waste that was transferred into the SST in the late 1960s. For this tank, water is periodically added to maintain a liquid cover (supernate) over the liquid sludge for enhanced thermal conductivity and evaporative cooling (DeFigh-Price and Wang, 1993). The amount of cooling liquid currently maintained in tank C-106 exceeds the interstitial holdup of the tank sludge; the excess cooling liquid is a primary concern because it could release radionuclides to the surrounding soil and groundwater if a tank leak develops. Because of high-heat concerns, tank C-106 was placed on the High-Heat Watch-list. Although the method of active ventilation

[6] Kinzer, J. 1996. U.S. Department of Energy. Reported in Tri-City Herald, October 31, 1996.

supplemented by water addition is effective for the short term, the long-term resolution for tank cooling is removal of the heat-generating waste in the tank. This solution is being pursued as the only remediation method for this safety issue, and tank C-106 has been selected as the first SST for retrieval and transfer of radioactive waste to a selected DST. Sluicing of tank C-106 is scheduled to begin in 1997.

4.2 OTHER HAZARDS

4.2.1 Crust Burn Issue Associated with Flammable Gas Tanks

In addition to the potential for ignition of flammable gases such as hydrogen/air and/or hydrogen/nitrous oxide, as discussed in section 4.1.1, another scenario of significant concern associated with the tank wastes is the potential for secondary ignition of organic-nitrate/nitrite mixtures in the crust layer initiated by the burning of flammable gases or by a mechanical in-tank energy source. This scenario has been called a "crust burn" issue. Crust heating by a burning gas or by mechanical energy (e.g., from friction during core sampling) could initiate an exothermic reaction between organic carbon and the nitrate or nitrite compounds. If the crust material gets too hot, volatile components could be released into the atmosphere as aerosols which could entrain and release radionuclides to the environment.

The crust burn problem was first evaluated for tank SY-101 based on visual observations of the waste surface with a television camera, chemical analyses of crust samples, and calorimetry tests of waste samples. Results of crust analyses and analytical modeling of crust heating were used to show that a "crust burn" was not a safety issue for tank SY-101 (Fox et al., 1992). Sampling activities have been scheduled for other tanks on the Flammable Gas Watch-list (Johnson, 1994). Primary data needed to determine the potential for a crust burn of the waste material are derived from calorimetry tests, including differential scanning calorimetry (DSC) which involves heating small samples at a programmed rate, by measuring differential temperatures between the sample and a reference chamber. The heat flow into or out of the sample is used to determine (i) whether an exothermic reaction exists, (ii) the temperatures required for it to occur, and (iii) the net amount of heat produced. A relatively recent characterization report by Baldwin et al. (1995) concluded that DSC measurements on crust samples from tank AW-101 show exotherms in nearly every subsample, but none of the observed exotherms exceeded the 586 J/g threshold set forth in the DQO on the crust burn issue (Johnson, 1994).

4.2.2 High-Efficiency Particulate Air Filter Blow-Out Issue Associated with Flammable Gas Tanks

Another scenario associated with the presence of flammable gas mixtures in waste tanks that needs to be addressed is that of a pressure pulse which can occur even without ignition of the gas (e.g., sudden release of gas accumulated in the waste). The HEPA filters on the tanks have an operating limit of +2.5 kPa (+10 in. of water) (McDuffie, 1995). If the gas pressure exceeds this value the filter seal could be breached and there would be an open pathway for release of radionuclides to the environment. Studies are under way to better understand mechanisms of gas accumulation and release in tank wastes. Plume burn analyses are also ongoing to determine the size of flammable gas release which can burst a HEPA filter upon ignition (McDuffie, 1995).

4.2.3 Organic Solvent Safety Issue

Various separation processes employed at the Hanford site involved the use of organic solvents which were inadvertently and/or purposely sent to the waste tanks. Subsequent waste transfer operations also distributed organic solvents among several of the Hanford tanks. The potential hazards associated with organic solvents are (i) contributing to headspace flammability (as discussed in section 4.1.1), (ii) igniting an organic solvent pool, and (iii) igniting an organic solvent that is entrained in waste solids.

Currently, one tank (C-103) is known to contain an organic solvent pool. Current characterization efforts include continued vapor sampling of the tank headspace to identify additional tanks that may contain an organic solvent pool or entrained organic solvent. If vapor sampling suggests the presence of organic solvent, liquid grab samples and/or near-surface samples will be obtained to better quantify the potential for an organic solvent fire.

4.2.4 Known and Assumed Leaking Tanks

Liquid waste from past tank leaks has resulted in vadose zone contamination beneath the leaking tanks and may be adversely affecting the groundwater in the vicinity of the tanks. As mentioned in section 2, potential groundwater impacts are currently being investigated as part of the RCRA Groundwater Assessments for the T Farm Waste Management Area and will be ongoing soon for the S-SX and B-BX-BY Waste Management Areas (U.S. Department of Energy, 1996d).

Leak monitoring is ongoing for the 177 waste tanks, and reports on waste inventory and surveillance are released monthly and quarterly. The report for the month ending July 31, 1996 (Hanlon, 1996) indicated that 67 of the 149 SSTs are assumed leakers. There are no reported leaks from the 28 DSTs. Table 4-3 provides a list of tank identification number, date at which the tank was declared a leaker, estimated leak volume, estimated activity of leak, and date the tank was interim stabilized. The leak volume ranges from approximately 1,300 L (350 gal.) from tank C-204 in the 200-East Area to 436,000 L (115,000 gal.) from tank T-106 in the 200-West Area. Estimates of total leak volume from all 67 assumed leakers range from 2.30E+06 to 3.4E+06 L (600,000 to 900,000 gal.). To minimize further releases to the environment, the DOE removed all SSTs from service in 1980 and initiated a program to transfer all pumpable liquid into DSTs and stabilize the SST tank wastes until final disposition. This effort, known as interim stabilization, is currently ongoing. Interim stabilization has been completed on all but five assumed leaking tanks. All SSTs (including nonleaking) are expected to be interim stabilized by the year 2000 (U.S. Department of Energy, 1996d).

4.2.5 Criticality

4.2.5.1 Known Criticality Hazards

In the DOE Final TWRS EIS, it is stated that:

> "Of the actions evaluated in the Final Safe Interim Storage EIS, only the retrieval of solids from tank SY-102 was affected by the technical uncertainties regarding criticality." (U.S. Department of Energy, 1996c; p. E-12).

As a result, the DOE has suspended retrieval of wastes from this tank, possibly for transfer into a DST, pending the outcome of a criticality safety evaluation process outlined for the Defense Nuclear Facility

Table 4-3. Tank Waste Remediation System tanks that are assumed to be leaking

Tank Number	Date Declared Confirmed or Assumed Leaker[1]	Volume[2,3] (gallons)	Associated Kilocuries Cs-137[4]	Interim Stabilized Date[5]
A-103	1987	5,500[6]	---	6/88
A-104	1975	500 to 2,500	0.8 to 1.8	9/78
A-105	1963	10,000 to 277,000	85 to 760	7/79
AX-102	1988	3,000[6]	---	9/88
AX-104	1977	---[7]	---	8/81
B-101	1974	---[7]	---	3/81
B-103	1978	---[7]	---	2/85
B-105	1978	---[7]	---	12/84
B-107	1980	8,000[6]	---	3/85
B-110	1981	10,000[6]	---	3/85
B-111	1978	---[7]	---	6/85
B-112	1978	2,000	---	5/85
B-201	1980	1,200[6]	---	8/81
B-203	1983	300[6]	---	6/84
B-204	1984	400[6]	---	6/84
BX-101	1972	---[7]	---	9/78
BX-102	1971	70,000	50	11/78
BX-108	1974	2,500	0.5	7/79
BX-110	1976	---[7]	---	8/85
BX-111	1984	---[7]	---	3/95[8]
BY-103	1973	<5,000	---	N/A
BY-105	1984	---[7]	---	N/A
BY-106	1984	---[7]	---	N/A
BY-107	1984	15,100[6]	---	7/79
BY-108	1972	<5,000	---	2/85
C-101	1980	20,000[6]	---	11/83
C-110	1984	2,000	---	5/95
C-111	1968	5,500	---	3/84

Table 4-3. Tank Waste Remediation System tanks that are assumed to be leaking (cont'd)

Tank Number	Date Declared Confirmed or Assumed Leaker[1]	Volume[2,3] (gallons)	Associated Kilocuries Cs-137[4]	Interim Stabilized Date[5]
C-201	1988	550	---	3/82
C-202	1988	450	---	8/81
C-203	1984	15,100[6]	---	3/82
C-204	1988	350	---	9/82
S-104	1968	24,000[6]	---	12/84
SX-104	1988	6,000[7]	---	N/A
SX-107	1964	<5,000	---	10/79
SX-108	1962	2,400 to 35,000	17 to 140	8/79
SX-109	1965	<10,000	<40	5/81
SX-110	1976	5,500[7]	---	8/79
SX-111	1974	500 to 2,000	0.6 to 2.4	7/79
SX-112	1969	30,000	40	7/79
SX-113	1962	15,000	8	11/78
SX-114	1972	---[7]	---	7/79
SX-115	1965	50,000	21	9/78
T-101	1992	7,500[6]	---	4/93
T-103	1974	<1,000[6]	---	11/83
T-106	1973	115,000[6]	40	8/81
T-107	1984	---[7]	---	N/A
T-108	1974	<1,000[6]	---	11/78
T-109	1974	<1,000[6]	---	12/84
T-111	1979,1994[9]	<1,000[6]	---	2/95
TX-105	1977	---[7]	---	4/83
TX-107	1984	2,500	---	10/79
TX-110	1977	---[7]	---	4/83
TX-113	1974	---[7]	---	4/83
TX-114	1974	---[7]	---	4/83
TX-115	1977	---[7]	---	9/83

Table 4-3. Tank Waste Remediation System tanks that are assumed to be leaking (cont'd)

Tank Number	Date Declared Confirmed or Assumed Leaker[1]	Volume[2,3] (gallons)	Associated Kilocuries Cs-137[4]	Interim Stabilized Date[5]
TX-116	1977	---[7]	---	4/83
TX-117	1977	---[7]	---	3/83
TY-101	1973	<1,000[6]	---	4/83
TY-103	1973	3,000	0.7	2/83
TY-104	1981	1,400[6]	---	11/83
TY-105	1960	35,000	4	2/83
TY-106	1959	20,000	2	11/78
U-101	1959	30,000	20	9/79
U-104	1961	55,000	0.09	10/78
U-110	1975	5,000 to 8,100[6]	0.05	12/84
U-112	1980	8,500[6]	---	9/79
Total of 67 tanks		Total volume of 600,000-900,000[10]		

Notes:

Source: Hanlon, 1996
- = No data provided
N/A = Not applicable (not yet interim stabilized)
[1]In many cases, a leak was suspected long before it was identified or confirmed. For example, tank U-104 was suspected of leaking in 1956. The leak was confirmed in 1961. This report lists the assumed leaker date as 1961. Using present standards, tank U-104 would have been declared as assumed leaker in 1956. In 1984, the criteria designations of "suspected leaker," "questionable integrity," "confirmed leaker," "declared leaker," "borderline," and "dormant" were merged into one category now reported as "assumed leaker." It is highly likely that there have been undetected leaks from SSTs because of the nature of their design and instrumentation.
[2]One gallon is equal to 3.788 L.
[3]These leak volume estimates do not include (with some exceptions) such things as (1) cooling/raw water leaks; (2) intrusions (rain infiltration) and subsequent leaks; (3) leaks inside the tank farm but not through the tank liner (surface leaks, pipeline leaks, leaks at the joint for the overflow or fill lines, etc.); and (4) leaks from catch tanks, diversion boxes, encasements, etc.
[4]The curie content list is not decayed to a consistent date; therefore, a cumulative total is inappropriate.
[5]These dates indicate when the tanks were declared to be interim stabilized. In some cases, the official interim stabilization documents were issued at a later date. Also, in some cases, the field work associated with interim stabilization was completed at an earlier date.
[6]Leak volume estimate is based solely on observed liquid level decreases in these tanks. This is considered to be the most accurate method for estimating leak volumes.
[7]The total leak volume estimate for these tanks is 570,000 L (150,000 gal.) [rounded to the nearest 38,000 L (10,000 gal.)], for an average of approximately 30,400 L (8,000 gal.) for each of the 19 tanks.
[8]Tank BX-111 was declared an assumed re-leaker in April 1993. Preparations for pumping were delayed, following an administrative hold placed on all tank farm operations in August 1993. Pumping resumed and the tank was declared interim stabilized on March 15, 1995.
[9]Tank T-111 was declared an assumed re-leaker on February 28, 1994, due to a decreasing trend in surface level measurement. This tank was pumped and interim stabilized on February 22, 1995.
[10]The total has been rounded to the nearest 190,000 L (50,000 gal.). Upperbound values were used in many cases in developing these estimates. It is likely that some of these tanks have not actually leaked.

Safety Board. Based on these statements, it could be assumed that the only significant risk of criticality known at this time is from retrieval of wastes from tank SY-102.

In order to determine if the statements made in the preceding paragraph accurately depict the criticality potential of other Hanford TWRS tank wastes relative to tank SY-102, a survey was performed to obtain information about the fissile nuclide content and criticality potential of other tanks. A report by Perry et al. (1994) contains information about the Pu-239 content and criticality potential of tank SY-101, a tank that one might expect to also have nontrivial criticality concerns. In this report, the authors used core sample data and the S_N[7] code ONEDANT to calculate the k_∞[8] corresponding to the Pu concentrations in sedimentary layers of this tank. They found that these layers have a k_∞ of about 0.012 percent and that an increase in the Pu-239 concentration by a factor of about 16,000 is necessary before the sediments would approach criticality. The analyses seem credible considering that the total tank inventory of Pu-239 in this tank was estimated to be 910 g (Perry et al., 1994) and the minimum critical masses of Pu-239 are 9,800 g for pure Pu metal, 900 g for Pu metal and light-water-moderated bare spherical reactor, and 320 g for a light-water-moderated and reflected spherical reactor (Knief, 1992).

Since the publication of Perry et al. (1994), additional information about the contents of the tanks has become available (Agnew, 1996). The Agnew (1996) report estimates the total inventory of Pu-239 in tank SY-101 to be about 3,580 g and the total inventory of U-235 to be about 89,500 g, implying that the major criticality concern with the tank wastes in SY-101 may be the U-235 concentration and not the Pu-239 concentration.

To determine if there is a risk of a U-based criticality in the tanks, the tanks were ranked based on the fissile enrichment of the U which they contain and it was found that tank AW-104 contains U with the highest enrichment at 0.866 percent. Calculations were performed using the MCNP Version 4A code. The results indicated that even with optimal moderation in a pure U-light water system, k_∞ is only 0.94 for this system with U at an enrichment of 0.866 percent. This value of k_∞ implies that U at the assumed enrichment would have a net poisoning effect on a critical system and that a U-based criticality is not possible.

As a result of these findings, the tanks in the Hanford TWRS were ranked based on their total Pu fissile nuclide content (Pu-239 plus Pu-241) in grams using data from Agnew (1996). The results of this rank ordering and the total fissile Pu content of each tank are shown in table 4-4a. Table 4-4b lists the same information with the tanks grouped by tank farm. It is noted that tank SY-102 is high on the list presented in table 4-4a but is not the highest ranking tank, implying that the waste in tank SY-102 may not pose the greatest risk of a nuclear criticality of all tank wastes, as assumed in the beginning of this section.

Because Pu is the primary fissile element, it is recommended that future CNWRA and NRC detailed investigations into criticality safety of the TWRS focus on retrieval and subsequent processing of wastes from tanks with high total fissile Pu nuclide contents, as well as on processes that could concentrate the fissile materials during waste processing such as chemical separation, evaporation, and settling.

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[7] S_N theory discretizes the Boltzman equation for neutron transport in solid angle as well as space to find the eigenvalue of the system (k_{eff}).

[8] k_∞ is the neutron multiplication factor for a material with infinite extent, that is, neutron leakage out of the system is zero.

Table 4-4a. A rank ordering of the tanks based on their fissile plutonium content

Tank	Fissile Pu Content (g)	Tank	Fissile Pu Content (g)	Tank	Fissile Pu Content (g)
TX-118	7.10E+04	SX-114	4.44E+03	BY-102	1.82E+03
C-102	5.98E+04	U-109	4.33E+03	AP-102	1.74E+03
SY-102	4.54E+04	SX-107	4.22E+03	SX-106	1.74E+03
C-104	3.94E+04	AN-103	4.01E+03	T-110	1.69E+03
AZ-102	3.56E+04	TX-101	3.93E+03	C-109	1.70E+03
S-107	2.89E+04	SX-105	3.88E+03	TX-116	1.64E+03
AY-101	2.82E+04	SX-102	3.78E+03	BY-112	1.64E+03
AZ-101	2.55E+04	C-103	3.78E+03	B-110	1.60E+03
A-106	2.41E+04	SX-112	3.77E+03	C-111	1.57E+03
AW-103	2.37E+04	BY-103	3.75E+03	TX-113	1.55E+03
C-107	2.27E+04	SX-109	3.74E+03	S-108	1.53E+03
C-106	1.86E+04	SX-108	3.74E+03	U-105	1.51E+03
AW-105	1.88E+04	BX-101	3.73E+03	U-103	1.51E+03
AW-104	1.55E+04	BY-106	3.17E+03	B-104	1.42E+03
AW-101	1.42E+04	AN-107	3.16E+03	T-106	1.41E+03
C-105	1.29E+04	SX-110	3.14E+03	TX-112	1.40E+03
B-101	1.33E+04	A-101	3.05E+03	TX-117	1.36E+03
T-101	1.17E+04	A-105	2.99E+03	BY-110	1.37E+03
U-108	1.04E+04	AN-104	2.93E+03	BX-103	1.34E+03
U-107	8.88E+03	SX-103	2.85E+03	TX-105	1.27E+03
AY-102	8.79E+03	T-103	2.82E+03	TX-114	1.27E+03
AX-102	7.38E+03	T-102	2.82E+03	U-102	1.19E+03
C-101	7.01E+03	S-109	2.70E+03	TX-115	1.19E+03
S-101	6.77E+03	AP-105	2.69E+03	U-111	1.16E+03
S-104	6.45E+03	A-102	2.58E+03	BX-111	1.15E+03
AX-101	6.23E+03	BY-111	2.51E+03	S-103	1.12E+03
S-110	5.93E+03	SY-103	2.48E+03	T-104	1.09E+03
SX-101	5.58E+03	AW-106	2.48E+03	AP-106	1.12E+03
SX-111	5.30E+03	B-109	2.43E+03	AX-104	1.10E+03
B-111	5.13E+03	BY-109	2.24E+03	A-103	1.07E+03
AN-105	5.12E+03	T-111	2.01E+03	BY-104	1.05E+03
SX-104	4.97E+03	BY-101	2.04E+03	S-105	1.02E+03
SY-101	4.93E+03	C-112	2.02E+03	BY-107	9.65E+02
AN-102	4.90E+03	BY-105	1.99E+03	TX-110	9.61E+02
S-111	4.71E+03	AW-102	1.98E+03	TX-109	9.42E+02
S-106	4.48E+03	S-112	1.87E+03	U-106	9.62E+02

Table 4-4a. A rank ordering of the tanks based on their fissile plutonium content (cont'd)

Tank	Fissile Pu Content (g)	Tank	Fissile Pu Content (g)
S-102	9.13E+02	BX-104	1.84E+02
TX-111	8.76E+02	T-107	1.78E+02
U-112	8.54E+02	TY-102	1.78E+02
TY-101	8.42E+02	U-110	1.73E+02
TX-106	8.45E+02	BX-106	1.76E+02
AN-101	8.37E+02	B-107	1.70E+02
BX-102	8.31E+02	B-103	1.69E+02
BX-107	6.80E+02	TX-103	1.67E+02
BX-110	6.44E+02	B-112	1.64E+02
BX-112	5.57E+02	BX-109	1.45E+02
TY-103	5.27E+02	U-104	1.34E+02
B-105	5.03E+02	T-108	1.10E+02
TX-102	5.01E+02	TX-104	1.10E+02
T-105	4.08E+02	TY-105	6.36E+01
U-202	4.08E+02	SX-113	5.98E+01
U-201	4.07E+02	BX-108	5.87E+01
BY-108	4.01E+02	AN-106	4.71E+01
B-106	3.50E+02	C-108	3.83E+01
T-112	2.99E+02	BX-105	2.33E+01
AP-103	3.09E+02	TX-107	1.36E+01
TY-104	2.79E+02	U-101	4.52E+00
AP-108	2.75E+02	AX-103	1.25E+02
A-104	2.62E+02	B-203	1.37E+00
AP-101	2.50E+02	B-204	1.34E+00
B-102	2.40E+02	T-204	1.04E+00
C-201	2.39E+02	T-203	9.56E-01
C-202	2.39E+02	B-201	7.65E-01
C-203	2.39E+02	T-201	7.65E-01
C-204	2.39E+02	B-202	7.39E-01
T-109	2.22E+02	T-202	5.74E-01
B-108	2.15E+02	TY-106	1.70E-01
SX-115	2.08E+02	AP-104	0.00E+00
U-203	2.06E+02	AP-107	0.00E+00
TX-108	2.06E+02		
U-204	2.04E+02		
C-110	1.95E+02		

Table 4-4b. The plutonium content of the tanks grouped by tank farm

Tank	Fissile Pu Content (g)	Tank	Fissile Pu Content (g)	Tank	Fissile Pu Content (g)
241-A-101	3.05E+03	241-B-102	2.40E+02	241-BY-110	1.37E+03
241-A-102	2.58E+03	241-B-103	1.69E+02	241-BY-111	2.51E+03
241-A-103	1.07E+03	241-B-104	1.42E+03	241-BY-112	1.64E+03
241-A-104	2.62E+02	241-B-105	5.03E+02	241-C-101	7.01E+03
241-A-105	2.99E+03	241-B-106	3.50E+02	241-C-102	5.98E+04
241-A-106	2.41E+04	241-B-107	1.70E+02	241-C-103	3.78E+03
241-AN-101	8.37E+02	241-B-108	2.15E+02	241-C-104	3.94E+04
241-AN-102	4.90E+03	241-B-109	2.43E+03	241-C-105	1.29E+04
241-AN-103	4.01E+03	241-B-110	1.60E+03	241-C-106	1.86E+04
241-AN-104	2.93E+03	241-B-111	5.13E+03	241-C-107	2.27E+04
241-AN-105	5.12E+03	241-B-112	1.64E+02	241-C-108	3.83E+01
241-AN-106	4.71E+01	241-B-201	7.65E-01	241-C-109	1.70E+03
241-AN-107	3.16E+03	241-B-202	7.39E-01	241-C-110	1.95E+02
241-AP-101	2.50E+02	241-B-203	1.37E+00	241-C-111	1.57E+03
241-AP-102	1.74E+03	241-B-204	1.34E+00	241-C-112	2.02E+03
241-AP-103	3.09E+02	241-BX-101	3.73E+03	241-C-201	2.39E+02
241-AP-104	0.00E+00	241-BX-102	8.31E+02	241-C-202	2.39E+02
241-AP-105	2.69E+03	241-BX-103	1.34E+03	241-C-203	2.39E+02
241-AP-106	1.12E+03	241-BX-104	1.84E+02	241-C-204	2.39E+02
241-AP-107	0.00E+00	241-BX-105	2.33E+01	241-S-101	6.77E+03
241-AP-108	2.75E+02	241-BX-106	1.76E+02	241-S-102	9.13E+02
241-AW-101	1.42E+04	241-BX-107	6.80E+02	241-S-103	1.12E+03
241-AW-102	1.98E+03	241-BX-108	5.87E+01	241-S-104	6.45E+03
241-AW-103	2.37E+04	241-BX-109	1.45E+02	241-S-105	1.02E+03
241-AW-104	1.55E+04	241-BX-110	6.44E+02	241-S-106	4.48E+03
241-AW-105	1.88E+04	241-BX-111	1.15E+03	241-S-107	2.89E+04
241-AW-106	2.48E+03	241-BX-112	5.57E+02	241-S-108	1.53E+03
241-AX-101	6.23E+03	241-BY-101	2.04E+03	241-S-109	2.70E+03
241-AX-102	7.38E+03	241-BY-102	1.82E+03	241-S-110	5.93E+03
241-AX-103	1.25E+02	241-BY-103	3.75E+03	241-S-111	4.71E+03
241-AX-104	1.10E+03	241-BY-104	1.05E+03	241-S-112	1.87E+03
241-AY-101	2.82E+04	241-BY-105	1.99E+03	241-SX-101	5.58E+03
241-AY-102	8.79E+03	241-BY-106	3.17E+03	241-SX-102	3.78E+03
241-AZ-101	2.55E+04	241-BY-107	9.65E+02	241-SX-103	2.85E+03
241-AZ-102	3.56E+04	241-BY-108	4.01E+02	241-SX-104	4.97E+03
241-B-101	1.33E+04	241-BY-109	2.24E+03	241-SX-105	3.88E+03

Table 4-4b. The plutonium content of the tanks grouped by tank farm (cont'd)

Tank	Fissile Pu Content (g)	Tank	Fissile Pu Content (g)
241-SX-106	1.74E+03	241-TX-108	2.06E+02
241-SX-107	4.22E+03	241-TX-109	9.42E+02
241-SX-108	3.74E+03	241-TX-110	9.61E+02
241-SX-109	3.74E+03	241-TX-111	8.76E+02
241-SX-110	3.14E+03	241-TX-112	1.40E+03
241-SX-111	5.30E+03	241-TX-113	1.55E+03
241-SX-112	3.77E+03	241-TX-114	1.27E+03
241-SX-113	5.98E+01	241-TX-115	1.19E+03
241-SX-114	4.44E+03	241-TX-116	1.64E+03
241-SX-115	2.08E+02	241-TX-117	1.36E+03
241-SY-101	4.93E+03	241-TX-118	7.10E+04
241-SY-102	4.54E+04	241-TY-101	8.42E+02
241-SY-103	2.48E+03	241-TY-102	1.78E+02
241-T-101	1.17E+04	241-TY-103	5.27E+02
241-T-102	2.82E+03	241-TY-104	2.79E+02
241-T-103	2.82E+03	241-TY-105	6.36E+01
241-T-104	1.09E+03	241-TY-106	1.70E-01
241-T-105	4.08E+02	241-U-101	4.52E+00
241-T-106	1.41E+03	241-U-102	1.19E+03
241-T-107	1.78E+02	241-U-103	1.51E+03
241-T-108	1.10E+02	241-U-104	1.34E+02
241-T-109	2.22E+02	241-U-105	1.51E+03
241-T-110	1.69E+03	241-U-106	9.62E+02
241-T-111	2.01E+03	241-U-107	8.88E+03
241-T-112	2.99E+02	241-U-108	1.04E+04
241-T-201	7.65E-01	241-U-109	4.33E+03
241-T-202	5.74E-01	241-U-110	1.73E+02
241-T-203	9.56E-01	241-U-111	1.16E+03
241-T-204	1.04E+00	241-U-112	8.54E+02
241-TX-101	3.93E+03	241-U-201	4.07E+02
241-TX-102	5.01E+02	241-U-202	4.08E+02
241-TX-103	1.67E+02	241-U-203	2.06E+02
241-TX-104	1.10E+02	241-U-204	2.04E+02
241-TX-105	1.27E+03		
241-TX-106	8.45E+02		
241-TX-107	1.36E+01		

4.2.5.2 Potential Criticality Hazards

Ex situ vitrification of wastes currently being stored in tank SY-102 may present some hazard for accidental criticalities during the removal, transportation, and solidification of these wastes. Since the exact solidification process that would be used is not known at this time, possible criticality hazards of similar processes that have been or are occurring elsewhere have been reviewed. These reviews are described in the following paragraphs.

Processes with the potential to cause accidental criticalities in the Plasma Hearth Process (PHP) were evaluated (Slate and Santee, 1996). The PHP is a technique currently under development by Science Applications International Corporation (SAIC) for the DOE that destroys the organic component of the waste and vitrifies the inert fraction into glass or slag. Three stages of the process that were susceptible to accidental criticalities were found: (i) the concentration of Pu in the crucible as multiple waste streams are processed, (ii) the pouring of molten slag into a collection drum, and (iii) the arranging of cooled collection drums into matrices that allow for neutron communication between drums during transportation and storage. For example, the maximum safe weight limit of weapons grade Pu was found to be 27 kg for the four-drum (of DOT-17C specifications) arrangement. This was the most reactive arrangement of weapons grade Pu slag drums that was studied. Although the actual numerical limits found by the authors have little meaning to the Hanford TWRS, the three stages of the process that they found susceptible to criticality may represent potential processes that need to be studied in criticality safety analyses at the Hanford vitrification operation.

The potential for accidental criticalities at the defense waste processing facility at the Savannah River Site (SRS) was assessed by Ha et al. (1996). The subprocesses or mechanisms that the authors studied which may lead to criticality during vitrification are: (i) chemical reactions that concentrate U and Pu with respect to iron and manganese neutron absorbers, (ii) fissile material adsorbed onto monosodium titanate, (iii) fissile material entrained in the sludge solids, (iv) Pu solubility in mercury, (v) process cleaning procedures, and (vi) melter accumulation. The authors concluded that in all of the aforementioned subprocesses criticality had a negligible chance of occurring due mainly to the low fissile content of the wastes, the presence of neutron absorbers such as iron and magnesium, and the lack of an identifiable chemical process that can cause the concentration of fissile nuclides relative to the neutron absorbers. Although the authors found that the risk of criticality was insignificant for the SRS, similar subprocesses or mechanisms should be examined for their potential significance for the Hanford TWRS.

4.2.6 Lightning Strikes

The Hanford site has an average of 10 days per year during which thunderstorms occur. Based on measurements made worldwide of the relationship between thunderstorm days per year and the number of lightning strikes to the ground, one can expect, on average, about one flash to ground per square kilometer per year at Hanford (Cowley and Stepnewski, 1994). Although actual lightning strikes in the tank farms have not been documented, tank farm operations personnel have indicated that lightning strikes do occur within the tank farms. This observation gives credence to the estimate that strikes occur within the tank farms about once a year. Thus a lightning strike to either an underground storage tank or a piece of support equipment is a credible event.

Studies described in a report by Cowley and Stepnewski (1994) were conducted to evaluate whether or not lightning strikes are a credible accident initiator in Hanford site tank farms and if lightning strikes could result in any unique accidents that are not already addressed in existing safety guidelines

for the Hanford site tank farms [e.g., Interim Safety Basis (Leach and Stahl, 1993)]. The study included a survey of equipment that supports the underground storage tanks in order to identify potential consequences of a lightning strike on support equipment and to relate the consequences to existing controls. A walkdown of all of the tank farms was also performed to help identify equipment and structural configurations that could result in the release of radioactive material from lightning strikes. All types of accidents that might be initiated by a lightning strike on support equipment or facilities were analyzed. The studies concluded that lightning strikes on support equipment and facilities do not result in any new accidents, that is, accidents not already addressed in the Interim Safety Basis. Lightning strikes increase the probability of occurrence of some accidents, but the potential damage could be limited by better equipment grounding and bonding techniques and increased use of transient protection on signal and power wiring.

No significant problems resulting from lightning strikes on DSTs were found. The accident with the greatest potential consequence for DSTs, ignition of a flammable gas mixture, was shown to have a calculated probability of occurrence in the 10^{-6} range. The actual probability is probably less because the calculated probability does not account for the DST acting as a faraday cage. Because the DST would act as a faraday cage, not every lightning strike would result in a spark inside the tank. The accident with the greatest potential consequence for SSTs, ignition of a flammable gas mixture, has a calculated probability of occurrence of 1.9×10^{-5}. However, this probability does not give any credit for the effectiveness of grounding and bonding of equipment. If proper bonding and grounding of equipment inserted through risers were ensured, the probability of an external lightning strike causing a spark inside a tank could be reduced below the credible range. Increased ventilation to the tanks would also reduce the probability of an ignition in SSTs because the increased ventilation flow would ensure that gases released to the tank headspace would remain below the LFL.

4.3 POTENTIAL SAFETY CONCERNS ASSOCIATED WITH RETRIEVAL, MIXING, AND TRANSFER OF TANK WASTES

The retrieval and transfer of wastes stored in Hanford waste tanks will require an assessment of waste compatibility. This assessment may be particularly important in connection with future retrieval and transfer of wastes for pretreatment and solidification. The overall problem relates to the potential incompatibility of wastes that are either stored in, or will be received into, the Hanford site DST system, which could result in safety and operations problems. The DOE has formalized the process for assessing waste compatibility for transfers into and within the DST system in its *Tank Farm Waste Transfer Compatibility Program* (Fowler, 1995a), and data needs for assessing waste transfers are specified in the *Data Quality Objectives for Tank Farms Waste Compatibility Program* (Fowler, 1995b). The primary goal of these programs is to assure that safety and operations problems such as flammable gas accumulation, tank corrosion, or transfer line plugging do not result due to or during waste transfers in the DST system.

There are two main issues of importance to waste compatibility assessment: (i) safety problems may arise as a result of commingling wastes under interim storage, and (ii) continued operability may be jeopardized during waste transfer and waste concentration/minimization (i.e., plugged transfer or process lines, trapped flammable gas, exothermic reactions, corroded lines or DSTs, or thermally-stressed DSTs). Potential safety problems that need to be considered include:

- Criticality
- Flammable gas generation and accumulation

- Energetics[9]
- Corrosion and leakage
- Unwanted chemical reactions

Considerations of the above processes help determine whether wastes may be transferred, combined, and stored in DSTs without causing any safety problem.

Evaluation of criticality safety requires information on fissile material concentration (Pu equivalent[10]), and in some cases, volume percent of solids. An estimation of solids density may also be needed for comparison of criticality limits given in g/L with measurable quantities such as μCi/L or μg/g. Criticality control in the DSTs is achieved by conducting operations in compliance with criticality prevention specifications (CPS) (Vail, 1994) which limit the Pu equivalent concentration in each DST. The CPS limit the fissile mass available and require a large concentration factor before safety is jeopardized.

The generation of hydrogen or other flammable gas does not by itself pose a safety problem. Safety becomes a concern when flammable gases accumulate to a level above their LFL. Specific gravity is currently used by the DOE as an indicator for potential flammable gas accumulation based on data on the specific gravities for the six DSTs currently on the Flammable Gas Watch-list. Although a direct correlation between specific gravity and gas accumulation has not been established, an evaluation of the method indicated that specific gravity is an appropriate limiting factor for formation of flammable accumulations (Reynolds, 1994). Other methods of evaluating gas accumulation potential are being investigated (Fowler, 1995b).

The components necessary to oxidize fuel are generally present in tank waste and incoming waste streams. If the temperature increases enough to dry out the waste and initiate a chemical reaction ($\sim$200 °C), an in-tank reaction could occur. Data needs for evaluating energetics include identification of separable organic material and characterization of waste by DSC and thermo-gravimetric analysis (TGA) augmented, when necessary, by adiabatic calorimetry.

Waste compatibility assessment is also needed to minimize corrosion of steel components of the DSTs, transfer piping, and support facilities and reduce the possibility of leakage to the environment. DOE operating specification documents establish waste composition limits to keep corrosion rates below 1 mil per yr and to inhibit stress corrosion cracking (Fowler, 1995b). These limits are specified in Westinghouse Hanford Company (1994b) and Westinghouse Hanford Company (1994c). Data needs for determination of the possible occurrence of corrosion and leakage include pH, temperature, and

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[9] Energetics refers to the ability of a waste to sustain a self-propagating exothermic reaction. This is generally measured via thermal analysis (e.g., DSC and TGA) (Fowler, 1995b).

[10] For purposes of criticality control, one gram of Pu is treated as one gram of ^{239}Pu. For the most part, waste generators need only consider the ^{239,240}Pu concentration when determining Pu equivalent concentration mass. Under certain circumstances, other fissile materials will have to be measured. These materials include ^{233}U, ^{235}U, ^{241}Pu, and (if present in sufficient quantities) ^{237}Np, ^{238}Pu, and ^{241}Am. Treatment of these materials on a Pu equivalent basis is defined in chapter 2 of the Nuclear Criticality Safety Manual, WHC-CM-4-29 (Westinghouse Hanford Company, 1994a).

concentrations of hydroxide, chloride, nitrate, and nitrite. These issues are briefly discussed in section 2.6.

For determining the potential of unwanted chemical reactions, DOE procedures call for determining chemical compatibility based on the reactivity group number of the source waste. This information is to be provided by the waste generator on a waste profile sheet in accordance with the Waste Analysis Plan (Mulkey and Jones, 1994). Source wastes will be categorized according to EPA compatibility matrix (U.S. Environmental Protection Agency, 1994a,b) and potential chemical compatibility hazards will be identified prior to acceptance into a DST (Fowler, 1995b).

In addition to safety concerns, waste compatibility assessment is also needed to address operational concerns including

- Heat load limits on receiving tank (tank farm ventilation capacity issue)
- Plugged pipeline and equipment (unanticipated precipitation)

Consideration of the above processes will help determine whether wastes may be transferred/combined without exceeding the physical constraints of the transfer piping and tanks in the DST system and will be instrumental in identifying safety issues and regulatory controls that are needed to assure safe operations.

DOE procedures place limits on the heat generation rates of the wastes to prevent localized boiling. This is necessary because the ventilation systems in tank farms AN, AP, AW, and SY were not designed to handle boiling, and internal boiling arising from excessive heat generation rates could lead to release of radionuclides. Although the other two tank farms, AY and AZ, have ventilation systems designed to handle boiling, waste heat generation rates in these tanks need to be kept below the vent system design limit (10×10^6 Btu/h per tank) (Fowler, 1995b). The heat generation rate is usually estimated based on the mean Sr-90 and Cs-137 concentrations. These are generally measured using beta counting and gamma energy analysis.

Waste compatibility analysis is needed to ensure pumpability of the source waste to the receiving tank and that no reactions occur that could lead to plugging of process lines and equipment. Plugging of process lines and equipment may be considered to be a safety issue because (i) rupturing of pipes may occur due to sudden overpressurization; not all transfer lines are equipped with appropriate rupture disks and leak catchment systems; and (ii) the measures taken to remove plugging and restart the system may need safety analyses. Pumpability of the source waste is estimated by determining the Reynolds number for the transfer system. Data needs for calculating the Reynolds number are density of the waste, viscosity of the waste, pipe diameter, and pump velocity (flow rate). Volume percent solids (measured and/or estimated) and the cooling curve verification of precipitating solids as a function of temperature may also be needed to aid in the determination of waste pumpability.

The DOE approach to evaluating waste compatibility for the DST system has been developed based on engineering process knowledge and observations of operational problems. Basic information needs and decision criteria established by DOE for compatibility assessments are discussed in Fowler (1995b). The chemical and physical data needed for these assessments are listed in table 4-5.

Table 4-5. Analytical data needs for compatibility assessment (taken from Fowler, 1995b)

Parameter	Safety Concerns				Operations Concerns
	Criticality	Flammable Gas	Energetics	Corrosion	
Aluminum					X
Americium-241					X
Carbonate					X
Cesium-137					X
Chloride				X	
Cooling Curve					X
Exotherm/Endotherm Ratio			X		
Fluoride				X[a]	X
Hydroxide				X	X
Nitrate				X	X
Nitrite				X	X
Organic Carbon					X
Organic, Separable			X		
pH				X	
Phosphate					X
Plutonium-239/240*	X				
Solids, Vol.%	X				X
Specific Gravity		X			X
Strontium-90					X
Sulfate				X[a]	X
Uranium	X				
Viscosity					X
Water, wt. %					X

a Although not included by Fowler (1995b), concentrations of fluoride and sulfate should be considered in the case of corrosion as potential aggressive anions.

* Total alpha may be used for this determination. Other fissile elements may be needed as noted in footnote 12 in section 4.3.1.

5 ADDITIONAL INFORMATION REQUIREMENTS FOR INPUT TO HAZARD ASSESSMENT

The NRC regulatory approach to the Hanford TWRS will evolve as a result of continued activities in subtasks 1.5 and 1.7, and improved understanding of the TWRS program. However, one proposed aspect of the NRC regulations and guidance to Hanford TWRS is contained in chapter 4, Integrated Safety Analyses (ISA), of the Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility[1]. Access to the additional information outlined below will support the ISA. In addition, knowledge of current site contamination is needed to assess the performance of LAW that will be disposed on site. Such a performance assessment is required for NRC approval of DOE's classification of waste streams into HLW and LAW.

Information requirements for hazard analyses will evolve as further knowledge is gained of the processes for tank waste retrieval, separations, feed preparation, solidification, and disposal. Studies under way in subtasks 1.2 and 1.6 are expected to contribute to this knowledge base. The additional information requirements are categorized below in terms of various components of the TWRS. Topics related to solidification processes and chemical reactions are not listed, since they will be discussed in other reports under subtasks 1.2 and 1.6, respectively.

5.1 SITE CONTAMINATION

At the time of this document's production, limited data were available regarding the extent and magnitude of radionuclide and chemical contamination of surface soils and subsurface soils of the vadose zone at the Hanford site. As planned site characterization activities proceed, specifically, the work to be accomplished by US Ecology near the 200 Areas, study of contaminant migration in the 200-West area under the SX tank farm, and study of the 200-East area (under one of the potential LAW disposal sites), new data made available from these investigations need to be evaluated, summarized, and incorporated in this document.

5.2 WASTE CHARACTERISTICS

Important information needs pertain to the chemical and physical characteristics of the wastes in each of the Hanford tanks. Data on tank chemical composition is needed for safety analysis and assessment of waste compatibility. Information on radionuclide composition of individual tanks is also needed for safety and waste compatibility analyses, as well as for determining shielding requirements for TWRS equipment. Waste rheology and shear strength need to be known to determine dilution requirements, equipment needs, and efficiency of retrieval of tank wastes. However, as pointed out in chapter 3, characterization of the chemical and radionuclide inventories of the tank wastes is not a straightforward task. Estimation of inventories based on facility records may be unreliable due to incomplete or inaccurate documentation of tank additions and waste transfers, whereas direct sample measurement is limited by the extreme physical and chemical heterogeneity of the tank contents. Inventories also change due to waste degradation, radioactive decay, and waste transfers. Although a relatively sophisticated and systematic estimation of individual tank contents is being conducted

[1] Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility (Draft NUREG-1520) and Integrated Safety Analysis Guidance Document (Draft NUREG-1513).

(e.g., Agnew, 1996), future NRC analyses of Hanford TWRS operations should cross-check and verify these estimates with actual data resulting from DOE waste characterization efforts.

5.3 TRANSFER LINES

As described in chapter 2, the transfer lines within the 200-East and -West Areas have a variety of designs. Some of these transfer lines are considered to be arterial lines, in that a leak or blockage may have a significant impact on the continued operation of the tank farms and the TWRS. In addition to the cross-transfer lines, selected transfer lines within the 200 Areas are planned to be upgraded to double-walled piping, and equipped with leak detection and corrosion protection systems. The transfer lines selected for replacement are: (i) the line connecting the T plant to the SY farm in the 200-West Area, (ii) the line connecting the PFP to the SY tank farm, (iii) other piping in the SY tank farm, (iv) the distribution piping in the A-tank farm, and (v) the piping in the AY and AZ tank farms. Two areas of additional information needs are: (i) the analyses of causes of old piping failure including blockage and corrosion, and (ii) the location of all existing piping systems, especially in the 200-East Area. The former is important to understanding the changes in the design of the piping systems and to determining if blockage would occur upon retrieval of wastes mixed from different tanks. The latter is important to understanding which transfer lines are most important to the safe functioning of the TWRS.

5.4 TANK WASTE CONTENTS

The information on tank waste contents described in chapter 3 has focused on the SSTs and DSTs. Information on the approximately 20 MUSTS and 40 Inactive Miscellaneous Underground Storage Tanks (IMUSTs) is sparse. While these are not of concern for Phase I of the TWRS, the wastes in the MUSTs and IMUSTs are planned to be retrieved and processed in Phase II (US Department of Energy, 1996b). The volume of wastes in these tanks is less than 1 percent of the total waste inventory, and the chemistry is expected to be similar to that of the SSTs. Nevertheless, the details of tank contents are not available at present.

6 SUMMARY AND RECOMMENDATIONS

The large amount of information pertaining to Hanford site, history of processes, the TWRS, and tank waste contents was reviewed in the previous chapters. This review is neither exhaustive nor critical. However, the objective of the report is to provide the reader sufficient background information to assess the safety aspects of TWRS and its performance of onsite waste disposal systems. It is recommended that this report be updated as further insight is gained regarding the site and TWRS activities.

Chapter 2 describes the Hanford site geographical and geological features, natural hazards, site contamination, the tank farms, reactors, and associated facilities, and ongoing activities related to TWRS. The geological and geographical features were provided in the form of a map generated by ArcView. This technique of generating the site map, in addition to its enhanced accuracy over image reproduction from previous reports, provides a particular advantage because as further information on the site characteristics and coordinates of various facilities is acquired, this can be overlaid on the existing maps electronically. The current state of knowledge of the groundwater, soil, and surface water contamination is also reviewed in chapter 2. A review of available information of site contamination suggested that, in general, concentrations of radionuclides in effluents has not changed significantly over the last few years since decommissioning of most production facilities. Onsite surface and near-surface soils had concentrations above applicable regulatory limits of Co-60, Sr-90, Cs-137, Pu-239, and Pu-240, with the highest levels near waste disposal sites. Borehole data show that below the 200-West Area, Cs was recorded to a depth of at least 38 m, which is the top of a low-permeability confining bed. Surface water analyses in the 200 Areas indicate that the radionuclide and the hazardous chemical contaminant concentrations are below regulatory limits. Analyses of surface water near the 100 Area reactors indicate elevated levels of Sr-90 and H-3. Only in the 100-K Area do the concentrations of nonradiological chemicals exceed the regulatory limits. Mapping of the groundwater contaminant plumes suggests that these are clustered around the various processing plants. Near the proposed privatization facilities, elevated levels of H-3 have been found. The only nonradiological components being discharged at elevated levels offsite to the Columbia River are chromium and nitrate.

The engineering systems of importance to the TWRS include the waste tanks, transfer systems (including valve pits, jumpers, and transfer lines), evaporator/crystallizer, and the solidification facilities. The soldification systems have not been constructed and will be reviewed as part of subtask 1.2. The new waste transfer line under construction between the 200-West and -East areas (known as the cross transfer line) was reviewed. Pitting, erosion, and malfunctioning of the cathodic protection system are considered to be the three most important performance limiting failure processes for the cross transfer piping system. Plugging of the lines due to chemical reactions or hydrodynamic changes is also an important consideration for performance. The evaporator/crystallizer is essential in reducing the waste volumes prior to solidification. At present, the expected life of the evaporator/crystallizer is 8 to 10 yr before replacement of the construction materials is needed.

The privatization facilities will be constructed in the area adjacent to the AP tank farm east of 200 East. At present, the site for disposal of the LAW products is not known. The ongoing programs pertaining to TWRS include vadose zone characterization, tank waste characterization, evaluation of watch-list tanks, resolution of unreviewed safety questions, continued operation of tank farms, construction and operation of cross-transfer piping, upgrades to the tank farms and transfer lines, development of the initial tank retrieval system, determining the disposition of Cs and Sr capsules, and initiating resolution of other issues pertaining to tank closure, retrieval of tank waste residuals, and contamination around tanks.

Chapter 2 also surveyed the information available on other facilities that are under construction or will be constructed as part of the TWRS. The CSB that is being constructed at the site of the former vitrification facility is an important component of the disposition of spent fuel from the K-basins. In the phased alternative of the TWRS, the CSB may also be used to store some of the high-level waste glass logs. Unfortunately, at the time of writing of this report, detailed design information regarding the CSB was not available.

Identification and quantification of Hanford tank waste contents are subjects of extensive study. Chapter 3 of this report includes a general description of DST and SST waste characteristics, and a discussion of tank inventories of chemicals and radionuclides. The wastes have been produced over a long period of time by a variety of processes; characterizing tank contents chemically and radiologically is therefore a challenging task. Two approaches to this question are being employed by Hanford, each complementing the other: direct sample assay and estimation based on facility records. The former is limited by the extreme physical and chemical heterogeneity of the tank contents, while the latter may be unreliable due to incomplete or inaccurate documentation of process and waste transfer transactions. The Hanford effort is centered on determination of a "best-basis" value for each constituent in each tank, based on a combination of the assay and historical data. Until that evaluation process is completed, the historically based HDW model being developed at LANL is the most complete and thorough data set of tank inventory estimates. The CNWRA has prepared a database (based on inventories from the HDW model) allowing access of tank information utilizing ARC/INFO geographical information system software. The available tank inventory estimates show that sodium is by far the most abundant metal, comprising 80 percent by weight of the metal cation population. Important inorganic anions are nitrate, hydroxide, nitrite, and carbonate, while the most abundant organic complexants are glycolate and HEDTA. The radionuclide inventory is dominated by Sr-90 (75 percent of the SST radioactivity and 27 percent of the DST radioactivity) and Cs-137 (24 percent of the SST and 72 percent of the DST).

Chapter 4 reviewed the various hazards posed by tank wastes and associated with the retrieval and mixing of wastes prior to solidification. The safety issues associated with solidification will be discussed in another report as part of subtask 1.2. The hazards posed by tank wastes and the TWRS activities include:

(i) Flammable gas: flammable gases such as hydrogen are generated due to radiolytic as well as organic reactions. Recently all 177 tanks were placed on the flammmable gas watch-list. Final resolution of how many tanks present risk due to flammable gas has not occurred.

(ii) Organics: the potential for exothermic and explosive reaction between organics and oxidants such as nitrates is a concern. Of the original 36 tanks placed under this list, only 20 tanks are still on the watch-list.

(iii) Ferrocyanide: the potential for explosion when ferrocyanide left over from Cs and Sr extraction combines with oxidants is a concern. At present all tanks have been removed from the ferrocyanide watch-list.

(iv) High-heat: radioactive decay may generate high heat that may in turn result in structural damage of the concrete walls. Only tank C-106 was placed on this watch-list and long-term resolution is being pursued.

Other hazards identified in this review include:

(i) Crust burn associated with secondary ignition of organic-nitrate/nitrite mixtures in the crust layer

(ii) HEPA filter blowout associated with flammable gas

(iii) Organic solvent leading to possible flammability and environmental contamination

(iv) Known and unknown leaking tanks

(v) Criticality

(vi) Lightning strikes

The report also evaluated potential safety concerns associated with retrieval, mixing, and transfer of tank wastes. Two important concerns are: (i) safety problems arising from commingling wastes under interim storage and (ii) operability of waste transfer systems that may be impeded by plugging, trapped flammable gas, exothermic reactions, and corroded lines. The physical and chemical data needs for compatibility assessments are provided in chapter 4.

Additional information requirements are outlined in chapter 5. Information needs pertain to: (i) knowledge of vadose zone contamination, especially beneath the 200-East area of potential sites for LAW disposal; (ii) understanding the evaluation of waste characteristics and chemistry in the underground storage tanks; (iii) location, design, and previous operational experience of the waste transfer lines; and (iv) information regarding the waste contents in MUSTs and IMUSTs.

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APPENDIX A

SUPPLEMENTARY TABLES FOR CHAPTER 3

A-1. Reproduction of total Hanford Site inventories from the Revision 4 Hanford Defined Waste model of Agnew (1997), by quadrant and tank type. Included are estimates for crib inventories and leakage. Except as noted, nonradioactive species are reported in kg, radionuclides in Ci.

(kg/Ci)	Volume (kgal)	Heat Load (BTU)	Na^+	Al^{3+}	Fe^{3+} (total Fe)	Cr^{3+}	Bi^{3+}	La^{3+}	Hg^{2+}	Zr (as $ZrO(OH)_2$)	Pb^{2+}	Ni^{2+}	Sr^{2+}	Mn^{2+}	Ca^{2+}	K^+	H_2O (kg)
NE Quad.	12,701	636,023	10,440,657	1,851,760	831,270	96,479	301,509	304	3,447	13,125	189,114	92,110	0	4,892	252,717	55,582	32,676,773
SW Quad.	13,220	642,140	15,516,159	3,641,310	420,849	520,340	19,747	173	1,745	6,562	56,929	36,118	0	7,816	133,098	107,340	26,065,772
NW Quad.	9,277	115,944	6,720,860	775,092	394,955	87,742	159,413	308	623	2,066	22,434	16,757	0	2,440	111,761	44,684	25,236,812
SE Quad.	25,694	776,239	16,492,077	2,103,766	225,471	289,517	11,508	138	1,047	192,390	10,973	38,507	0	23,700	122,751	312,958	73,259,827
SST's	35,198	1,394,107	32,677,677	6,268,162	1,647,074	704,562	480,668	785	5,815	21,753	268,476	144,985	0	15,148	497,576	207,606	83,979,356
DST's	25,694	776,239	16,492,077	2,103,766	225,471	289,517	11,508	138	1,047	192,390	10,973	38,507	0	23,700	122,751	312,958	73,259,827
All Tanks	60,892	2,170,346	49,169,753	8,371,928	1,872,546	994,078	492,176	923	6,862	214,143	279,449	183,492	0	38,849	620,327	520,564	157,239,183
CRIB	118,238	44,649	21,586,791	24,740	35,665	78,613	258,425	15,566	97.9	4,126	346	35,877	0	8,263	129,446	401,423	410,190,504
Leaks	428	3,963	177,818	29,225	258	6,283	69.5	5.21E-05	0.570	3.36	66.8	193	0	54.6	675	1,105	1,378,437
Total Site	**179,558**	**2,218,958**	**70,934,363**	**8,425,893**	**1,908,469**	**1,078,975**	**750,870**	**16,489**	**6,961**	**218,272**	**279,863**	**219,561**	**0**	**47,166**	**750,448**	**923,092**	**568,808,124**

A-1. Reproduction of total Hanford Site inventories from the Revision 4 Hanford Defined Waste model of Agnew (1997), by quadrant and tank type. Included are estimates for crib inventories and leakage. Except as noted, nonradioactive species are reported in kg, radionuclides in Ci. (cont'd)

(kg/Ci)	TOC (kg)	free OH⁻	OH⁻	NO_2^-	NO_3^-	CO_3^{2-}	PO_4^{3-}	SO_4^{2-}	Si (as SiO_3^{2-})	F^-	Cl^-	$C_2H_3O_2^-$	$EDTA^{4-}$	$HEDTA^{3-}$	glycolate⁻	acetate⁻	$oxalate^{2-}$
NE Quad.	352,739	287,977	6,252,403	12,955,883	2,520,205	1,139,079	1,361,531	631,970	232,392	87,210	162,625	118,351	117,840	165,515	106,384	40,340	54,502
SW Quad.	421,742	283,027	11,902,808	14,760,909	5,331,687	1,159,820	428,251	897,270	156,424	51,345	370,429	200,415	137,809	242,511	229,905	13,606	144
NW Quad.	151,343	15,133	2,987,735	7,884,183	1,506,888	571,674	1,286,616	448,138	135,235	72,291	141,146	51,634	43,883	79,292	73,564	2,907	59,433
SE Quad.	892,667	25,082	8,298,086	14,829,477	4,734,713	1,965,896	718,998	1,248,561	137,655	363,737	424,975	307,785	319,951	546,836	690,970	42,620	115
SST's	925,824	586,136	21,142,946	35,600,976	9,358,780	2,870,572	3,076,397	1,977,377	524,052	210,846	674,200	370,400	299,532	487,318	409,853	56,853	114,079
DST's	892,667	25,082	8,298,086	14,829,477	4,734,713	1,965,896	718,998	1,248,561	137,655	363,737	424,975	307,785	319,951	546,836	690,970	42,620	115
All Tanks	1,818,491	611,218	29,441,031	50,430,453	14,093,493	4,836,468	3,795,395	3,225,938	661,707	574,583	1,099,174	678,185	619,483	1,034,154	1,100,823	99,474	114,194
CRIB	3,989	0	309,627	39,446,737	1,133,316	312,615	4,217,584	2,910,093	235,640	1,110,035	598,047	0	0	0	0	0	12,921
Leaks	1,717	0	111,790	142,118	64,386	13,633	6,447	13,984	1,012	313	4,280	1,570	37.1	71.1	1,274	0.330	4.32E-05
Total Site	1,824,197	611,218	29,862,448	90,019,308	15,291,195	5,162,716	8,019,426	6,150,015	898,359	1,684,930	1,701,501	679,755	619,520	1,034,225	1,102,097	99,474	127,115

A-1. Reproduction of total Hanford Site inventories from the Revision 4 Hanford Defined Waste model of Agnew (1997), by quadrant and tank type. Included are estimates for crib inventories and leakage. Except as noted, nonradioactive species are reported in kg, radionuclides in Ci. (cont'd)

(kg/Ci)	DBP	butanol	NH_3	$Fe(CN)_6^{4-}$	H-3	C-14	Ni-59	Ni-63	Co-60	Se-79	Sr-90	Y-90	Zr-93	Nb-93m	Tc-99	Ru-106	Cd-113m	Sb-125	Sn-126	I-129
NE Quad.	124,714	43,976	44,352	131,900	4,011	837	420	41,306	890	236	22,986,095	22,991,812	1,067	849	5,313	2.63	3,689	3,995	371	10.3
SW Quad.	149,437	52,694	83,415	0	11,165	1,472	243	23,550	1,586	197	19,159,986	19,164,613	944	724	10,509	0.279	3,815	6,722	293	20.2
NW Quad.	48,769	17,197	35,607	15,897	2,886	410	38.4	3,720	451	43.4	1,899,539	1,900,007	213	155	2,921	8.24E-02	1,096	1,932	65.5	5.63
SE Quad.	238,869	84,207	337,698	0	53,532	2,088	233	23,455	9,370	295	17,548,685	17,553,116	1,404	957	13,812	104,490	8,285	195,645	457	26.8
SST's	322,921	113,867	163,374	147,797	18,062	2,720	701	68,576	2,928	477	44,045,620	44,056,431	2,224	1,728	18,744	2.99	8,601	12,648	729	36.2
DST's	238,869	84,207	337,698	0	53,532	2,088	233	23,455	9,370	295	17,548,685	17,553,116	1,404	957	13,812	104,490	8,285	195,645	457	26.8
All Tanks	561,790	198,074	501,072	147,797	71,594	4,808	934	92,032	12,297	773	61,594,305	61,609,547	3,628	2,685	32,557	104,493	16,885	208,294	1,186	63.0
CRIB	676	238	80,099	0	810	125	14.0	1,261	29.4	26.3	1,067,365	1,067,656	125	105	868	5.22E-05	308	29.3	39.5	1.64
Leaks	969	342	675	0	156	14.5	1.21	117	14.5	1.85	54,779	54,792	9.07	6.72	107	2.67E-03	41.6	58.6	2.81	0.204
Total Site	563,435	198,654	581,845	147,797	72,560	4,947	949	93,410	12,341	801	62,716,449	62,731,995	3,762	2,796	33,531	104,493	17,235	208,381	1,228	64.8

A-1. Reproduction of total Hanford Site inventories from the Revision 4 Hanford Defined Waste model of Agnew (1997), by quadrant and tank type. Included are estimates for crib inventories and leakage. Except as noted, nonradioactive species are reported in kg, radionuclides in Ci. (cont'd)

(kg/Ci)	Cs-134	Cs-137	Ba-137m	Sm-151	Eu-152	Eu-154	Eu-155	Ra-226	Ra-228	Ac-227	Pa-231	Th-229	Th-232	U-232	U-233	U-234	U-235	U-236	U-238
NE Quad.	64.6	6,708,895	6,346,586	859,981	374	21,561	22,936	2.77E-02	55.8	87.4	155	1.31	2.53	173	662	390	17.0	5.24	448
SW Quad.	107	12,591,260	11,911,477	698,550	306	26,062	16,685	1.83E-02	4.94	9.47E-02	0.247	0.116	0.330	26.0	99.6	214	9.30	3.58	214
NW Quad.	39.4	4,515,937	4,272,095	152,941	53.8	7,423	3,200	2.49E-03	3.34	3.65E-02	9.19E-02	8.03E-02	0.205	17.0	65.2	165	7.24	2.23	168
SE Quad.	88,013	23,288,711	22,031,483	1,039,476	743	92,223	93,541	1.47E-02	13.0	8.28E-02	0.261	0.301	1.30	43.6	167	80.9	3.14	5.06	75.2
SST's	211	23,816,092	22,530,157	1,711,472	734	55,046	42,820	4.85E-02	64.1	87.5	155	1.51	3.06	216	827	769	33.5	11.0	830
DST's	88,013	23,288,711	22,031,483	1,039,476	743	92,223	93,541	1.47E-02	13.0	8.28E-02	0.261	0.301	1.30	43.6	167	80.9	3.14	5.06	75.2
All Tanks	88,224	47,104,804	44,561,641	2,750,948	1,477	147,269	136,361	6.31E-02	77.1	87.6	156	1.81	4.36	259	994	850	36.6	16.1	906
CRIB	0.195	1,256,247	1,188,398	97,674	3.75	535	279	7.11E-03	1.38E-08	3.64E-02	7.92E-02	2.67E-06	3.56E-08	1.19E-03	5.85E-05	62.0	2.76	0.539	1,310
Leaks	1.06	168,938	159,818	6,555	1.60	259	87.2	1.00E-04	3.57E-04	5.81E-04	2.33E-03	1.61E-05	1.30E-04	1.72E-02	6.65E-02	0.507	2.11E-02	1.58E-02	0.463
Total Site	88,225	48,529,989	45,909,857	2,855,176	1,482	148,063	136,728	7.03E-02	77.1	87.6	156	1.81	4.36	259	994	913	39.4	16.7	2,216

A-1. Reproduction of total Hanford Site inventories from the Revision 4 Hanford Defined Waste model of Agnew (1997), by quadrant and tank type. Included are estimates for crib inventories and leakage. Except as noted, nonradioactive species are reported in kg, radionuclides in Ci. (cont'd)

(kg/Ci)	U-Total (kg)	Np-237	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Pu-Total (kg)	Am-241	Am-243	Cm-242	Cm-243	Cm-244
NE Quad.	1,147,765	18.1	640	16,504	3,135	45,598	0.253	272	11,074	0.689	13.0	1.27	40.6
SW Quad.	620,223	39.4	261	8,921	1,457	14,456	7.56E-02	142	4,544	0.171	10.6	0.963	17.9
NW Quad.	489,198	10.6	59.1	6,810	1,426	3,210	1.25E-02	115	5,196	2.66E-02	2.01	0.181	1.75
SE Quad.	186,564	73.3	1,116	14,722	3,852	103,420	0.450	246	49,037	8.45	51.4	7.63	181
SST's	2,257,185	68.1	960	32,235	6,017	63,265	0.341	529	20,815	0.886	25.6	2.42	60.3
DST's	186,564	73.3	1,116	14,722	3,852	103,420	0.450	246	49,037	8.45	51.4	7.63	181
All Tanks	2,443,749	141	2,076	46,956	9,869	166,685	0.790	774	69,851	9.34	77.0	10.0	242
CRIB	188,469	5.33	16.3	2,496	214	643	2.88E-03	41.1	239	1.68E-03	6.89E-02	1.43E-03	4.22E-02
Leaks	1,382	0.428	0.577	22.0	3.33	34.3	1.84E-04	0.309	29.0	9.44E-04	6.63E-02	6.25E-03	6.80E-02
Total Site	2,633,600	147	2,093	49,475	10,086	167,362	0.794	816	70,120	9.34	77.1	10.1	242

A-2. Reproduction of Agnew (1997) inventory for Tank A-101. Included in this and the following five tables are estimated 67 and 95 percent confidence intervals (CI).

HDW Model Rev. 4

Single-Shell Tank 241-A-101							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	1.43E+04 (kg)	(2.99 kgal)	----	----	----	----	----
Heat Load	0.879 (kW)	(3.00E+03 BTU/hr)	----	0.742	0.833	0.907	0.926
Bulk Density	1.26 (g/cc)	----	----	1.16	1.20	1.30	1.33
Void Fraction	0.841	----	----	0.796	0.813	0.890	0.925
Water wt%	67.2	----	----	63.3	64.8	71.1	74.6
TOC wt% C (wet)	0	----	----	0	0	0	0
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	1.83	3.33E+04	475	0.348	0.564	2.62	3.30
Al^{3+}	0	0	0	0	0	0	0
Fe^{3+} (total Fe)	2.63	1.16E+05	1.66E+03	2.53	2.60	2.65	2.67
Cr^{3+}	6.75E-03	278	3.97	3.52E-03	5.22E-03	8.29E-03	9.78E-03
Bi^{3+}	0	0	0	0	0	0	0
La^{3+}	0	0	0	0	0	0	0
Hg^{2+}	0	0	0	0	0	0	0
Zr (as $ZrO(OH)_2$)	0	0	0	0	0	0	0
Pb^{2+}	0	0	0	0	0	0	0
Ni^{2+}	0.102	4.73E+03	67.5	1.13E-02	7.18E-02	0.119	0.130
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	0	0	0	0	0	0	0
Ca^{2+}	0.421	1.34E+04	191	7.95E-03	0.271	0.508	0.577
K^+	2.65E-03	82.0	1.17	1.38E-03	2.05E-03	3.26E-03	3.84E-03
OH^-	8.24	1.11E+05	1.58E+03	7.69	8.05	8.37	8.46
$NO3^-$	2.20E-15	1.08E-10	1.54E-12	3.31E-16	7.31E-16	1.21E-14	2.80E-13
$NO2^-$	0.379	1.38E+04	197	0.198	0.293	0.466	0.549
$CO3^{2-}$	0.421	2.00E+04	286	7.95E-03	0.271	0.508	0.577
$PO4^{3-}$	0	0	0	0	0	0	0
$SO4^{2-}$	3.68E-02	2.80E+03	40.0	1.92E-02	2.84E-02	4.52E-02	5.33E-02
Si (as SiO_3^{2-})	0.621	1.38E+04	197	2.06E-02	5.49E-02	1.00	1.37
F^-	0	0	0	0	0	0	0
Cl^-	1.22E-02	342	4.88	6.35E-03	9.42E-03	1.50E-02	1.77E-02
$C_6H_5O_7^{3-}$	0	0	0	0	0	0	0
$EDTA^{4-}$	0	0	0	0	0	0	0
$HEDTA^{3-}$	0	0	0	0	0	0	0
$glycolate^-$	0	0	0	0	0	0	0
$acetate^-$	0	0	0	0	0	0	0
$oxalate^{2-}$	0	0	0	0	0	0	0
DBP	0	0	0	0	0	0	0
butanol	0	0	0	0	0	0	0
NH_3	0.170	2.29E+03	32.7	8.66E-02	0.134	0.207	0.242
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

A-2. Reproduction of Agnew (1997) inventory for Tank A-101. Included in this and the following five tables are estimated 67 and 95 percent confidence intervals (CI). (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-A-101							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	5.36E+06 (kg)	(950 kgal)	----	----	----	----	----
Heat Load	6.42 (kW)	(2.19E+04 BTU/hr)	----	5.78	6.16	6.65	7.00
Bulk Density*	1.49 (g/cc)	----	----	1.44	1.47	1.50	1.51
Water wt%	42.2	----	----	40.1	40.8	43.6	45.3
TOC wt% C (wet)	1.19	----	----	0.665	0.923	1.46	1.71
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	11.2	1.73E+05	9.27E+05	10.2	10.8	11.6	11.9
Al^{3+}	1.40	2.53E+04	1.36E+05	1.17	1.35	1.44	1.47
Fe^{3+} (total Fe)	7.80E-03	293	1.57E+03	6.69E-03	7.24E-03	8.37E-03	8.91E-03
Cr^{3+}	9.86E-02	3.44E+03	1.84E+04	8.72E-02	9.33E-02	0.103	0.110
Bi^{3+}	1.02E-03	143	767	9.61E-04	9.90E-04	1.05E-03	1.10E-03
La^{3+}	1.96E-05	1.83	9.78	1.44E-05	1.69E-05	2.22E-05	2.48E-05
Hg^{2+}	8.15E-06	1.10	5.88	7.81E-06	7.98E-06	8.32E-06	8.48E-06
Zr (as $ZrO(OH)_2$)	1.29E-04	7.90	42.3	1.19E-04	1.23E-04	1.33E-04	1.39E-04
Pb^{2+}	1.10E-03	152	817	8.52E-04	9.72E-04	1.22E-03	1.34E-03
Ni^{2+}	4.31E-03	170	911	4.14E-03	4.22E-03	4.36E-03	4.40E-03
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	3.77E-03	139	746	3.24E-03	3.50E-03	4.05E-03	4.31E-03
Ca^{2+}	2.35E-02	632	3.39E+03	2.19E-02	2.27E-02	2.43E-02	2.51E-02
K^+	5.39E-02	1.41E+03	7.57E+03	4.64E-02	4.95E-02	5.89E-02	6.58E-02
OH^-	7.88	8.99E+04	4.82E+05	6.80	7.58	8.07	8.22
$NO3^-$	3.58	1.49E+05	7.98E+05	3.40	3.49	3.67	3.76
$NO2^-$	2.04	6.31E+04	3.38E+05	1.65	1.81	2.29	2.36
$CO3^{2-}$	0.422	1.70E+04	9.11E+04	0.389	0.405	0.439	0.450
$PO4^{3-}$	7.68E-02	4.90E+03	2.62E+04	6.67E-02	7.11E-02	8.13E-02	8.73E-02
$SO4^{2-}$	0.235	1.51E+04	8.11E+04	0.188	0.208	0.267	0.269
Si (as SiO_3^{2-})	6.27E-02	1.18E+03	6.33E+03	5.51E-02	5.88E-02	6.66E-02	7.03E-02
F^-	5.53E-02	705	3.78E+03	4.73E-02	5.06E-02	6.05E-02	6.83E-02
Cl^-	0.194	4.62E+03	2.47E+04	0.167	0.180	0.200	0.205
$C_6H_5O_7^{3-}$	2.72E-02	3.46E+03	1.85E+04	2.49E-02	2.59E-02	2.87E-02	3.09E-02
$EDTA^{4-}$	2.87E-02	5.55E+03	2.97E+04	9.27E-03	1.88E-02	3.87E-02	4.84E-02
$HEDTA^{3-}$	5.15E-02	9.48E+03	5.08E+04	1.27E-02	3.17E-02	7.15E-02	9.11E-02
glycolate$^-$	0.107	5.37E+03	2.87E+04	6.77E-02	8.67E-02	0.127	0.146
acetate$^-$	1.86E-02	739	3.96E+03	1.48E-02	1.65E-02	2.10E-02	2.46E-02
oxalate^{2-}	2.57E-05	1.52	8.12	2.29E-05	2.42E-05	2.71E-05	2.85E-05
DBP	2.18E-02	3.07E+03	1.65E+04	1.82E-02	1.98E-02	2.40E-02	2.72E-02
butanol	2.18E-02	1.08E+03	5.80E+03	1.82E-02	1.98E-02	2.40E-02	2.72E-02
NH_3	5.02E-02	573	3.07E+03	4.16E-02	4.50E-02	5.69E-02	6.46E-02
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

A-2. Reproduction of Agnew (1997) inventory for Tank A-101. Included in this and the following five tables are estimated 67 and 95 percent confidence intervals (CI). (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-A-101							
Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	5.37E+06 (kg)	(953 kgal)	----	----	----	----	----
Heat Load	7.29 (kW)	(2.49E+04 BTU/hr)	----	6.66	7.03	7.53	7.88
Bulk Density†	1.49 (g/cc)	----	----	1.44	1.47	1.50	1.51
Water wt%†	42.3	----	----	40.1	40.8	43.6	45.4
TOC wt% C (wet)†	1.19	----	----	0.664	0.921	1.45	1.71
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	11.2	1.73E+05	9.27E+05	10.2	10.7	11.6	11.9
Al^{3+}	1.39	2.53E+04	1.36E+05	1.17	1.34	1.43	1.47
Fe^{3+} (total Fe)	1.60E-02	601	3.23E+03	1.49E-02	1.55E-02	1.66E-02	1.71E-02
Cr^{3+}	9.83E-02	3.43E+03	1.84E+04	8.69E-02	9.30E-02	0.103	0.109
Bi^{3+}	1.02E-03	143	767	9.58E-04	9.87E-04	1.05E-03	1.10E-03
La^{3+}	1.95E-05	1.82	9.78	1.44E-05	1.69E-05	2.22E-05	2.47E-05
Hg^{2+}	8.12E-06	1.09	5.88	7.79E-06	7.95E-06	8.29E-06	8.46E-06
Zr (as $ZrO(OH)_2$)	1.29E-04	7.88	42.3	1.19E-04	1.22E-04	1.33E-04	1.38E-04
Pb^{2+}	1.09E-03	152	817	8.49E-04	9.68E-04	1.22E-03	1.34E-03
Ni^{2+}	4.62E-03	182	978	4.34E-03	4.53E-03	4.67E-03	4.71E-03
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	3.76E-03	139	746	3.23E-03	3.49E-03	4.03E-03	4.29E-03
Ca^{2+}	2.47E-02	666	3.58E+03	2.32E-02	2.39E-02	2.55E-02	2.63E-02
K^+	5.37E-02	1.41E+03	7.58E+03	4.62E-02	4.94E-02	5.88E-02	6.56E-02
OH^-	7.88	9.00E+04	4.83E+05	6.80	7.58	8.07	8.22
$NO3^-$	3.57	1.49E+05	7.98E+05	3.39	3.48	3.66	3.75
$NO2^-$	2.04	6.30E+04	3.38E+05	1.64	1.81	2.29	2.35
$CO3^{2-}$	0.422	1.70E+04	9.13E+04	0.389	0.405	0.439	0.450
$PO4^{3-}$	7.66E-02	4.88E+03	2.62E+04	6.65E-02	7.09E-02	8.11E-02	8.70E-02
$SO4^{2-}$	0.234	1.51E+04	8.11E+04	0.188	0.207	0.266	0.268
Si (as SiO_3^{2-})	6.45E-02	1.22E+03	6.53E+03	5.69E-02	6.06E-02	6.83E-02	7.21E-02
F^-	5.51E-02	704	3.78E+03	4.72E-02	5.05E-02	6.03E-02	6.81E-02
Cl^-	0.194	4.61E+03	2.47E+04	0.167	0.179	0.200	0.205
$C_6H_5O_7^{3-}$	2.72E-02	3.45E+03	1.85E+04	2.49E-02	2.58E-02	2.86E-02	3.08E-02
$EDTA^{4-}$	2.86E-02	5.53E+03	2.97E+04	9.24E-03	1.87E-02	3.86E-02	4.83E-02
$HEDTA^{3-}$	5.14E-02	9.46E+03	5.08E+04	1.27E-02	3.16E-02	7.13E-02	9.08E-02
glycolate$^-$	0.106	5.35E+03	2.87E+04	6.75E-02	8.64E-02	0.126	0.146
acetate$^-$	1.86E-02	737	3.96E+03	1.48E-02	1.64E-02	2.09E-02	2.45E-02
oxalate^{2-}	2.56E-05	1.51	8.12	2.28E-05	2.42E-05	2.70E-05	2.84E-05
DBP	2.17E-02	3.06E+03	1.65E+04	1.81E-02	1.97E-02	2.39E-02	2.71E-02
butanol	2.17E-02	1.08E+03	5.80E+03	1.81E-02	1.97E-02	2.39E-02	2.71E-02
NH_3	5.06E-02	578	3.10E+03	4.20E-02	4.54E-02	5.72E-02	6.49E-02
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

†Water wt% derived from the difference of density and total dissolved species.

A-2. Reproduction of Agnew (1997) inventory for Tank A-101. Included in this and the following five tables are estimated 67 and 95 percent confidence intervals (CI). (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-A-101							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	1.43E+04 (kg)	(2.99 kgal)	-	----	----	----	----
Heat Load	0.879 (kW)	(3.00E+03 BTU/hr)	----	0.742	0.833	0.907	0.926
Bulk Density	1.26 (g/cc)	----	----	1.16	1.20	1.30	1.33
Void Fraction	0.841	----	----	0.796	0.813	0.890	0.925
Water wt%	67.2	----	----	63.3	64.8	71.1	74.6
TOC wt% C (wet)	0	----	----	0	0	0	0
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	2.85E-05	2.25E-02	0.322	7.26E-06	1.66E-05	4.36E-05	6.12E-05
C-14	1.21E-05	9.54E-03	0.136	6.28E-06	9.32E-06	1.48E-05	1.75E-05
Ni-59	1.03E-04	8.15E-02	1.16	1.15E-05	7.26E-05	1.21E-04	1.32E-04
Ni-63	9.95E-03	7.86	112	1.11E-03	7.01E-03	1.16E-02	1.27E-02
Co-60	8.45E-06	6.68E-03	9.54E-02	4.40E-06	6.53E-06	1.04E-05	1.22E-05
Se-79	4.88E-05	3.86E-02	0.552	1.33E-06	1.55E-05	8.10E-05	1.12E-04
Sr-90	11.4	8.98E+03	1.28E+05	9.65	10.8	11.7	11.9
Y-90	11.4	8.98E+03	1.28E+05	9.65	10.8	11.7	11.9
Zr-93	2.04E-04	0.161	2.31	6.28E-06	3.74E-05	3.65E-04	5.19E-04
Nb-93m	1.98E-04	0.156	2.24	4.92E-06	8.12E-05	3.10E-04	4.19E-04
Tc-99	8.44E-05	6.67E-02	0.954	4.39E-05	6.52E-05	1.04E-04	1.22E-04
Ru-106	2.66E-10	2.10E-07	3.00E-06	1.38E-10	2.05E-10	3.27E-10	3.85E-10
Cd-113m	4.62E-05	3.65E-02	0.522	2.41E-05	3.57E-05	7.85E-04	1.71E-03
Sb-125	2.09E-05	1.66E-02	0.237	1.09E-05	1.62E-05	2.57E-05	3.03E-05
Sn-126	8.00E-05	6.33E-02	0.904	2.06E-06	3.00E-05	1.28E-04	1.75E-04
I-129	1.63E-07	1.29E-04	1.84E-03	8.50E-08	1.26E-07	2.00E-07	2.36E-07
Cs-134	6.31E-07	4.99E-04	7.13E-03	3.29E-07	4.88E-07	7.75E-07	9.14E-07
Cs-137	0.276	218	3.12E+03	0.144	0.213	0.339	0.399
Ba-137m	0.261	206	2.95E+03	0.136	0.202	0.320	0.378
Sm-151	0.184	146	2.08E+03	4.79E-03	6.76E-02	0.297	0.405
Eu-152	7.22E-05	5.71E-02	0.815	7.15E-05	7.19E-05	7.25E-05	7.28E-05
Eu-154	1.87E-04	0.148	2.11	9.73E-05	1.44E-04	2.29E-04	3.59E-03
Eu-155	4.06E-03	3.21	45.9	4.03E-03	4.04E-03	4.08E-03	4.09E-03
Ra-226	8.29E-09	6.55E-06	9.36E-05	5.17E-09	7.25E-09	9.28E-09	1.02E-08
Ra-228	5.32E-14	4.20E-11	6.01E-10	5.27E-14	5.30E-14	5.34E-14	5.36E-14
Ac-227	4.24E-08	3.35E-05	4.79E-04	2.43E-08	3.64E-08	4.82E-08	5.38E-08
Pa-231	5.89E-08	4.66E-05	6.66E-04	1.43E-09	2.56E-08	9.11E-08	1.22E-07
Th-229	1.05E-11	8.33E-09	1.19E-07	1.04E-11	1.05E-11	1.06E-11	1.06E-11
Th-232	2.67E-15	2.11E-12	3.01E-11	1.39E-15	2.06E-15	3.28E-15	3.86E-15
U-232	1.90E-12	1.50E-09	2.15E-08	9.90E-13	1.47E-12	2.34E-12	2.75E-12
U-233	6.24E-14	4.93E-11	7.04E-10	3.25E-14	4.82E-14	7.66E-14	9.03E-14
U-234	3.64E-08	2.88E-05	4.12E-04	1.90E-08	2.81E-08	4.47E-08	5.27E-08
U-235	1.56E-09	1.23E-06	1.76E-05	8.11E-10	1.20E-09	1.91E-09	2.25E-09
U-236	6.20E-10	4.90E-07	7.01E-06	3.23E-10	4.79E-10	7.62E-10	8.98E-10
U-238	3.73E-08	2.95E-05	4.21E-04	1.94E-08	2.88E-08	4.58E-08	5.40E-08
Np-237	3.38E-07	2.67E-04	3.82E-03	1.76E-07	2.61E-07	4.15E-07	4.89E-07
Pu-238	3.64E-05	2.88E-02	0.411	2.96E-05	3.42E-05	3.86E-05	4.07E-05
Pu-239	2.38E-03	1.88	26.9	1.94E-03	2.23E-03	2.52E-03	2.66E-03
Pu-240	3.56E-04	0.282	4.03	2.90E-04	3.34E-04	3.78E-04	3.98E-04
Pu-241	2.69E-03	2.12	30.3	2.18E-03	2.52E-03	2.85E-03	3.00E-03
Pu-242	1.00E-08	7.93E-06	1.13E-04	8.16E-09	9.41E-09	1.06E-08	1.12E-08
Am-241	1.01E-03	0.795	11.4	2.26E-05	5.05E-04	1.49E-03	1.95E-03
Am-243	1.00E-08	7.94E-06	1.13E-04	2.26E-10	5.04E-09	1.49E-08	1.95E-08
Cm-242	1.44E-06	1.14E-03	1.62E-02	1.42E-06	1.43E-06	1.44E-06	1.45E-06
Cm-243	3.64E-08	2.88E-05	4.11E-04	3.61E-08	3.62E-08	3.65E-08	3.67E-08
Cm-244	2.16E-08	1.71E-05	2.45E-04	1.13E-08	1.67E-08	2.66E-08	3.13E-08
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	3.99E-02 (g/L)	----	0.451	3.24E-02	3.74E-02	4.23E-02	4.45E-02
U	4.69E-04	88.3	1.26	2.44E-04	3.63E-04	5.76E-04	6.79E-04

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

A-2. Reproduction of Agnew (1997) inventory for Tank A-101. Included in this and the following five tables are estimated 67 and 95 percent confidence intervals (CI). (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-A-101							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	5.36E+06 (kg)	(950 kgal)	--	----	----	----	----
Heat Load	6.42 (kW)	(2.19E+04 BTU/hr)	----	5.78	6.16	6.65	7.00
Bulk Density*	1.49 (g/cc)	----	----	1.44	1.47	1.50	1.51
Water wt%†	42.2	----	----	40.1	40.8	43.6	45.3
TOC wt% C (wet)	1.19	----	----	0.665	0.923	1.46	1.71
Radiological Constituents	**Ci/L**	**pCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	2.03E-04	0.136	731	1.35E-04	1.35E-04	2.18E-04	2.37E-04
C-14	3.19E-05	2.14E-02	115	1.77E-05	1.77E-05	3.24E-05	3.30E-05
Ni-59	1.67E-06	1.12E-03	6.00	1.00E-06	1.00E-06	1.70E-06	1.73E-06
Ni-63	1.64E-04	0.110	591	9.82E-05	9.82E-05	1.68E-04	1.71E-04
Co-60	4.03E-05	2.71E-02	145	2.41E-05	2.41E-05	4.14E-05	4.25E-05
Se-79	3.15E-06	2.11E-03	11.3	2.24E-06	2.24E-06	3.48E-06	3.79E-06
Sr-90	9.80E-02	65.8	3.53E+05	9.03E-02	9.58E-02	0.100	0.103
Y-90	9.81E-02	65.8	3.53E+05	6.67E-02	6.67E-02	0.100	0.103
Zr-93	1.55E-05	1.04E-02	55.8	1.10E-05	1.10E-05	1.72E-05	1.87E-05
Nb-93m	1.11E-05	7.47E-03	40.0	7.96E-06	7.96E-06	1.23E-05	1.34E-05
Tc-99	2.41E-04	0.162	868	1.88E-04	2.14E-04	2.72E-04	3.13E-04
Ru-106	7.11E-09	4.77E-06	2.56E-02	5.01E-09	5.01E-09	7.72E-09	8.30E-09
Cd-113m	8.55E-05	5.74E-02	307	5.83E-05	5.83E-05	9.53E-05	1.05E-04
Sb-125	1.81E-04	0.121	651	1.11E-04	1.11E-04	1.87E-04	1.93E-04
Sn-126	4.75E-06	3.19E-03	17.1	3.39E-06	3.39E-06	5.24E-06	5.71E-06
I-129	4.66E-07	3.13E-04	1.68	3.64E-07	4.14E-07	5.25E-07	6.04E-07
Cs-134	3.51E-06	2.35E-03	12.6	2.04E-06	2.76E-06	4.26E-06	5.00E-06
Cs-137	0.240	161	8.63E+05	0.213	0.224	0.254	0.274
Ba-137m	0.227	152	8.16E+05	0.188	0.188	0.240	0.253
Sm-151	1.11E-02	7.43	3.98E+04	7.89E-03	7.89E-03	1.22E-02	1.33E-02
Eu-152	4.24E-06	2.85E-03	15.3	3.12E-06	3.12E-06	4.78E-06	5.31E-06
Eu-154	6.30E-04	0.423	2.27E+03	4.03E-04	4.03E-04	7.12E-04	7.49E-04
Eu-155	2.54E-04	0.171	915	1.87E-04	1.87E-04	2.87E-04	3.20E-04
Ra-226	1.20E-10	8.06E-08	4.32E-04	9.19E-11	9.19E-11	1.30E-10	1.40E-10
Ra-228	3.09E-07	2.08E-04	1.11	8.90E-08	8.90E-08	3.41E-07	3.75E-07
Ac-227	7.47E-10	5.01E-07	2.69E-03	5.84E-10	5.84E-10	8.06E-10	8.63E-10
Pa-231	3.61E-09	2.43E-06	1.30E-02	2.71E-09	2.71E-09	3.94E-09	4.26E-09
Th-229	7.18E-09	4.82E-06	2.58E-02	2.09E-09	2.09E-09	7.87E-09	8.61E-09
Th-232	3.30E-08	2.21E-05	0.119	5.75E-09	5.75E-09	4.05E-08	4.76E-08
U-232	9.40E-07	6.31E-04	3.38	7.26E-07	8.16E-07	1.08E-06	1.23E-06
U-233	3.60E-06	2.42E-03	13.0	2.79E-06	3.13E-06	4.15E-06	4.72E-06
U-234	6.10E-07	4.09E-04	2.19	5.90E-07	6.02E-07	6.18E-07	6.25E-07
U-235	2.42E-08	1.62E-05	8.70E-02	2.34E-08	2.39E-08	2.46E-08	2.48E-08
U-236	1.96E-08	1.32E-05	7.05E-02	1.90E-08	1.94E-08	1.98E-08	2.01E-08
U-238	8.36E-07	5.61E-04	3.01	8.18E-07	8.29E-07	8.45E-07	8.71E-07
Np-237	8.41E-07	5.65E-04	3.02	6.68E-07	7.53E-07	9.39E-07	1.07E-06
Pu-238	1.29E-06	8.65E-04	4.63	1.09E-06	1.19E-06	1.39E-06	1.49E-06
Pu-239	4.27E-05	2.87E-02	154	3.75E-05	4.01E-05	4.54E-05	4.79E-05
Pu-240	7.38E-06	4.95E-03	26.5	6.41E-06	6.89E-06	7.87E-06	8.35E-06
Pu-241	8.94E-05	6.00E-02	321	7.56E-05	8.23E-05	9.65E-05	1.03E-04
Pu-242	4.89E-10	3.28E-07	1.76E-03	4.06E-10	4.47E-10	5.31E-10	5.72E-10
Am-241	5.17E-05	3.47E-02	186	4.21E-05	4.68E-05	5.67E-05	6.14E-05
Am-243	1.99E-09	1.33E-06	7.15E-03	1.61E-09	1.78E-09	2.23E-09	2.43E-09
Cm-242	1.44E-07	9.70E-05	0.519	9.83E-08	9.83E-08	1.65E-07	1.85E-07
Cm-243	1.35E-08	9.06E-06	4.85E-02	9.09E-09	9.09E-09	1.53E-08	1.71E-08
Cm-244	1.10E-07	7.40E-05	0.397	6.50E-08	6.50E-08	1.26E-07	1.35E-07
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	4.81E-04 (g/L)	----	1.73	3.82E-04	4.31E-04	5.31E-04	5.79E-04
U	6.84E-03	1.09E+03	5.86E+03	6.61E-03	6.75E-03	6.95E-03	7.03E-03

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

A-2. Reproduction of Agnew (1997) inventory for Tank A-101. Included in this and the following five tables are estimated 67 and 95 percent confidence intervals (CI). (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-A-101							
Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	5.37E+06 (kg)	(953 kgal)		----	----	----	----
Heat Load	7.29 (kW)	(2.49E+04 BTU/hr)	----	6.66	7.03	7.53	7.88
Bulk Density†	1.49 (g/cc)	----	----	1.44	1.47	1.50	1.51
Water wt%†	42.3	----	----	40.1	40.8	43.6	45.4
TOC wt% C (wet)†	1.19	----	----	0.664	0.921	1.45	1.71
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	2.03E-04	0.136	731	1.35E-04	1.35E-04	2.18E-04	2.37E-04
C-14	3.18E-05	2.14E-02	115	1.76E-05	1.76E-05	3.24E-05	3.29E-05
Ni-59	1.99E-06	1.33E-03	7.16	1.32E-06	1.32E-06	2.04E-06	2.08E-06
Ni-63	1.95E-04	0.131	703	1.29E-04	1.29E-04	2.00E-04	2.04E-04
Co-60	4.02E-05	2.70E-02	145	2.40E-05	2.40E-05	4.13E-05	4.24E-05
Se-79	3.29E-06	2.21E-03	11.9	2.39E-06	2.39E-06	3.62E-06	3.93E-06
Sr-90	0.133	89.5	4.81E+05	0.126	0.131	0.136	0.138
Y-90	0.133	89.6	4.81E+05	0.102	0.102	0.136	0.138
Zr-93	1.61E-05	1.08E-02	58.1	1.16E-05	1.16E-05	1.77E-05	1.93E-05
Nb-93m	1.17E-05	7.87E-03	42.3	8.55E-06	8.55E-06	1.29E-05	1.40E-05
Tc-99	2.41E-04	0.162	869	1.88E-04	2.14E-04	2.71E-04	3.12E-04
Ru-106	7.09E-09	4.76E-06	2.56E-02	4.99E-09	4.99E-09	7.69E-09	8.27E-09
Cd-113m	8.53E-05	5.73E-02	308	5.82E-05	5.82E-05	9.52E-05	1.05E-04
Sb-125	1.80E-04	0.121	651	1.10E-04	1.10E-04	1.87E-04	1.93E-04
Sn-126	4.98E-06	3.35E-03	18.0	3.63E-06	3.63E-06	5.47E-06	5.95E-06
I-129	4.65E-07	3.13E-04	1.68	3.63E-07	4.13E-07	5.24E-07	6.03E-07
Cs-134	3.50E-06	2.35E-03	12.6	2.03E-06	2.75E-06	4.25E-06	4.99E-06
Cs-137	0.240	161	8.66E+05	0.213	0.225	0.254	0.274
Ba-137m	0.227	152	8.19E+05	0.188	0.188	0.240	0.253
Sm-151	1.16E-02	7.79	4.19E+04	8.44E-03	8.44E-03	1.28E-02	1.38E-02
Eu-152	4.46E-06	2.99E-03	16.1	3.34E-06	3.34E-06	4.99E-06	5.52E-06
Eu-154	6.29E-04	0.422	2.27E+03	4.03E-04	4.03E-04	7.10E-04	7.47E-04
Eu-155	2.66E-04	0.179	961	2.00E-04	2.00E-04	2.99E-04	3.31E-04
Ra-226	1.46E-10	9.78E-08	5.25E-04	1.18E-10	1.18E-10	1.56E-10	1.65E-10
Ra-228	3.08E-07	2.07E-04	1.11	8.87E-08	8.87E-08	3.40E-07	3.74E-07
Ac-227	8.78E-10	5.89E-07	3.17E-03	7.15E-10	7.15E-10	9.36E-10	9.93E-10
Pa-231	3.79E-09	2.54E-06	1.37E-02	2.88E-09	2.88E-09	4.11E-09	4.43E-09
Th-229	7.16E-09	4.81E-06	2.58E-02	2.08E-09	2.08E-09	7.85E-09	8.59E-09
Th-232	3.29E-08	2.21E-05	0.119	5.73E-09	5.73E-09	4.03E-08	4.75E-08
U-232	9.37E-07	6.30E-04	3.38	7.24E-07	8.14E-07	1.08E-06	1.23E-06
U-233	3.59E-06	2.41E-03	13.0	2.78E-06	3.12E-06	4.13E-06	4.71E-06
U-234	6.08E-07	4.08E-04	2.19	5.88E-07	6.00E-07	6.16E-07	6.23E-07
U-235	2.41E-08	1.62E-05	8.70E-02	2.33E-08	2.38E-08	2.45E-08	2.48E-08
U-236	1.96E-08	1.31E-05	7.05E-02	1.90E-08	1.93E-08	1.98E-08	2.00E-08
U-238	8.34E-07	5.60E-04	3.01	8.15E-07	8.26E-07	8.42E-07	8.68E-07
Np-237	8.40E-07	5.64E-04	3.03	6.67E-07	7.51E-07	9.38E-07	1.07E-06
Pu-238	1.40E-06	9.39E-04	5.05	1.20E-06	1.30E-06	1.50E-06	1.60E-06
Pu-239	5.00E-05	3.36E-02	181	4.48E-05	4.74E-05	5.27E-05	5.52E-05
Pu-240	8.47E-06	5.69E-03	30.6	7.51E-06	7.98E-06	8.97E-06	9.44E-06
Pu-241	9.75E-05	6.55E-02	352	8.37E-05	9.05E-05	1.05E-04	1.11E-04
Pu-242	5.19E-10	3.49E-07	1.87E-03	4.37E-10	4.77E-10	5.61E-10	6.02E-10
Am-241	5.47E-05	3.68E-02	197	4.51E-05	4.98E-05	5.96E-05	6.43E-05
Am-243	2.01E-09	1.35E-06	7.26E-03	1.63E-09	1.81E-09	2.25E-09	2.46E-09
Cm-242	1.48E-07	9.97E-05	0.536	1.03E-07	1.03E-07	1.69E-07	1.89E-07
Cm-243	1.36E-08	9.11E-06	4.89E-02	9.18E-09	9.18E-09	1.54E-08	1.72E-08
Cm-244	1.10E-07	7.39E-05	0.397	6.48E-08	6.48E-08	1.25E-07	1.35E-07
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	6.03E-04 (g/L)	----	2.18	5.06E-04	5.54E-04	6.54E-04	7.02E-04
U	6.82E-03	1.09E+03	5.86E+03	6.59E-03	6.73E-03	6.93E-03	7.00E-03

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

†Volume average for density, mass average Water wt% and TOC wt% C.

A-3. Tank AW-104

HDW Model Rev. 4

Double-Shell Tank 241-AW-104							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	4.71E+05 (kg)	(103 kgal)	----	----	----	----	----
Heat Load	9.78E-04 (kW)	(3.34 BTU/hr)	----	1.60E-05	5.10E-04	1.46E-03	1.93E-03
Bulk Density	1.21 (g/cc)	----	----	1.12	1.16	1.24	1.27
Void Fraction	0.886	----	----	0.866	0.874	0.910	0.943
Water wt%	72.9	----	----	68.7	70.5	76.4	80.3
TOC wt% C (wet)	3.44E-02	----	----	1.66E-02	2.59E-02	4.27E-02	5.06E-02
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	0.810	1.54E+04	7.25E+03	0.511	0.660	0.960	1.10
Al^{3+}	0	0	0	0	0	0	0
Fe^{3+} (total Fe)	1.83	8.45E+04	3.98E+04	1.70	1.79	1.85	1.87
Cr^{3+}	6.78E-03	292	137	3.05E-03	4.90E-03	8.65E-03	1.05E-02
Bi^{3+}	0	0	0	0	0	0	0
La^{3+}	0	0	0	0	0	0	0
Hg^{2+}	1.02E-04	16.9	7.96	1.57E-07	9.71E-05	1.03E-04	1.04E-04
Zr (as $ZrO(OH)_2$)	4.50E-02	3.40E+03	1.60E+03	6.85E-05	4.36E-02	4.55E-02	4.57E-02
Pb^{2+}	3.68E-05	6.31	2.97	1.65E-05	2.66E-05	4.70E-05	5.68E-05
Ni^{2+}	0.106	5.17E+03	2.43E+03	1.52E-03	7.05E-02	0.126	0.138
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	5.08E-03	231	109	2.28E-03	3.68E-03	6.49E-03	2.26E-02
Ca^{2+}	0.442	1.47E+04	6.91E+03	1.15E-02	0.263	0.540	0.606
K^+	1.51E-02	488	230	5.95E-03	1.06E-02	1.96E-02	2.41E-02
OH^-	6.21	8.74E+04	4.12E+04	5.30	5.72	6.58	6.86
$NO3^-$	0.234	1.20E+04	5.65E+03	0.114	0.174	0.294	0.352
$NO2^-$	8.92E-03	339	160	4.25E-03	6.57E-03	1.13E-02	1.35E-02
$CO3^{2-}$	0.528	2.62E+04	1.24E+04	5.03E-02	0.325	0.650	0.732
$PO4^{3-}$	5.89E-02	4.63E+03	2.18E+03	2.65E-02	4.26E-02	7.52E-02	9.08E-02
$SO4^{2-}$	3.42E-03	272	128	1.54E-03	2.48E-03	4.37E-03	5.28E-03
Si (as SiO_3^{2-})	0	0	0	0	0	0	0
F^-	0.257	4.04E+03	1.90E+03	5.28E-04	0.144	0.294	0.312
Cl^-	3.50E-03	103	48.4	1.68E-03	2.59E-03	4.42E-03	5.30E-03
$C_6H_5O_7^{3-}$	0	0	0	0	0	0	0
$EDTA^{4-}$	0	0	0	0	0	0	0
$HEDTA^{3-}$	0	0	0	0	0	0	0
glycolate$^-$	0	0	0	0	0	0	0
acetate$^-$	0	0	0	0	0	0	0
oxalate^{2-}	0	0	0	0	0	0	0
DBP	2.89E-03	502	236	1.30E-03	2.09E-03	3.68E-03	4.45E-03
butanol	2.89E-03	177	83.4	1.30E-03	2.09E-03	3.68E-03	4.45E-03
NH_3	3.18E-02	447	211	5.28E-04	1.67E-02	4.68E-02	6.13E-02
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

A-3. Tank AW-104 (cont'd)

HDW Model Rev. 4

Double-Shell Tank 241-AW-104							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	3.95E+06 (kg)	(1.02E+03 kgal)	----	----	----	----	----
Heat Load	3.35E-03 (kW)	(11.4 BTU/hr)	----	3.07E-03	3.22E-03	3.45E-03	3.61E-03
Bulk Density*	1.02 (g/cc)	----	----	1.01	1.02	1.03	1.04
Water wt%	95.7	----	----	93.2	94.4	96.8	98.0
TOC wt% C (wet)	4.49E-02	----	----	1.97E-02	3.21E-02	5.76E-02	6.97E-02
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	0.594	1.34E+04	5.28E+04	0.254	0.420	0.769	0.936
Al^{3+}	7.25E-04	19.1	75.5	6.27E-04	7.02E-04	7.48E-04	7.70E-04
Fe^{3+} (total Fe)	1.84E-03	100	396	1.02E-03	1.42E-03	2.26E-03	2.66E-03
Cr^{3+}	7.39E-03	376	1.48E+03	3.14E-03	5.22E-03	9.57E-03	1.17E-02
Bi^{3+}	5.23E-07	0.107	0.422	4.93E-07	5.07E-07	5.38E-07	5.56E-07
La^{3+}	7.39E-09	1.00E-03	3.97E-03	5.46E-09	6.40E-09	8.39E-09	9.34E-09
Hg^{2+}	6.60E-09	1.30E-03	5.11E-03	4.89E-09	6.47E-09	6.73E-09	6.86E-09
Zr (as $ZrO(OH)_2$)	8.31E-07	7.41E-02	0.293	4.27E-07	7.80E-07	8.81E-07	9.30E-07
Pb^{2+}	4.04E-05	8.20	32.3	1.73E-05	2.86E-05	5.22E-05	6.36E-05
Ni^{2+}	1.65E-03	94.9	374	1.49E-03	1.57E-03	1.74E-03	1.82E-03
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	5.51E-03	296	1.17E+03	2.32E-03	3.88E-03	7.14E-03	8.25E-03
Ca^{2+}	8.27E-03	324	1.28E+03	5.05E-03	6.62E-03	9.90E-03	1.15E-02
K^+	6.38E-03	244	962	2.73E-03	4.52E-03	8.24E-03	1.00E-02
OH^-	3.87E-02	644	2.54E+03	2.61E-02	3.52E-02	4.00E-02	4.12E-02
$NO3^-$	0.238	1.44E+04	5.70E+04	0.101	0.168	0.308	0.375
$NO2^-$	1.01E-02	457	1.80E+03	4.83E-03	7.43E-03	1.29E-02	1.55E-02
$CO3^{2-}$	0.102	6.00E+03	2.37E+04	4.67E-02	7.45E-02	0.130	0.157
$PO4^{3-}$	6.39E-02	5.93E+03	2.34E+04	2.69E-02	4.50E-02	8.28E-02	0.101
$SO4^{2-}$	3.83E-03	360	1.42E+03	1.68E-03	2.73E-03	4.93E-03	5.99E-03
Si (as SiO_3^{2-})	3.58E-05	0.983	3.88	3.05E-05	3.31E-05	3.84E-05	4.08E-05
F^-	8.87E-05	1.65	6.51	3.05E-05	7.89E-05	9.85E-05	1.08E-04
Cl^-	3.70E-03	128	506	1.62E-03	2.64E-03	4.76E-03	5.79E-03
$C_6H_5O_7^{3-}$	1.53E-05	2.83	11.2	1.27E-05	1.40E-05	1.66E-05	1.79E-05
$EDTA^{4-}$	1.19E-05	3.35	13.2	3.92E-06	7.82E-06	1.60E-05	2.00E-05
$HEDTA^{3-}$	2.12E-05	5.68	22.4	5.23E-06	1.30E-05	2.94E-05	3.74E-05
glycolate$^-$	8.77E-05	6.44	25.4	5.36E-05	7.03E-05	1.05E-04	1.22E-04
acetate$^-$	8.35E-06	0.482	1.90	6.70E-06	7.40E-06	9.36E-06	1.09E-05
oxalate^{2-}	9.69E-09	8.34E-04	3.29E-03	8.64E-09	9.15E-09	1.02E-08	1.07E-08
DBP	3.14E-03	645	2.55E+03	1.33E-03	2.21E-03	4.07E-03	4.96E-03
butanol	3.14E-03	228	898	1.33E-03	2.21E-03	4.07E-03	4.96E-03
NH_3	2.23E-04	3.71	14.7	2.75E-05	1.22E-04	3.26E-04	4.28E-04
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

A-3. Tank AW-104 (cont'd)

HDW Model Rev. 4

Double-Shell Tank 241-AW-104							
Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	4.42E+06 (kg)	(1.12E+03 kgal)	----	----	----	----	----
Heat Load	4.32E-03 (kW)	(14.8 BTU/hr)	----	3.30E-03	3.83E-03	4.83E-03	5.33E-03
Bulk Density†	1.04 (g/cc)	----	----	1.02	1.03	1.05	1.06
Water wt%†	93.2	----	----	90.6	91.8	94.7	96.2
TOC wt% C (wet)†	4.38E-02	----	----	1.94E-02	3.15E-02	5.60E-02	6.76E-02
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^{+}	0.614	1.36E+04	6.00E+04	0.277	0.442	0.786	0.952
Al^{3+}	6.59E-04	17.1	75.5	5.70E-04	6.38E-04	6.79E-04	6.99E-04
Fe^{3+} (total Fe)	0.169	9.09E+03	4.02E+04	0.157	0.166	0.171	0.172
Cr^{3+}	7.34E-03	367	1.62E+03	3.13E-03	5.19E-03	9.49E-03	1.16E-02
Bi^{3+}	4.75E-07	9.55E-02	0.422	4.48E-07	4.61E-07	4.88E-07	5.05E-07
La^{3+}	6.72E-09	8.98E-04	3.97E-03	4.96E-09	5.82E-09	7.62E-09	8.49E-09
Hg^{2+}	9.34E-06	1.80	7.97	1.88E-08	8.91E-06	9.48E-06	9.55E-06
Zr (as $ZrO(OH)_2$)	4.13E-03	362	1.60E+03	6.67E-06	4.00E-03	4.17E-03	4.19E-03
Pb^{2+}	4.01E-05	7.99	35.3	1.73E-05	2.84E-05	5.18E-05	6.30E-05
Ni^{2+}	1.13E-02	636	2.81E+03	1.55E-03	7.96E-03	1.30E-02	1.41E-02
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	5.47E-03	289	1.28E+03	2.32E-03	3.86E-03	7.08E-03	9.57E-03
Ca^{2+}	4.80E-02	1.85E+03	8.19E+03	7.39E-03	3.16E-02	5.70E-02	6.24E-02
K^{+}	7.17E-03	270	1.19E+03	3.57E-03	5.34E-03	9.01E-03	1.08E-02
OH^{-}	0.605	9.90E+03	4.37E+04	0.510	0.556	0.639	0.664
$NO3^{-}$	0.238	1.42E+04	6.26E+04	0.103	0.169	0.307	0.373
$NO2^{-}$	1.00E-02	444	1.96E+03	4.78E-03	7.35E-03	1.27E-02	1.53E-02
$CO3^{2-}$	0.141	8.16E+03	3.60E+04	4.70E-02	9.75E-02	0.178	0.209
$PO4^{3-}$	6.34E-02	5.80E+03	2.56E+04	2.69E-02	4.48E-02	8.21E-02	0.100
$SO4^{2-}$	3.79E-03	351	1.55E+03	1.67E-03	2.71E-03	4.88E-03	5.92E-03
Si (as SiO_3^{2-})	3.25E-05	0.878	3.88	2.77E-05	3.01E-05	3.49E-05	3.70E-05
F^{-}	2.36E-02	432	1.91E+03	7.61E-05	1.33E-02	2.70E-02	2.87E-02
Cl^{-}	3.68E-03	126	554	1.63E-03	2.63E-03	4.73E-03	5.74E-03
$C_6H_5O_7^{3-}$	1.39E-05	2.53	11.2	1.16E-05	1.27E-05	1.51E-05	1.62E-05
$EDTA^{4-}$	1.08E-05	2.99	13.2	3.56E-06	7.10E-06	1.45E-05	1.82E-05
$HEDTA^{3-}$	1.92E-05	5.07	22.4	4.75E-06	1.18E-05	2.67E-05	3.39E-05
glycolate^{-}	7.97E-05	5.75	25.4	4.87E-05	6.38E-05	9.56E-05	1.11E-04
acetate^{-}	7.58E-06	0.431	1.90	6.09E-06	6.73E-06	8.50E-06	9.91E-06
oxalate^{2-}	8.80E-09	7.45E-04	3.29E-03	7.84E-09	8.31E-09	9.28E-09	9.75E-09
DBP	3.12E-03	630	2.78E+03	1.32E-03	2.20E-03	4.03E-03	4.91E-03
butanol	3.12E-03	222	981	1.32E-03	2.20E-03	4.03E-03	4.91E-03
NH_3	3.12E-03	51.0	225	7.34E-05	1.65E-03	4.59E-03	6.01E-03
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

†Water wt% derived from the difference of density and total dissolved species.

A-3. Tank AW-104 (cont'd)

HDW Model Rev. 4

Double-Shell Tank 241-AW-104							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	4.71E+05 (kg)	(103 kgal)	----	----	----	----	----
Heat Load	9.78E-04 (kW)	(3.34 BTU/hr)	----	1.60E-05	5.10E-04	1.46E-03	1.93E-03
Bulk Density	1.21 (g/cc)	----	----	1.12	1.16	1.24	1.27
Void Fraction	0.886	----	----	0.866	0.874	0.910	0.943
Water wt%	72.9	----	----	68.7	70.5	76.4	80.3
TOC wt% C (wet)	3.44E-02	----	----	1.66E-02	2.59E-02	4.27E-02	5.06E-02
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	8.48E-07	7.01E-04	0.330	1.39E-08	4.41E-07	1.26E-06	1.67E-06
C-14	1.04E-08	8.64E-06	4.07E-03	1.71E-10	5.44E-09	1.55E-08	2.06E-08
Ni-59	6.88E-09	5.70E-06	2.68E-03	6.88E-09	6.88E-09	6.88E-09	6.88E-09
Ni-63	7.96E-07	6.58E-04	0.310	7.96E-07	7.96E-07	7.96E-07	7.96E-07
Co-60	1.61E-07	1.33E-04	6.27E-02	2.63E-09	8.38E-08	2.40E-07	3.17E-07
Sc-79	1.30E-09	1.08E-06	5.09E-04	2.13E-11	6.80E-10	1.94E-09	2.57E-09
Sr-90	2.05E-04	0.169	79.7	3.34E-06	1.07E-04	3.05E-04	4.03E-04
Y-90	2.05E-04	0.169	79.8	3.35E-06	1.07E-04	3.05E-04	4.03E-04
Zr-93	6.29E-09	5.21E-06	2.45E-03	1.03E-10	3.28E-09	9.37E-09	1.24E-08
Nb-93m	2.66E-09	2.20E-06	1.04E-03	4.34E-11	1.38E-09	3.96E-09	5.23E-09
Tc-99	4.36E-08	3.61E-05	1.70E-02	7.13E-10	2.27E-08	6.49E-08	8.59E-08
Ru-106	2.51E-05	2.08E-02	9.78	2.49E-05	2.51E-05	2.51E-05	2.51E-05
Cd-113m	6.79E-08	5.62E-05	2.65E-02	1.11E-09	3.54E-08	1.01E-07	1.34E-07
Sb-125	3.90E-06	3.23E-03	1.52	6.37E-08	2.03E-06	5.81E-06	7.68E-06
Sn-126	2.06E-09	1.70E-06	8.02E-04	3.36E-11	1.07E-09	3.06E-09	4.05E-09
I-129	8.75E-11	7.25E-08	3.41E-05	1.43E-12	4.56E-11	1.30E-10	1.72E-10
Cs-134	1.73E-06	1.43E-03	0.674	2.83E-08	9.01E-07	2.58E-06	3.41E-06
Cs-137	2.42E-04	0.200	94.1	3.95E-06	1.26E-04	3.60E-04	4.76E-04
Ba-137m	2.29E-04	0.189	89.1	3.73E-06	1.19E-04	3.40E-04	4.50E-04
Sm-151	4.51E-06	3.73E-03	1.76	7.38E-08	2.35E-06	6.72E-06	8.89E-06
Eu-152	5.08E-08	4.21E-05	1.98E-02	4.67E-08	4.88E-08	5.29E-08	5.49E-08
Eu-154	1.20E-06	9.95E-04	0.469	1.97E-08	6.27E-07	1.79E-06	2.37E-06
Eu-155	9.23E-06	7.64E-03	3.60	8.47E-06	8.86E-06	9.60E-06	9.97E-06
Ra-226	1.05E-14	8.70E-12	4.10E-09	1.72E-16	5.48E-15	1.57E-14	2.07E-14
Ra-228	4.61E-18	3.81E-15	1.80E-12	4.23E-18	4.42E-18	4.79E-18	4.98E-18
Ac-227	6.05E-14	5.00E-11	2.36E-08	9.88E-16	3.15E-14	9.01E-14	1.19E-13
Pa-231	3.45E-13	2.86E-10	1.34E-07	5.64E-15	1.80E-13	5.14E-13	6.80E-13
Th-229	5.27E-16	4.36E-13	2.05E-10	4.84E-16	5.06E-16	5.48E-16	5.69E-16
Th-232	1.76E-18	1.46E-15	6.87E-13	2.88E-20	9.18E-19	2.62E-18	3.47E-18
U-232	1.42E-09	1.18E-06	5.53E-04	9.90E-11	1.29E-10	2.53E-09	3.21E-09
U-233	1.46E-11	1.21E-08	5.68E-06	1.01E-12	1.32E-12	2.60E-11	3.29E-11
U-234	6.39E-06	5.29E-03	2.49	4.45E-07	5.80E-07	1.14E-05	1.44E-05
U-235	2.43E-07	2.01E-04	9.46E-02	1.69E-08	2.21E-08	4.33E-07	5.49E-07
U-236	5.26E-07	4.35E-04	0.205	3.66E-08	4.78E-08	9.38E-07	1.19E-06
U-238	4.38E-06	3.63E-03	1.71	3.06E-07	3.98E-07	7.82E-06	9.91E-06
Np-237	6.39E-10	5.28E-07	2.49E-04	1.04E-11	3.33E-10	9.51E-10	1.26E-09
Pu-238	2.70E-04	0.223	105	2.02E-04	2.49E-04	2.87E-04	3.04E-04
Pu-239	2.19E-03	1.81	853	1.64E-03	2.02E-03	2.33E-03	2.47E-03
Pu-240	6.64E-04	0.550	259	4.98E-04	6.13E-04	7.08E-04	7.49E-04
Pu-241	2.76E-02	22.8	1.07E+04	2.07E-02	2.55E-02	2.94E-02	3.11E-02
Pu-242	1.03E-07	8.51E-05	4.01E-02	7.70E-08	9.49E-08	1.10E-07	1.16E-07
Am-241	8.04E-07	6.65E-04	0.313	1.31E-08	4.19E-07	1.20E-06	5.25E-06
Am-243	1.69E-10	1.40E-07	6.60E-05	2.77E-12	8.82E-11	2.52E-10	1.11E-09
Cm-242	4.48E-09	3.71E-06	1.75E-03	4.11E-09	4.30E-09	4.66E-09	4.84E-09
Cm-243	7.50E-10	6.21E-07	2.92E-04	6.89E-10	7.20E-10	7.81E-10	8.11E-10
Cm-244	3.08E-09	2.55E-06	1.20E-03	5.04E-11	1.61E-09	8.08E-09	2.20E-08
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	3.84E-02 (g/L)	----	15.0	2.88E-02	3.55E-02	4.09E-02	4.33E-02
U	5.53E-02	1.09E+04	5.13E+03	3.85E-03	5.03E-03	9.87E-02	0.125

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

HDW Model Rev. 4

Double-Shell Tank 241-AW-104							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	3.95E+06 (kg)	(1.02E+03 kgal)	----	----	----	----	----
Heat Load	3.35E-03 (kW)	(11.4 BTU/hr)	----	3.07E-03	3.22E-03	3.45E-03	3.61E-03
Bulk Density*	1.02 (g/cc)	----	----	1.01	1.02	1.03	1.04
Water wt%†	95.7	----	----	93.2	94.4	96.8	98.0
TOC wt% C (wet)	4.49E-02	----	----	1.97E-02	3.21E-02	5.76E-02	6.97E-02
Radiological Constituents	**Ci/L**	**pCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	1.06E-07	1.04E-04	0.411	7.54E-08	7.54E-08	1.13E-07	1.20E-07
C-14	1.47E-08	1.44E-05	5.67E-02	8.18E-09	8.18E-09	1.49E-08	1.52E-08
Ni-59	8.12E-10	7.94E-07	3.13E-03	5.06E-10	5.06E-10	8.27E-10	8.42E-10
Ni-63	7.99E-08	7.81E-05	0.308	4.97E-08	4.97E-08	8.14E-08	8.29E-08
Co-60	1.96E-08	1.92E-05	7.57E-02	1.22E-08	1.22E-08	2.01E-08	2.06E-08
Se-79	1.65E-09	1.61E-06	6.36E-03	1.23E-09	1.23E-09	1.80E-09	1.94E-09
Sr-90	5.24E-05	5.12E-02	202	4.92E-05	5.13E-05	5.34E-05	5.44E-05
Y-90	5.24E-05	5.12E-02	202	3.81E-05	3.81E-05	5.34E-05	5.44E-05
Zr-93	8.01E-09	7.84E-06	3.09E-02	5.94E-09	5.94E-09	8.76E-09	9.48E-09
Nb-93m	5.84E-09	5.71E-06	2.25E-02	4.39E-09	4.39E-09	6.36E-09	6.87E-09
Tc-99	1.10E-07	1.08E-04	0.426	8.61E-08	9.80E-08	1.23E-07	1.41E-07
Ru-106	5.44E-12	5.32E-09	2.10E-05	4.33E-12	4.48E-12	6.00E-12	6.54E-12
Cd-113m	4.18E-08	4.09E-05	0.161	2.94E-08	2.94E-08	4.63E-08	5.06E-08
Sb-125	1.15E-07	1.13E-04	0.444	8.29E-08	8.29E-08	1.28E-07	1.40E-07
Sn-126	2.50E-09	2.45E-06	9.66E-03	1.88E-09	1.88E-09	2.73E-09	2.94E-09
I-129	2.13E-10	2.09E-07	8.23E-04	1.66E-10	1.89E-10	2.38E-10	2.73E-10
Cs-134	1.94E-08	1.90E-05	7.49E-02	8.90E-09	1.40E-08	2.49E-08	3.03E-08
Cs-137	1.10E-04	0.107	424	9.81E-05	1.03E-04	1.16E-04	1.25E-04
Ba-137m	1.04E-04	0.102	401	8.70E-05	8.70E-05	1.09E-04	1.14E-04
Sm-151	5.82E-06	5.69E-03	22.5	4.37E-06	4.37E-06	6.34E-06	6.85E-06
Eu-152	2.09E-09	2.05E-06	8.09E-03	1.58E-09	1.58E-09	2.31E-09	2.53E-09
Eu-154	3.09E-07	3.02E-04	1.19	2.05E-07	2.05E-07	3.46E-07	3.61E-07
Eu-155	1.30E-07	1.27E-04	0.503	9.96E-08	9.96E-08	1.44E-07	1.57E-07
Ra-226	6.81E-14	6.66E-11	2.63E-07	5.44E-14	5.52E-14	7.51E-14	7.72E-14
Ra-228	1.48E-10	1.45E-07	5.71E-04	5.29E-11	5.29E-11	1.67E-10	1.87E-10
Ac-227	4.24E-13	4.15E-10	1.64E-06	3.45E-13	3.50E-13	4.64E-13	4.77E-13
Pa-231	1.88E-12	1.84E-09	7.26E-06	1.47E-12	1.47E-12	2.03E-12	2.17E-12
Th-229	3.43E-12	3.36E-09	1.33E-05	1.24E-12	1.24E-12	3.85E-12	4.29E-12
Th-232	1.51E-11	1.48E-08	5.84E-05	3.38E-12	3.38E-12	1.83E-11	2.14E-11
U-232	5.71E-10	5.59E-07	2.20E-03	4.44E-10	5.06E-10	6.47E-10	7.27E-10
U-233	1.83E-09	1.79E-06	7.06E-03	1.34E-09	1.58E-09	2.12E-09	2.43E-09
U-234	4.24E-07	4.14E-04	1.64	2.25E-07	3.77E-07	4.45E-07	4.66E-07
U-235	1.61E-08	1.58E-05	6.22E-02	8.57E-09	1.43E-08	1.69E-08	1.77E-08
U-236	3.49E-08	3.41E-05	0.135	1.85E-08	3.10E-08	3.66E-08	3.83E-08
U-238	2.91E-07	2.85E-04	1.12	1.55E-07	2.59E-07	3.06E-07	3.20E-07
Np-237	3.91E-10	3.83E-07	1.51E-03	3.12E-10	3.51E-10	4.33E-10	4.91E-10
Pu-238	9.54E-07	9.33E-04	3.68	2.78E-07	6.09E-07	1.30E-06	1.63E-06
Pu-239	7.74E-06	7.58E-03	29.9	2.27E-06	4.95E-06	1.05E-05	1.32E-05
Pu-240	2.35E-06	2.30E-03	9.07	6.87E-07	1.50E-06	3.20E-06	4.01E-06
Pu-241	9.74E-05	9.53E-02	376	2.84E-05	6.22E-05	1.33E-04	1.66E-04
Pu-242	3.63E-10	3.55E-07	1.40E-03	1.06E-10	2.32E-10	4.95E-10	6.21E-10
Am-241	3.55E-08	3.47E-05	0.137	2.89E-08	3.21E-08	3.89E-08	4.12E-08
Am-243	2.40E-12	2.35E-09	9.26E-06	1.37E-12	1.87E-12	2.94E-12	3.01E-12
Cm-242	7.73E-11	7.56E-08	2.98E-04	5.62E-11	5.62E-11	8.57E-11	9.39E-11
Cm-243	7.64E-12	7.47E-09	2.95E-05	5.63E-12	5.63E-12	8.39E-12	9.13E-12
Cm-244	8.86E-11	8.67E-08	3.42E-04	6.65E-11	6.79E-11	9.99E-11	1.11E-10
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	1.36E-04 (g/L)	----	0.525	3.97E-05	8.68E-05	1.85E-04	2.32E-04
U	3.67E-03	854	3.37E+03	1.95E-03	3.26E-03	3.86E-03	4.04E-03

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

A-3. Tank AW-104 (cont'd)

HDW Model Rev. 4

Double-Shell Tank 241-AW-104 Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	4.42E+06 (kg)	(1.12E+03 kgal)	----	----	----	----	----
Heat Load	4.32E-03 (kW)	(14.8 BTU/hr)	----	3.30E-03	3.83E-03	4.83E-03	5.33E-03
Bulk Density†	1.04 (g/cc)	----	----	1.02	1.03	1.05	1.06
Water wt%†	93.2	----	----	90.6	91.8	94.7	96.2
TOC wt% C (wet)††	4.38E-02	----	----	1.94E-02	3.15E-02	5.60E-02	6.76E-02
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	1.74E-07	1.68E-04	0.741	9.33E-08	1.35E-07	2.15E-07	2.55E-07
C-14	1.43E-08	1.37E-05	6.07E-02	8.39E-09	8.39E-09	1.48E-08	1.53E-08
Ni-59	1.37E-09	1.32E-06	5.82E-03	1.09E-09	1.09E-09	1.38E-09	1.40E-09
Ni-63	1.45E-07	1.40E-04	0.618	1.18E-07	1.18E-07	1.47E-07	1.48E-07
Co-60	3.26E-08	3.13E-05	0.138	1.72E-08	2.50E-08	4.03E-08	4.78E-08
Se-79	1.62E-09	1.56E-06	6.87E-03	1.24E-09	1.24E-09	1.75E-09	1.88E-09
Sr-90	6.63E-05	6.38E-02	282	4.67E-05	5.67E-05	7.61E-05	8.57E-05
Y-90	6.63E-05	6.38E-02	282	4.67E-05	5.33E-05	7.61E-05	8.57E-05
Zr-93	7.86E-09	7.56E-06	3.34E-02	5.97E-09	5.97E-09	8.54E-09	9.19E-09
Nb-93m	5.54E-09	5.34E-06	2.36E-02	4.23E-09	4.23E-09	6.02E-09	6.48E-09
Tc-99	1.04E-07	1.00E-04	0.443	8.22E-08	9.30E-08	1.16E-07	1.32E-07
Ru-106	2.30E-06	2.21E-03	9.78	2.29E-06	2.30E-06	2.30E-06	2.30E-06
Cd-113m	4.42E-08	4.25E-05	0.188	3.29E-08	3.29E-08	4.83E-08	5.22E-08
Sb-125	4.62E-07	4.45E-04	1.96	8.89E-08	2.80E-07	6.48E-07	8.31E-07
Sn-126	2.46E-09	2.37E-06	1.05E-02	1.90E-09	1.90E-09	2.67E-09	2.86E-09
I-129	2.02E-10	1.94E-07	8.57E-04	1.59E-10	1.80E-10	2.25E-10	2.56E-10
Cs-134	1.76E-07	1.70E-04	0.749	1.07E-08	9.53E-08	2.59E-07	3.40E-07
Cs-137	1.22E-04	0.117	518	9.87E-05	1.10E-04	1.33E-04	1.45E-04
Ba-137m	1.15E-04	0.111	490	9.33E-05	1.00E-04	1.26E-04	1.37E-04
Sm-151	5.70E-06	5.48E-03	24.2	4.38E-06	4.38E-06	6.17E-06	6.63E-06
Eu-152	6.56E-09	6.32E-06	2.79E-02	6.10E-09	6.10E-09	6.77E-09	6.96E-09
Eu-154	3.91E-07	3.76E-04	1.66	2.76E-07	2.97E-07	4.48E-07	5.05E-07
Eu-155	9.64E-07	9.28E-04	4.10	8.91E-07	9.28E-07	1.00E-06	1.04E-06
Ra-226	6.28E-14	6.04E-11	2.67E-07	5.04E-14	5.11E-14	6.92E-14	7.11E-14
Ra-228	1.34E-10	1.29E-07	5.71E-04	4.80E-11	4.80E-11	1.52E-10	1.70E-10
Ac-227	3.91E-13	3.76E-10	1.66E-06	3.19E-13	3.23E-13	4.27E-13	4.39E-13
Pa-231	1.74E-12	1.67E-09	7.39E-06	1.36E-12	1.36E-12	1.88E-12	2.01E-12
Th-229	3.12E-12	3.00E-09	1.33E-05	1.12E-12	1.12E-12	3.49E-12	3.89E-12
Th-232	1.37E-11	1.32E-08	5.84E-05	3.07E-12	3.07E-12	1.67E-11	1.95E-11
U-232	6.49E-10	6.24E-07	2.76E-03	4.88E-10	5.21E-10	7.51E-10	8.13E-10
U-233	1.66E-09	1.60E-06	7.07E-03	1.22E-09	1.44E-09	1.93E-09	2.21E-09
U-234	9.70E-07	9.34E-04	4.12	2.46E-07	3.96E-07	1.43E-06	1.71E-06
U-235	3.69E-08	3.55E-05	0.157	9.34E-09	1.50E-08	5.43E-08	6.49E-08
U-236	7.99E-08	7.69E-05	0.339	2.02E-08	3.25E-08	1.18E-07	1.41E-07
U-238	6.66E-07	6.41E-04	2.83	1.69E-07	2.72E-07	9.82E-07	1.17E-06
Np-237	4.14E-10	3.98E-07	1.76E-03	3.42E-10	3.77E-10	4.52E-10	5.05E-10
Pu-238	2.56E-05	2.47E-02	109	1.94E-05	2.37E-05	2.69E-05	2.82E-05
Pu-239	2.08E-04	0.200	882	1.57E-04	1.92E-04	2.18E-04	2.28E-04
Pu-240	6.31E-05	6.07E-02	268	4.78E-05	5.84E-05	6.62E-05	6.93E-05
Pu-241	2.62E-03	2.52	1.11E+04	1.98E-03	2.42E-03	2.75E-03	2.88E-03
Pu-242	9.76E-09	9.39E-06	4.15E-02	7.39E-09	9.04E-09	1.03E-08	1.07E-08
Am-241	1.06E-07	1.02E-04	0.450	2.90E-08	6.84E-08	1.44E-07	5.11E-07
Am-243	1.77E-11	1.70E-08	7.53E-05	1.50E-12	9.79E-12	2.58E-11	1.03E-10
Cm-242	4.81E-10	4.63E-07	2.04E-03	4.45E-10	4.62E-10	4.99E-10	5.16E-10
Cm-243	7.57E-11	7.29E-08	3.22E-04	6.98E-11	7.28E-11	7.87E-11	8.16E-11
Cm-244	3.63E-10	3.49E-07	1.54E-03	6.81E-11	2.19E-10	8.28E-10	2.08E-09
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	3.65E-03 (g/L)	----	15.5	2.76E-03	3.38E-03	3.83E-03	4.01E-03
U	8.40E-03	1.92E+03	8.50E+03	2.13E-03	3.43E-03	1.24E-02	1.48E-02

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

†Volume average for density, mass average Water wt% and TOC wt% C.

A-4. Tank BY-106

HDW Model Rev. 4

Single-Shell Tank 241-BY-106							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	4.00E+06 (kg)	(642 kgal)	----	----	----	----	----
Heat Load	4.63 (kW)	(1.58E+04 BTU/hr)	----	3.41	4.09	5.00	5.19
Bulk Density	1.65 (g/cc)	----	----	1.38	1.52	1.75	1.85
Void Fraction	0.741	----	----	0.485	0.646	0.852	0.922
Water wt%	35.0	----	----	18.2	26.5	45.9	55.2
TOC wt% C (wet)	0.447	----	----	0.365	0.429	0.470	0.478
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	13.0	1.81E+05	7.26E+05	7.63	10.2	15.2	17.7
Al^{3+}	1.79	2.93E+04	1.17E+05	0.772	1.11	2.62	3.42
Fe^{3+} (total Fe)	0.159	5.40E+03	2.16E+04	0.151	0.155	0.163	0.167
Cr^{3+}	4.69E-02	1.48E+03	5.92E+03	3.75E-02	4.24E-02	4.87E-02	5.04E-02
Bi^{3+}	4.11E-02	5.21E+03	2.09E+04	3.97E-02	4.04E-02	4.18E-02	4.25E-02
La^{3+}	1.73E-06	0.146	0.585	1.43E-06	1.62E-06	1.80E-06	1.77E-06
Hg^{2+}	3.07E-05	3.74	15.0	2.76E-05	2.91E-05	3.23E-05	3.38E-05
Zr (as $ZrO(OH)_2$)	2.88E-05	1.59	6.38	2.37E-05	2.62E-05	2.98E-05	2.98E-05
Pb^{2+}	4.81E-03	604	2.42E+03	2.62E-03	3.69E-03	5.92E-03	6.99E-03
Ni^{2+}	3.18E-02	1.13E+03	4.53E+03	2.79E-02	2.99E-02	3.27E-02	3.28E-02
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	2.75E-03	91.6	367	2.02E-03	2.38E-03	3.12E-03	3.47E-03
Ca^{2+}	0.105	2.54E+03	1.02E+04	8.07E-02	9.24E-02	0.117	0.128
K^+	3.52E-02	835	3.34E+03	2.58E-02	3.10E-02	3.87E-02	3.62E-02
OH^-	8.66	8.93E+04	3.58E+05	4.36	5.86	12.0	15.1
$NO3^-$	7.08	2.67E+05	1.07E+06	3.97	5.57	8.04	8.95
$NO2^-$	1.63	4.54E+04	1.82E+05	1.03	1.34	1.83	2.47
$CO3^{2-}$	0.471	1.71E+04	6.87E+04	0.338	0.380	0.560	0.608
$PO4^{3-}$	0.110	6.32E+03	2.53E+04	9.94E-02	0.106	0.113	0.128
$SO4^{2-}$	0.179	1.05E+04	4.19E+04	0.109	0.145	0.209	0.286
Si (as SiO_3^{2-})	7.45E-02	1.27E+03	5.08E+03	4.80E-02	6.22E-02	9.33E-02	0.111
F^-	6.53E-02	753	3.01E+03	5.49E-02	5.99E-02	9.14E-02	0.173
Cl^-	0.118	2.54E+03	1.02E+04	6.65E-02	9.18E-02	0.123	0.123
$C_6H_5O_7^{3-}$	2.03E-02	2.32E+03	9.31E+03	1.67E-02	1.97E-02	2.06E-02	2.07E-02
$EDTA^{4-}$	4.55E-03	795	3.18E+03	4.01E-03	4.38E-03	4.63E-03	4.64E-03
$HEDTA^{3-}$	6.14E-04	102	409	1.85E-04	4.18E-04	7.71E-04	7.84E-04
glycolate$^-$	1.43E-02	649	2.60E+03	7.22E-03	1.11E-02	1.67E-02	1.63E-02
acetate$^-$	2.71E-02	969	3.88E+03	2.36E-02	2.66E-02	2.73E-02	2.76E-02
oxalate^{2-}	2.27E-06	0.121	0.486	1.66E-06	2.07E-06	2.48E-06	2.59E-06
DBP	2.15E-02	2.74E+03	1.10E+04	1.86E-02	2.05E-02	2.21E-02	2.20E-02
butanol	2.15E-02	968	3.87E+03	1.86E-02	2.05E-02	2.21E-02	2.20E-02
NH_3	5.48E-02	565	2.26E+03	3.20E-02	4.50E-02	5.82E-02	5.94E-02
$Fe(CN)_6^{4-}$	1.67E-02	2.75E+03	1.10E+04	1.67E-02	1.67E-02	1.67E-02	1.67E-02

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

A-4. Tank BY-106 (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-BY-106							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	0 (kg)	(6.00E-03 kgal)	----	----	----	----	----
Heat Load	0 (kW)	(0 BTU/hr)	----	0	0	0	0
Bulk Density*	0 (g/cc)	----	----	0	0	0	0
Water wt%	0	----	----	0	0	0	0
TOC wt% C (wet)	0	----	----	0	0	0	0
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	0	0	0	0	0	0	0
Al^{3+}	0	0	0	0	0	0	0
Fe^{3+} (total Fe)	0	0	0	0	0	0	0
Cr^{3+}	0	0	0	0	0	0	0
Bi^{3+}	0	0	0	0	0	0	0
La^{3+}	0	0	0	0	0	0	0
Hg^{2+}	0	0	0	0	0	0	0
Zr (as $ZrO(OH)_2$)	0	0	0	0	0	0	0
Pb^{2+}	0	0	0	0	0	0	0
Ni^{2+}	0	0	0	0	0	0	0
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	0	0	0	0	0	0	0
Ca^{2+}	0	0	0	0	0	0	0
K^+	0	0	0	0	0	0	0
OH^-	0	0	0	0	0	0	0
$NO3^-$	0	0	0	0	0	0	0
$NO2^-$	0	0	0	0	0	0	0
$CO3^{2-}$	0	0	0	0	0	0	0
$PO4^{3-}$	0	0	0	0	0	0	0
$SO4^{2-}$	0	0	0	0	0	0	0
Si (as SiO_3^{2-})	0	0	0	0	0	0	0
F^-	0	0	0	0	0	0	0
Cl^-	0	0	0	0	0	0	0
$C_6H_5O_7^{3-}$	0	0	0	0	0	0	0
$EDTA^{4-}$	0	0	0	0	0	0	0
$HEDTA^{3-}$	0	0	0	0	0	0	0
glycolate$^-$	0	0	0	0	0	0	0
acetate$^-$	0	0	0	0	0	0	0
oxalate^{2-}	0	0	0	0	0	0	0
DBP	0	0	0	0	0	0	0
butanol	0	0	0	0	0	0	0
NH_3	0	0	0	0	0	0	0
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

A-4. Tank BY-106 (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-BY-106 Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	4.00E+06 (kg)	(642 kgal)	----	----	----	----	----
Heat Load	4.63 (kW)	(1.58E+04 BTU/hr)	----	3.41	4.09	5.00	5.19
Bulk Density†	1.65 (g/cc)	----	----	1.38	1.52	1.75	1.85
Water wt%†	35.0	----	----	18.2	26.5	45.9	55.2
TOC wt% C (wet)†	0.447	----	----	0.365	0.429	0.470	0.478
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	13.0	1.81E+05	7.26E+05	7.63	10.2	15.2	17.7
Al^{3+}	1.79	2.93E+04	1.17E+05	0.772	1.11	2.62	3.42
Fe^{3+} (total Fe)	0.159	5.40E+03	2.16E+04	0.151	0.155	0.163	0.167
Cr^{3+}	4.69E-02	1.48E+03	5.92E+03	3.75E-02	4.24E-02	4.87E-02	5.04E-02
Bi^{3+}	4.11E-02	5.21E+03	2.09E+04	3.97E-02	4.04E-02	4.18E-02	4.25E-02
La^{3+}	1.73E-06	0.146	0.585	1.43E-06	1.62E-06	1.80E-06	1.77E-06
Hg^{2+}	3.07E-05	3.74	15.0	2.76E-05	2.91E-05	3.23E-05	3.38E-05
Zr (as $ZrO(OH)_2$)	2.88E-05	1.59	6.38	2.37E-05	2.62E-05	2.98E-05	2.98E-05
Pb^{2+}	4.81E-03	604	2.42E+03	2.62E-03	3.69E-03	5.92E-03	6.99E-03
Ni^{2+}	3.18E-02	1.13E+03	4.53E+03	2.79E-02	2.99E-02	3.27E-02	3.28E-02
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	2.75E-03	91.6	367	2.02E-03	2.38E-03	3.12E-03	3.47E-03
Ca^{2+}	0.105	2.54E+03	1.02E+04	8.07E-02	9.24E-02	0.117	0.128
K^+	3.52E-02	835	3.34E+03	2.58E-02	3.10E-02	3.87E-02	3.62E-02
OH^-	8.66	8.93E+04	3.58E+05	4.36	5.86	12.0	15.1
$NO3^-$	7.08	2.67E+05	1.07E+06	3.97	5.57	8.04	8.95
$NO2^-$	1.63	4.54E+04	1.82E+05	1.03	1.34	1.83	2.47
$CO3^{2-}$	0.471	1.71E+04	6.87E+04	0.338	0.380	0.560	0.608
$PO4^{3-}$	0.110	6.32E+03	2.53E+04	9.94E-02	0.106	0.113	0.128
$SO4^{2-}$	0.179	1.05E+04	4.19E+04	0.109	0.145	0.209	0.286
Si (as SiO_3^{2-})	7.45E-02	1.27E+03	5.08E+03	4.80E-02	6.22E-02	9.33E-02	0.111
F^-	6.53E-02	753	3.01E+03	5.49E-02	5.99E-02	9.14E-02	0.173
Cl^-	0.118	2.54E+03	1.02E+04	6.65E-02	9.18E-02	0.123	0.123
$C_6H_5O_7^{3-}$	2.03E-02	2.32E+03	9.31E+03	1.67E-02	1.97E-02	2.06E-02	2.07E-02
$EDTA^{4-}$	4.55E-03	795	3.18E+03	4.01E-03	4.38E-03	4.63E-03	4.64E-03
$HEDTA^{3-}$	6.14E-04	102	409	1.85E-04	4.18E-04	7.71E-04	7.84E-04
$glycolate^-$	1.43E-02	649	2.60E+03	7.22E-03	1.11E-02	1.67E-02	1.63E-02
$acetate^-$	2.71E-02	969	3.88E+03	2.36E-02	2.66E-02	2.73E-02	2.76E-02
$oxalate^{2-}$	2.27E-06	0.121	0.486	1.66E-06	2.07E-06	2.48E-06	2.59E-06
DBP	2.15E-02	2.74E+03	1.10E+04	1.86E-02	2.05E-02	2.21E-02	2.20E-02
butanol	2.15E-02	968	3.87E+03	1.86E-02	2.05E-02	2.21E-02	2.20E-02
NH_3	5.48E-02	565	2.26E+03	3.20E-02	4.50E-02	5.82E-02	5.94E-02
$Fe(CN)_6^{4-}$	1.67E-02	2.75E+03	1.10E+04	1.67E-02	1.67E-02	1.67E-02	1.67E-02

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).
†Water wt% derived from the difference of density and total dissolved species.

A-4. Tank BY-106 (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-BY-106							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	4.00E+06 (kg)	(642 kgal)	----	----	----	----	----
Heat Load	4.63 (kW)	(1.58E+04 BTU/hr)	----	3.41	4.09	5.00	5.19
Bulk Density	1.65 (g/cc)	----	----	1.38	1.52	1.75	1.85
Void Fraction	0.741	----	----	0.485	0.646	0.852	0.922
Water wt%	35.0	----	----	18.2	26.5	45.9	55.2
TOC wt% C (wet)	0.447	----	----	0.365	0.429	0.470	0.478
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	1.11E-04	6.73E-02	270	4.29E-07	4.29E-07	1.12E-04	1.13E-04
C-14	2.88E-05	1.75E-02	70.1	5.95E-08	5.95E-08	2.99E-05	3.09E-05
Ni-59	3.64E-06	2.21E-03	8.84	5.66E-07	5.66E-07	3.77E-06	3.90E-06
Ni-63	3.56E-04	0.216	865	5.10E-05	5.10E-05	3.69E-04	3.82E-04
Co-60	2.70E-05	1.64E-02	65.5	1.36E-08	1.36E-08	2.72E-05	2.75E-05
Se-79	2.43E-06	1.47E-03	5.90	1.25E-08	1.25E-08	2.97E-06	3.48E-06
Sr-90	0.156	94.9	3.80E+05	0.133	0.150	0.163	0.170
Y-90	0.156	94.9	3.80E+05	4.86E-02	4.86E-02	0.163	0.170
Zr-93	1.17E-05	7.11E-03	28.5	5.96E-08	5.96E-08	1.44E-05	1.69E-05
Nb-93m	8.48E-06	5.15E-03	20.6	5.03E-08	5.03E-08	1.04E-05	1.21E-05
Tc-99	1.61E-04	9.76E-02	391	8.32E-05	1.26E-04	1.88E-04	1.83E-04
Ru-106	5.38E-09	3.26E-06	1.31E-02	5.66E-15	5.66E-15	5.87E-09	6.28E-09
Cd-113m	6.19E-05	3.76E-02	150	1.46E-07	1.46E-07	7.81E-05	9.22E-05
Sb-125	1.21E-04	7.33E-02	294	1.26E-08	1.26E-08	1.22E-04	1.23E-04
Sn-126	3.63E-06	2.20E-03	8.82	1.89E-08	1.89E-08	4.45E-06	5.21E-06
I-129	3.11E-07	1.89E-04	0.756	1.61E-07	2.44E-07	3.64E-07	3.55E-07
Cs-134	1.32E-06	7.99E-04	3.20	4.46E-09	4.46E-09	1.32E-06	1.33E-06
Cs-137	0.182	110	4.42E+05	0.108	0.144	0.205	0.217
Ba-137m	0.172	105	4.18E+05	5.17E-02	5.17E-02	0.173	0.174
Sm-151	8.40E-03	5.10	2.04E+04	4.67E-05	4.67E-05	1.03E-02	1.20E-02
Eu-152	3.88E-06	2.36E-03	9.43	9.03E-08	9.03E-08	3.89E-06	3.90E-06
Eu-154	4.55E-04	0.276	1.11E+03	2.45E-07	2.45E-07	5.90E-04	5.66E-04
Eu-155	2.36E-04	0.143	574	6.81E-06	6.81E-06	2.37E-04	2.38E-04
Ra-226	1.19E-10	7.25E-08	2.90E-04	3.42E-12	3.42E-12	1.50E-10	1.77E-10
Ra-228	1.44E-06	8.74E-04	3.50	3.45E-16	3.45E-16	1.45E-06	1.47E-06
Ac-227	1.66E-09	1.01E-06	4.04E-03	1.75E-11	1.75E-11	2.20E-09	2.70E-09
Pa-231	8.51E-09	5.17E-06	2.07E-02	3.80E-11	3.80E-11	1.12E-08	1.37E-08
Th-229	3.33E-08	2.02E-05	8.08E-02	6.70E-14	6.70E-14	3.35E-08	3.38E-08
Th-232	5.32E-08	3.23E-05	0.129	1.70E-17	1.70E-17	6.78E-08	8.18E-08
U-232	8.03E-06	4.87E-03	19.5	3.61E-06	5.85E-06	1.06E-05	1.33E-05
U-233	3.08E-05	1.87E-02	74.8	1.38E-05	2.24E-05	4.05E-05	5.08E-05
U-234	2.19E-06	1.33E-03	5.32	1.68E-06	2.09E-06	2.29E-06	2.38E-06
U-235	8.11E-08	4.92E-05	0.197	6.52E-08	7.72E-08	8.50E-08	8.88E-08
U-236	7.26E-08	4.41E-05	0.176	6.00E-08	6.90E-08	7.61E-08	7.96E-08
U-238	4.57E-06	2.77E-03	11.1	4.12E-06	4.48E-06	4.66E-06	4.74E-06
Np-237	5.40E-07	3.28E-04	1.31	2.94E-07	4.31E-07	6.27E-07	6.06E-07
Pu-238	2.15E-06	1.31E-03	5.23	9.63E-07	1.55E-06	2.75E-06	3.33E-06
Pu-239	7.73E-05	4.69E-02	188	3.75E-05	5.77E-05	9.68E-05	1.15E-04
Pu-240	1.32E-05	8.03E-03	32.1	6.25E-06	9.73E-06	1.67E-05	2.00E-05
Pu-241	1.55E-04	9.40E-02	376	6.93E-05	1.12E-04	1.98E-04	2.40E-04
Pu-242	7.45E-10	4.52E-07	1.81E-03	3.35E-10	5.37E-10	9.54E-10	1.16E-09
Am-241	3.78E-05	2.30E-02	91.9	1.32E-05	2.53E-05	4.98E-05	5.90E-05
Am-243	1.31E-09	7.93E-07	3.17E-03	4.03E-10	8.35E-10	1.78E-09	2.16E-09
Cm-242	2.14E-09	1.30E-06	5.20E-03	1.65E-09	1.65E-09	2.15E-09	2.15E-09
Cm-243	4.38E-11	2.66E-08	1.06E-04	3.39E-11	3.39E-11	4.40E-11	4.40E-11
Cm-244	1.91E-10	1.16E-07	4.65E-04	1.89E-11	1.89E-11	1.97E-10	1.98E-10
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	1.01E-03 (g/L)	----	2.45	3.06E-04	6.62E-04	1.35E-03	1.68E-03
U	2.29E-02	3.31E+03	1.33E+04	1.84E-02	2.18E-02	2.40E-02	2.51E-02

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

A-4. Tank BY-106 (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-BY-106							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	0 (kg)	(6,004,403 kgal)	----	----	----	----	----
Heat Load	0 (kW)	(0 BTU/hr)	----	0	0	0	0
Bulk Density*	0 (g/cc)	----	----	0	0	0	0
Water wt%†	0	----	----	0	0	0	0
TOC wt% C (wet)	0	----	----	0	0	0	0
Radiological Constituents	**Ci/L**	**pCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	0	0	0	0	0	0	0
C-14	0	0	0	0	0	0	0
Ni-59	0	0	0	0	0	0	0
Ni-63	0	0	0	0	0	0	0
Co-60	0	0	0	0	0	0	0
Se-79	0	0	0	0	0	0	0
Sr-90	0	0	0	0	0	0	0
Y-90	0	0	0	0	0	0	0
Zr-93	0	0	0	0	0	0	0
Nb-93m	0	0	0	0	0	0	0
Tc-99	0	0	0	0	0	0	0
Ru-106	0	0	0	0	0	0	0
Cd-113m	0	0	0	0	0	0	0
Sb-125	0	0	0	0	0	0	0
Sn-126	0	0	0	0	0	0	0
I-129	0	0	0	0	0	0	0
Cs-134	0	0	0	0	0	0	0
Cs-137	0	0	0	0	0	0	0
Ba-137m	0	0	0	0	0	0	0
Sm-151	0	0	0	0	0	0	0
Eu-152	0	0	0	0	0	0	0
Eu-154	0	0	0	0	0	0	0
Eu-155	0	0	0	0	0	0	0
Ra-226	0	0	0	0	0	0	0
Ra-228	0	0	0	0	0	0	0
Ac-227	0	0	0	0	0	0	0
Pa-231	0	0	0	0	0	0	0
Th-229	0	0	0	0	0	0	0
Th-232	0	0	0	0	0	0	0
U-232	0	0	0	0	0	0	0
U-233	0	0	0	0	0	0	0
U-234	0	0	0	0	0	0	0
U-235	0	0	0	0	0	0	0
U-236	0	0	0	0	0	0	0
U-238	0	0	0	0	0	0	0
Np-237	0	0	0	0	0	0	0
Pu-238	0	0	0	0	0	0	0
Pu-239	0	0	0	0	0	0	0
Pu-240	0	0	0	0	0	0	0
Pu-241	0	0	0	0	0	0	0
Pu-242	0	0	0	0	0	0	0
Am-241	0	0	0	0	0	0	0
Am-243	0	0	0	0	0	0	0
Cm-242	0	0	0	0	0	0	0
Cm-243	0	0	0	0	0	0	0
Cm-244	0	0	0	0	0	0	0
Totals	**M**	**pg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	0 (g/L)	----	0	0	0	0	0
U	0	0	0	0	0	0	0

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

HDW Model Rev. 4

Single-Shell Tank 241-BY-106 Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	4.104E+06 (kg)	(642 kgal)		----	----	----	----
Heat Load	4.63 (kW)	(1.58E+04 BTU/hr)	----	3.41	4.09	5.00	5.19
Bulk Density†	1.65 (g/cc)	----	----	1.38	1.52	1.75	1.85
Water wt%†	35.0	----	----	18.2	26.5	45.9	55.2
TOC wt% C (wet)†	0.447	----	----	0.365	0.429	0.470	0.478
Radiological Constituents	**CI/L**	**µCI/g**	**CI**	**-95 CI (CI/L)**	**-67 CI (CI/L)**	**+67 CI (CI/L)**	**+95 CI (CI/L)**
H-3	1.11E-04	6.73E-02	270	4.29E-07	4.29E-07	1.12E-04	1.13E-04
C-14	2.88E-05	1.75E-02	70.1	5.95E-08	5.95E-08	2.99E-05	3.09E-05
Ni-59	3.64E-06	2.21E-03	8.84	5.66E-07	5.66E-07	3.77E-06	3.90E-06
Ni-63	3.56E-04	0.216	865	5.10E-05	5.10E-05	3.69E-04	3.82E-04
Co-60	2.70E-05	1.64E-02	65.5	1.36E-08	1.36E-08	2.72E-05	2.75E-05
Se-79	2.43E-06	1.47E-03	5.90	1.25E-08	1.25E-08	2.97E-06	3.48E-06
Sr-90	0.156	94.9	3.80E+05	0.133	0.150	0.163	0.170
Y-90	0.156	94.9	3.80E+05	4.86E-02	4.86E-02	0.163	0.170
Zr-93	1.17E-05	7.11E-03	28.5	5.96E-08	5.96E-08	1.44E-05	1.69E-05
Nb-93m	8.48E-06	5.15E-03	20.6	5.03E-08	5.03E-08	1.04E-05	1.21E-05
Tc-99	1.61E-04	9.76E-02	391	8.32E-05	1.26E-04	1.88E-04	1.83E-04
Ru-106	5.38E-09	3.26E-06	1.31E-02	5.66E-15	5.66E-15	5.87E-09	6.28E-09
Cd-113m	6.19E-05	3.76E-02	150	1.46E-07	1.46E-07	7.81E-05	9.22E-05
Sb-125	1.21E-04	7.33E-02	294	1.26E-08	1.26E-08	1.22E-04	1.23E-04
Sn-126	3.63E-06	2.20E-03	8.82	1.89E-08	1.89E-08	4.45E-06	5.21E-06
I-129	3.11E-07	1.89E-04	0.756	1.61E-07	2.44E-07	3.64E-07	3.55E-07
Cs-134	1.32E-06	7.99E-04	3.20	4.46E-09	4.46E-09	1.32E-06	1.33E-06
Cs-137	0.182	110	4.42E+05	0.108	0.144	0.205	0.217
Ba-137m	0.172	105	4.18E+05	5.17E-02	5.17E-02	0.173	0.174
Sm-151	8.40E-03	5.10	2.04E+04	4.67E-05	4.67E-05	1.03E-02	1.20E-02
Eu-152	3.88E-06	2.36E-03	9.43	9.03E-08	9.03E-08	3.89E-06	3.90E-06
Eu-154	4.55E-04	0.276	1.11E+03	2.45E-07	2.45E-07	5.90E-04	5.66E-04
Eu-155	2.36E-04	0.143	574	6.81E-06	6.81E-06	2.37E-04	2.38E-04
Ra-226	1.19E-10	7.25E-08	2.90E-04	3.42E-12	3.42E-12	1.50E-10	1.77E-10
Ra-228	1.44E-06	8.74E-04	3.50	3.45E-16	3.45E-16	1.45E-06	1.47E-06
Ac-227	1.66E-09	1.01E-06	4.04E-03	1.75E-11	1.75E-11	2.20E-09	2.70E-09
Pa-231	8.51E-09	5.17E-06	2.07E-02	3.80E-11	3.80E-11	1.12E-08	1.37E-08
Th-229	3.33E-08	2.02E-05	8.08E-02	6.70E-14	6.70E-14	3.35E-08	3.38E-08
Th-232	5.32E-08	3.23E-05	0.129	1.70E-17	1.70E-17	6.78E-08	8.18E-08
U-232	8.03E-06	4.87E-03	19.5	3.61E-06	5.85E-06	1.06E-05	1.33E-05
U-233	3.08E-05	1.87E-02	74.8	1.38E-05	2.24E-05	4.05E-05	5.08E-05
U-234	2.19E-06	1.33E-03	5.32	1.68E-06	2.09E-06	2.29E-06	2.38E-06
U-235	8.11E-08	4.92E-05	0.197	6.52E-08	7.72E-08	8.50E-08	8.88E-08
U-236	7.26E-08	4.41E-05	0.176	6.00E-08	6.90E-08	7.61E-08	7.96E-08
U-238	4.57E-06	2.77E-03	11.1	4.12E-06	4.48E-06	4.66E-06	4.74E-06
Np-237	5.40E-07	3.28E-04	1.31	2.94E-07	4.31E-07	6.27E-07	6.06E-07
Pu-238	2.15E-06	1.31E-03	5.23	9.63E-07	1.55E-06	2.75E-06	3.33E-06
Pu-239	7.73E-05	4.69E-02	188	3.75E-05	5.77E-05	9.68E-05	1.15E-04
Pu-240	1.32E-05	8.03E-03	32.1	6.25E-06	9.73E-06	1.67E-05	2.00E-05
Pu-241	1.55E-04	9.40E-02	376	6.93E-05	1.12E-04	1.98E-04	2.40E-04
Pu-242	7.45E-10	4.52E-07	1.81E-03	3.35E-10	5.37E-10	9.54E-10	1.16E-09
Am-241	3.78E-05	2.30E-02	91.9	1.32E-05	2.53E-05	4.98E-05	5.90E-05
Am-243	1.31E-09	7.93E-07	3.17E-03	4.03E-10	8.35E-10	1.78E-09	2.16E-09
Cm-242	2.14E-09	1.30E-06	5.20E-03	1.65E-09	1.65E-09	2.15E-09	2.15E-09
Cm-243	4.38E-11	2.66E-08	1.06E-04	3.39E-11	3.39E-11	4.40E-11	4.40E-11
Cm-244	1.91E-10	1.16E-07	4.65E-04	1.89E-11	1.89E-11	1.97E-10	1.98E-10
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	1.01E-03 (g/L)	----	2.45	3.06E-04	6.62E-04	1.35E-03	1.68E-03
U	2.29E-02	3.31E+03	1.33E+04	1.84E-02	2.18E-02	2.40E-02	2.51E-02

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).
†Volume average for density, mass average Water wt% and TOC wt% C.

A-5. Tank C-106

HDW Model Rev. 4

Single-Shell Tank 241-C-106							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	1.08E+06 (kg)	(197 kgal)	----	----	----	----	----
Heat Load	40.6 (kW)	(1.39E+05 BTU/hr)	----	32.7	38.1	42.1	43.0
Bulk Density	1.44 (g/cc)	----	----	1.37	1.39	1.48	1.48
Void Fraction	0.760	----	----	0.726	0.729	0.798	0.802
Water wt%	55.6	----	----	54.1	52.7	60.2	61.3
TOC wt% C (wet)	7.21E-02	----	----	4.26E-02	6.39E-02	8.01E-02	0.111
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	6.01	9.58E+04	1.03E+05	4.51	4.91	6.70	7.20
Al^{3+}	1.73	3.24E+04	3.48E+04	1.71	1.72	1.74	1.76
Fe^{3+} (total Fe)	1.37	5.29E+04	5.69E+04	1.25	1.34	1.38	1.40
Cr^{3+}	7.47E-03	269	290	7.36E-03	7.37E-03	7.57E-03	7.58E-03
Bi^{3+}	4.70E-06	0.680	0.732	3.97E-06	4.33E-06	5.07E-06	5.43E-06
La^{3+}	0	0	0	0	0	0	0
Hg^{2+}	4.36E-04	60.6	65.2	4.31E-04	4.34E-04	4.38E-04	4.40E-04
Zr (as $ZrO(OH)_2$)	1.86E-08	1.17E-03	1.26E-03	1.84E-08	1.85E-08	1.86E-08	1.88E-08
Pb^{2+}	2.03E-02	2.92E+03	3.14E+03	1.89E-02	1.96E-02	2.11E-02	2.18E-02
Ni^{2+}	0.387	1.57E+04	1.69E+04	0.302	0.360	0.402	0.411
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	1.08E-03	41.1	44.2	7.49E-04	9.11E-04	1.25E-03	1.41E-03
Ca^{2+}	0.154	4.29E+03	4.61E+03	0.102	0.102	0.231	0.290
K^+	6.25E-03	169	182	5.21E-03	5.77E-03	6.74E-03	7.64E-03
OH^-	10.7	1.26E+05	1.36E+05	10.1	10.5	10.8	11.1
$NO3^-$	1.12	4.79E+04	5.16E+04	9.87E-02	0.173	1.84	1.13
$NO2^-$	0.597	1.90E+04	2.05E+04	0.518	0.575	0.615	0.688
$CO3^{2-}$	0.262	1.09E+04	1.17E+04	0.126	0.203	0.343	0.393
$PO4^{3-}$	1.58E-02	1.04E+03	1.12E+03	1.14E-02	1.18E-02	1.98E-02	2.83E-02
$SO4^{2-}$	4.77E-02	3.17E+03	3.41E+03	4.28E-02	4.33E-02	5.20E-02	5.26E-02
Si (as SiO_3^{2-})	1.74	3.38E+04	3.64E+04	1.11	1.23	2.07	2.39
F^-	1.58E-04	2.08	2.23	1.47E-04	1.55E-04	1.58E-04	1.60E-04
Cl^-	2.30E-02	565	608	1.82E-02	2.01E-02	2.59E-02	3.78E-02
$C_6H_5O_7^{3-}$	2.65E-03	348	374	1.49E-03	2.27E-03	2.92E-03	4.19E-03
$EDTA^{4-}$	0	0	0	0	0	0	0
$HEDTA^{3-}$	0	0	0	0	0	0	0
$glycolate^-$	3.54E-02	1.84E+03	1.98E+03	1.99E-02	3.03E-02	3.90E-02	5.59E-02
$acetate^-$	0	0	0	0	0	0	0
$oxalate^{2-}$	0	0	0	0	0	0	0
DBP	1.06E-06	0.155	0.167	2.31E-08	1.33E-07	1.99E-06	2.12E-06
butanol	1.06E-06	5.46E-02	5.87E-02	2.31E-08	1.33E-07	1.99E-06	2.12E-06
NH_3	0.123	1.45E+03	1.56E+03	0.102	0.117	0.128	0.146
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

HDW Model Rev. 4

Single-Shell Tank 241-C-106							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	1.24E+05 (kg)	(32.0 kgal)	----	----	----	----	----
Heat Load	4.37E-03 (kW)	(14.9 BTU/hr)	----	3.74E-03	4.05E-03	4.69E-03	5.00E-03
Bulk Density*	1.02 (g/cc)	----	----	1.01	1.01	1.03	1.03
Water wt%	96.6	----	----	94.8	95.6	97.5	98.4
TOC wt% C (wet)	9.09E-02	----	----	4.16E-02	6.58E-02	0.116	0.139
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	0.537	1.21E+04	1.50E+03	0.245	0.390	0.685	0.820
Al^{3+}	4.11E-02	1.09E+03	134	1.86E-02	2.96E-02	5.26E-02	6.36E-02
Fe^{3+} (total Fe)	3.15E-04	17.2	2.13	1.74E-04	2.43E-04	3.87E-04	4.56E-04
Cr^{3+}	4.67E-08	2.38E-03	2.94E-04	2.94E-08	3.79E-08	5.56E-08	6.40E-08
Bi^{3+}	2.40E-11	4.91E-06	6.07E-07	2.26E-11	2.33E-11	2.47E-11	2.54E-11
La^{3+}	4.43E-18	6.03E-13	7.45E-14	3.20E-18	3.80E-18	5.05E-18	5.66E-18
Hg^{2+}	4.97E-13	9.77E-08	1.21E-08	4.72E-13	4.84E-13	5.10E-13	5.22E-13
Zr (as $ZrO(OH)_2$)	6.55E-13	5.85E-08	7.24E-09	4.50E-13	5.34E-13	7.54E-13	8.74E-13
Pb^{2+}	7.70E-11	1.56E-05	1.93E-06	5.90E-11	6.78E-11	8.62E-11	9.51E-11
Ni^{2+}	2.83E-04	16.3	2.02	2.55E-04	2.69E-04	2.98E-04	3.12E-04
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	2.68E-09	1.44E-04	1.79E-05	2.13E-09	2.40E-09	2.96E-09	3.24E-09
Ca^{2+}	1.42E-03	55.6	6.88	7.37E-04	1.13E-03	1.63E-03	1.63E-03
K^+	2.12E-03	81.4	10.1	9.61E-04	1.53E-03	2.72E-03	3.29E-03
OH^-	0.365	6.08E+03	751	0.166	0.263	0.467	0.564
$NO3^-$	0.131	7.96E+03	985	5.93E-02	9.44E-02	0.168	0.203
$NO2^-$	8.38E-03	378	46.7	3.79E-03	6.03E-03	1.07E-02	1.30E-02
$CO3^{2-}$	4.24E-02	2.49E+03	308	1.93E-02	3.07E-02	5.39E-02	6.19E-02
$PO4^{3-}$	1.58E-03	147	18.2	7.13E-04	1.14E-03	2.02E-03	2.44E-03
$SO4^{2-}$	6.94E-03	653	80.8	3.14E-03	5.00E-03	8.89E-03	1.07E-02
Si (as SiO_3^{2-})	5.35E-03	147	18.2	2.71E-03	4.00E-03	6.70E-03	7.88E-03
F^-	9.83E-10	1.83E-05	2.26E-06	8.50E-10	9.04E-10	1.05E-09	1.12E-09
Cl^-	9.77E-03	339	42.0	4.42E-03	7.04E-03	1.25E-02	1.51E-02
$C_6H_5O_7^{3-}$	2.37E-03	438	54.2	1.07E-03	1.70E-03	3.03E-03	3.66E-03
$EDTA^{4-}$	3.66E-12	1.03E-06	1.28E-07	2.51E-12	3.07E-12	4.25E-12	4.83E-12
$HEDTA^{3-}$	3.10E-12	8.32E-07	1.03E-07	8.20E-13	1.93E-12	4.27E-12	5.41E-12
$glycolate^-$	3.15E-02	2.32E+03	287	1.43E-02	2.27E-02	4.04E-02	4.88E-02
$acetate^-$	1.36E-11	7.85E-07	9.71E-08	1.10E-11	1.23E-11	1.49E-11	1.62E-11
$oxalate^{2-}$	5.80E-18	5.00E-13	6.18E-14	5.14E-18	5.46E-18	6.14E-18	6.46E-18
DBP	4.03E-09	8.31E-04	1.03E-04	3.47E-09	3.75E-09	4.32E-09	4.60E-09
butanol	4.03E-09	2.93E-04	3.62E-05	3.47E-09	3.75E-09	4.32E-09	4.60E-09
NH_3	1.81E-05	0.301	3.72E-02	8.16E-06	1.30E-05	2.32E-05	2.80E-05
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

HDW Model Rev. 4

Single-Shell Tank 241-C-106							
Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	1.20E+06 (kg)	(229 kgal)	----	----	----	----	----
Heat Load	40.6 (kW)	(1.39E+05 BTU/hr)	----	32.7	38.1	42.1	43.0
Bulk Density†	1.38 (g/cc)	----	----	1.32	1.34	1.41	1.42
Water wt%†	59.9	----	----	58.3	57.1	64.1	65.1
TOC wt% C (wet)†	7.40E-02	----	----	4.25E-02	6.41E-02	8.16E-02	0.114
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	5.25	8.72E+04	1.05E+05	3.91	4.28	5.84	6.27
Al^{3+}	1.49	2.91E+04	3.50E+04	1.47	1.48	1.50	1.52
Fe^{3+} (total Fe)	1.17	4.74E+04	5.69E+04	1.07	1.15	1.19	1.20
Cr^{3+}	6.43E-03	242	290	6.33E-03	6.34E-03	6.51E-03	6.52E-03
Bi^{3+}	4.04E-06	0.610	0.732	3.41E-06	3.72E-06	4.36E-06	4.67E-06
La^{3+}	6.19E-19	6.21E-14	7.45E-14	4.47E-19	5.31E-19	7.06E-19	7.91E-19
Hg^{2+}	3.75E-04	54.4	65.2	3.71E-04	3.73E-04	3.77E-04	3.78E-04
Zr (as $ZrO(OH)_2$)	1.60E-08	1.05E-03	1.26E-03	1.58E-08	1.59E-08	1.60E-08	1.62E-08
Pb^{2+}	1.75E-02	2.62E+03	3.14E+03	1.63E-02	1.69E-02	1.81E-02	1.87E-02
Ni^{2+}	0.333	1.41E+04	1.69E+04	0.260	0.309	0.346	0.354
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	9.28E-04	36.8	44.2	6.45E-04	7.83E-04	1.07E-03	1.21E-03
Ca^{2+}	0.133	3.85E+03	4.62E+03	8.75E-02	8.81E-02	0.199	0.249
K^+	5.68E-03	160	192	4.62E-03	5.26E-03	6.09E-03	7.03E-03
OH^-	9.25	1.14E+05	1.36E+05	8.68	9.06	9.37	9.59
$NO3^-$	0.978	4.38E+04	5.25E+04	0.103	0.167	1.60	0.993
$NO2^-$	0.515	1.71E+04	2.05E+04	0.446	0.495	0.530	0.593
$CO3^{2-}$	0.231	1.00E+04	1.20E+04	0.117	0.179	0.303	0.344
$PO4^{3-}$	1.38E-02	949	1.14E+03	1.00E-02	1.04E-02	1.73E-02	2.46E-02
$SO4^{2-}$	4.20E-02	2.91E+03	3.49E+03	3.78E-02	3.82E-02	4.57E-02	4.64E-02
Si (as SiO_3^{2-})	1.50	3.04E+04	3.64E+04	0.958	1.06	1.78	2.05
F^-	1.36E-04	1.86	2.23	1.27E-04	1.34E-04	1.36E-04	1.37E-04
Cl^-	2.12E-02	542	650	1.63E-02	1.86E-02	2.37E-02	3.39E-02
$C_6H_5O_7^{3-}$	2.61E-03	357	428	1.43E-03	2.19E-03	2.94E-03	4.12E-03
$EDTA^{4-}$	5.12E-13	1.07E-07	1.28E-07	3.51E-13	4.30E-13	5.94E-13	6.75E-13
$HEDTA^{3-}$	4.33E-13	8.58E-08	1.03E-07	1.15E-13	2.70E-13	5.97E-13	7.57E-13
glycolate$^-$	3.48E-02	1.89E+03	2.26E+03	1.91E-02	2.93E-02	3.92E-02	5.49E-02
acetate$^-$	1.90E-12	8.10E-08	9.71E-08	1.54E-12	1.71E-12	2.08E-12	2.26E-12
oxalate^{2-}	8.11E-19	5.16E-14	6.18E-14	7.18E-19	7.63E-19	8.58E-19	9.03E-19
DBP	9.15E-07	0.139	0.167	2.04E-08	1.15E-07	1.71E-06	1.82E-06
butanol	9.15E-07	4.90E-02	5.88E-02	2.04E-08	1.15E-07	1.71E-06	1.82E-06
NH_3	0.106	1.30E+03	1.56E+03	8.76E-02	0.101	0.110	0.125
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).
†Water wt% derived from the difference of density and total dissolved species.

HDW Model Rev. 4

Single-Shell Tank 241-C-106							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	1.08E+06 (kg)	(197 kgal)		----	----	----	----
Heat Load	40.6 (kW)	(1.39E+05 BTU/hr)	----	32.7	38.1	42.1	43.0
Bulk Density	1.44 (g/cc)	----	----	1.37	1.39	1.48	1.48
Void Fraction	0.760	----	----	0.726	0.729	0.798	0.802
Water wt%	55.6	----	----	54.1	52.7	60.2	61.3
TOC wt% C (wet)	7.21E-02	----	----	4.26E-02	6.39E-02	8.01E-02	0.111
Radiological Constituents	**Ci/L**	**pCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	7.07E-06	4.90E-03	5.27	3.83E-06	5.43E-06	8.84E-06	1.32E-05
C-14	5.75E-06	3.98E-03	4.28	5.62E-06	5.70E-06	5.78E-06	8.83E-06
Ni-59	1.04E-04	7.24E-02	77.9	9.12E-05	1.00E-04	1.07E-04	1.09E-04
Ni-63	1.03E-02	7.14	7.68E+03	8.99E-03	9.88E-03	1.05E-02	1.07E-02
Co-60	6.17E-06	4.28E-03	4.60	5.88E-06	6.07E-06	6.24E-06	6.55E-06
Sc-79	2.48E-05	1.72E-02	18.5	1.43E-06	8.68E-06	4.09E-05	7.02E-05
Sr-90	8.00	5.55E+03	5.97E+06	6.41	7.49	8.29	8.47
Y-90	8.01	5.55E+03	5.97E+06	6.41	7.50	8.29	8.47
Zr-93	1.04E-04	7.21E-02	77.6	6.70E-06	2.34E-05	1.85E-04	3.09E-04
Nb-93m	9.42E-05	6.53E-02	70.2	5.14E-06	3.77E-05	1.51E-04	2.57E-04
Tc-99	4.03E-05	2.80E-02	30.1	3.95E-05	4.01E-05	4.06E-05	4.15E-05
Ru-106	4.27E-07	2.96E-04	0.319	1.93E-07	3.50E-07	5.04E-07	5.78E-07
Cd-113m	7.54E-05	5.22E-02	56.2	2.77E-05	2.82E-05	5.28E-04	9.93E-04
Sb-125	2.47E-05	1.71E-02	18.4	2.29E-05	2.41E-05	2.51E-05	2.70E-05
Sn-126	4.04E-05	2.80E-02	30.1	2.23E-06	1.62E-05	6.46E-05	1.12E-04
I-129	7.80E-08	5.41E-05	5.82E-02	7.64E-08	7.75E-08	7.84E-08	8.03E-08
Cs-134	9.41E-07	6.52E-04	0.702	9.32E-07	9.37E-07	9.46E-07	9.53E-07
Cs-137	0.128	89.0	9.58E+04	0.127	0.128	0.129	0.130
Ba-137m	0.121	84.2	9.06E+04	0.120	0.121	0.122	0.123
Sm-151	9.53E-02	66.0	7.10E+04	5.22E-03	3.88E-02	0.152	0.259
Eu-152	7.60E-05	5.27E-02	56.6	7.59E-05	7.59E-05	7.60E-05	7.61E-05
Eu-154	1.38E-04	9.56E-02	103	1.29E-04	1.33E-04	1.42E-04	3.15E-03
Eu-155	4.66E-03	3.23	3.47E+03	4.65E-03	4.66E-03	4.66E-03	4.66E-03
Ra-226	5.17E-09	3.58E-06	3.85E-03	3.51E-09	3.92E-09	6.41E-09	7.61E-09
Ra-228	4.04E-10	2.80E-07	3.02E-04	4.04E-10	4.04E-10	4.05E-10	4.05E-10
Ac-227	2.55E-08	1.77E-05	1.90E-02	1.83E-08	1.83E-08	3.28E-08	3.97E-08
Pa-231	2.53E-08	1.75E-05	1.89E-02	1.42E-09	9.53E-09	4.10E-08	6.58E-08
Th-229	1.90E-10	1.32E-07	1.42E-04	1.90E-10	1.90E-10	1.90E-10	1.90E-10
Th-232	4.36E-11	3.02E-08	3.25E-05	4.32E-11	4.34E-11	4.39E-11	4.42E-11
U-232	2.57E-08	1.78E-05	1.92E-02	2.31E-08	2.44E-08	2.70E-08	2.83E-08
U-233	9.91E-08	6.87E-05	7.39E-02	8.92E-08	9.40E-08	1.04E-07	1.09E-07
U-234	1.95E-06	1.35E-03	1.46	1.80E-06	1.88E-06	2.01E-06	2.06E-06
U-235	8.33E-08	5.77E-05	6.21E-02	7.67E-08	8.03E-08	8.57E-08	8.77E-08
U-236	3.47E-08	2.41E-05	2.59E-02	3.21E-08	3.35E-08	3.57E-08	3.65E-08
U-238	2.00E-06	1.38E-03	1.49	1.84E-06	1.92E-06	2.05E-06	2.10E-06
Np-237	1.27E-07	8.84E-05	9.50E-02	1.25E-07	1.27E-07	1.28E-07	1.31E-07
Pu-238	7.14E-05	4.95E-02	53.2	4.83E-05	6.28E-05	7.97E-05	8.73E-05
Pu-239	1.46E-03	1.01	1.09E+03	1.05E-03	1.28E-03	1.63E-03	1.80E-03
Pu-240	2.98E-04	0.207	222	2.10E-04	2.62E-04	3.33E-04	3.67E-04
Pu-241	5.02E-03	3.48	3.74E+03	3.39E-03	4.41E-03	5.60E-03	6.14E-03
Pu-242	3.18E-08	2.20E-05	2.37E-02	2.12E-08	2.79E-08	3.54E-08	3.88E-08
Am-241	1.89E-03	1.31	1.41E+03	8.22E-04	1.29E-03	2.50E-03	3.08E-03
Am-243	9.95E-08	6.90E-05	7.42E-02	1.84E-08	5.64E-08	1.37E-07	1.70E-07
Cm-242	2.98E-06	2.06E-03	2.22	2.97E-06	2.98E-06	2.98E-06	2.98E-06
Cm-243	2.74E-07	1.90E-04	0.204	2.73E-07	2.73E-07	2.74E-07	2.74E-07
Cm-244	6.41E-06	4.44E-03	4.78	1.73E-06	4.87E-06	7.95E-06	9.42E-06
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	2.43E-02 (g/L)	----	18.1	1.74E-02	2.14E-02	2.73E-02	3.02E-02
U	2.51E-02	4.14E+03	4.45E+03	2.31E-02	2.42E-02	2.59E-02	2.65E-02

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

A-5. Tank C-106 (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-C-106							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	1.24E+05 (kg)	(32.0 kgal)	----	----	----	----	----
Heat Load	4.37E-03 (kW)	(14.9 BTU/hr)	----	3.74E-03	4.05E-03	4.69E-03	5.00E-03
Bulk Density*	1.02 (g/cc)	----	----	1.01	1.01	1.03	1.03
Water wt%†	96.6	----	----	94.8	95.6	97.5	98.4
TOC wt% C (wet)	9.09E-02	----	----	4.16E-02	6.58E-02	0.116	0.139
Radiological Constituents	**Ci/L**	**pCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	3.89E-06	3.81E-03	0.471	8.03E-07	2.03E-06	6.35E-06	9.19E-06
C-14	2.62E-07	2.57E-04	3.17E-02	1.19E-07	1.89E-07	3.36E-07	3.87E-07
Ni-59	4.43E-08	4.34E-05	5.37E-03	4.24E-08	4.34E-08	4.51E-08	4.57E-08
Ni-63	4.39E-06	4.30E-03	0.532	4.20E-06	4.30E-06	4.47E-06	4.53E-06
Co-60	5.89E-07	5.78E-04	7.14E-02	2.67E-07	4.24E-07	7.55E-07	9.13E-07
Sc-79	1.78E-07	1.74E-04	2.15E-02	8.04E-08	1.27E-07	2.28E-07	2.75E-07
Sr-90	5.35E-03	5.24	648	4.58E-03	4.96E-03	5.74E-03	6.12E-03
Y-90	5.35E-03	5.25	648	4.58E-03	4.96E-03	5.75E-03	6.12E-03
Zr-93	7.99E-07	7.83E-04	9.69E-02	3.62E-07	5.48E-07	1.02E-06	1.24E-06
Nb-93m	6.40E-07	6.27E-04	7.75E-02	2.89E-07	4.61E-07	8.20E-07	9.91E-07
Tc-99	1.75E-06	1.72E-03	0.212	7.93E-07	1.26E-06	2.25E-06	2.71E-06
Ru-106	7.87E-10	7.71E-07	9.53E-05	2.29E-10	5.02E-10	1.07E-09	1.34E-09
Cd-113m	2.73E-06	2.67E-03	0.330	1.23E-06	1.96E-06	3.96E-06	4.22E-06
Sb-125	3.61E-06	3.53E-03	0.437	1.63E-06	2.60E-06	4.62E-06	5.58E-06
Sn-126	2.81E-07	2.75E-04	3.40E-02	1.27E-07	2.02E-07	3.59E-07	4.35E-07
I-129	3.41E-09	3.34E-06	4.13E-04	1.54E-09	2.46E-09	4.37E-09	5.28E-09
Cs-134	2.46E-12	2.41E-09	2.98E-07	2.06E-12	2.25E-12	2.66E-12	2.86E-12
Cs-137	3.25E-07	3.18E-04	3.94E-02	2.93E-07	3.08E-07	3.41E-07	3.57E-07
Ba-137m	3.07E-07	3.01E-04	3.72E-02	2.77E-07	2.92E-07	3.23E-07	3.38E-07
Sm-151	6.44E-04	0.631	78.0	2.91E-04	4.64E-04	8.25E-04	9.97E-04
Eu-152	1.61E-07	1.57E-04	1.95E-02	7.27E-08	1.16E-07	2.06E-07	2.49E-07
Eu-154	1.78E-05	1.75E-02	2.16	8.07E-06	1.28E-05	2.28E-05	2.76E-05
Eu-155	9.21E-06	9.02E-03	1.12	4.17E-06	6.63E-06	1.18E-05	1.43E-05
Ra-226	9.76E-12	9.56E-09	1.18E-06	2.84E-12	6.23E-12	1.33E-11	1.34E-11
Ra-228	1.19E-15	1.17E-12	1.44E-10	4.87E-16	8.30E-16	1.61E-15	2.05E-15
Ac-227	5.66E-11	5.55E-08	6.86E-06	1.65E-11	3.62E-11	7.69E-11	6.82E-11
Pa-231	1.58E-10	1.55E-07	1.91E-05	6.74E-11	1.08E-10	2.02E-10	2.44E-10
Th-229	1.28E-14	1.25E-11	1.55E-09	5.80E-15	9.20E-15	1.63E-14	1.97E-14
Th-232	3.51E-16	3.44E-13	4.26E-11	2.77E-16	3.14E-16	3.95E-16	4.42E-16
U-232	4.32E-13	4.23E-10	5.23E-08	2.27E-13	3.27E-13	5.37E-13	6.37E-13
U-233	2.28E-13	2.24E-10	2.77E-08	2.12E-13	2.20E-13	2.37E-13	2.45E-13
U-234	1.41E-09	1.38E-06	1.71E-04	6.38E-10	1.02E-09	1.81E-09	2.18E-09
U-235	5.46E-11	5.35E-08	6.62E-06	2.47E-11	3.93E-11	6.99E-11	8.45E-11
U-236	1.03E-10	1.01E-07	1.24E-05	4.64E-11	7.39E-11	1.31E-10	1.59E-10
U-238	1.09E-09	1.07E-06	1.32E-04	4.92E-10	7.83E-10	1.39E-09	1.68E-09
Np-237	5.60E-09	5.49E-06	6.79E-04	2.53E-09	4.03E-09	7.17E-09	8.67E-09
Pu-238	7.78E-08	7.62E-05	9.42E-03	2.17E-08	4.86E-08	1.08E-07	1.39E-07
Pu-239	1.36E-06	1.34E-03	0.165	3.97E-07	8.70E-07	1.85E-06	2.33E-06
Pu-240	2.96E-07	2.90E-04	3.58E-02	8.46E-08	1.87E-07	4.06E-07	5.15E-07
Pu-241	5.45E-06	5.34E-03	0.661	1.52E-06	3.41E-06	7.59E-06	9.75E-06
Pu-242	3.55E-11	3.48E-08	4.30E-06	9.83E-12	2.21E-11	4.96E-11	6.40E-11
Am-241	4.72E-06	4.63E-03	0.572	1.37E-06	3.01E-06	6.43E-06	7.59E-06
Am-243	3.57E-10	3.50E-07	4.33E-05	9.23E-11	2.14E-10	5.22E-10	6.65E-10
Cm-242	8.54E-09	8.37E-06	1.04E-03	3.87E-09	6.15E-09	1.09E-08	1.32E-08
Cm-243	9.10E-10	8.92E-07	1.10E-04	4.12E-10	6.55E-10	1.17E-09	1.41E-09
Cm-244	1.57E-08	1.54E-05	1.91E-03	4.58E-09	1.00E-08	2.14E-08	2.69E-08
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	2.33E-05 (g/L)	----	2.82E-03	6.78E-06	1.49E-05	3.17E-05	3.98E-05
U	1.37E-05	3.20	0.395	6.20E-06	9.87E-06	1.76E-05	2.12E-05

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

A-5. Tank C-106 (cont'd)

HDW Model Rev. 4

Single-Shell Tank 241-C-106 Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	1.24E+06 (kg)	(229 kgal)	----	----	----	----	----
Heat Load	40.6 (kW)	(1.39E+05 BTU/hr)	----	32.7	38.1	42.1	43.0
Bulk Density†	1.38 (g/cc)	----	----	1.32	1.34	1.41	1.42
Water wt%†	59.9	----	----	58.3	57.1	64.1	65.1
TOC wt% C (wet)†	7.40E-02	----	----	4.25E-02	6.41E-02	8.16E-02	0.114
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	6.63E-06	4.79E-03	5.75	3.41E-06	4.95E-06	8.49E-06	1.27E-05
C-14	4.98E-06	3.60E-03	4.32	4.85E-06	4.93E-06	5.02E-06	7.65E-06
Ni-59	8.98E-05	6.49E-02	77.9	7.85E-05	8.62E-05	9.19E-05	9.35E-05
Ni-63	8.86E-03	6.40	7.68E+03	7.73E-03	8.50E-03	9.06E-03	9.22E-03
Co-60	5.39E-06	3.89E-03	4.67	5.09E-06	5.28E-06	5.47E-06	5.76E-06
Se-79	2.14E-05	1.54E-02	18.5	1.26E-06	7.49E-06	3.52E-05	6.04E-05
Sr-90	6.89	4.98E+03	5.97E+06	5.52	6.45	7.13	7.29
Y-90	6.89	4.98E+03	5.97E+06	5.52	6.45	7.14	7.29
Zr-93	8.96E-05	6.48E-02	77.7	5.87E-06	2.03E-05	1.59E-04	2.66E-04
Nb-93m	8.11E-05	5.86E-02	70.3	4.51E-06	3.25E-05	1.30E-04	2.21E-04
Tc-99	3.49E-05	2.53E-02	30.3	3.41E-05	3.46E-05	3.52E-05	3.61E-05
Ru-106	3.68E-07	2.66E-04	0.319	1.66E-07	3.01E-07	4.34E-07	4.97E-07
Cd-113m	6.52E-05	4.71E-02	56.5	2.42E-05	2.46E-05	4.55E-04	8.54E-04
Sb-125	2.17E-05	1.57E-02	18.8	1.99E-05	2.11E-05	2.22E-05	2.40E-05
Sn-126	3.48E-05	2.52E-02	30.2	1.96E-06	1.40E-05	5.56E-05	9.63E-05
I-129	6.76E-08	4.89E-05	5.86E-02	6.59E-08	6.70E-08	6.81E-08	6.98E-08
Cs-134	8.10E-07	5.85E-04	0.702	8.02E-07	8.06E-07	8.14E-07	8.20E-07
Cs-137	0.110	79.8	9.58E+04	0.109	0.110	0.111	0.112
Ba-137m	0.105	75.5	9.06E+04	0.104	0.104	0.105	0.106
Sm-151	8.20E-02	59.3	7.11E+04	4.58E-03	3.35E-02	0.131	0.223
Eu-152	6.54E-05	4.72E-02	56.7	6.53E-05	6.53E-05	6.54E-05	6.55E-05
Eu-154	1.21E-04	8.75E-02	105	1.12E-04	1.17E-04	1.25E-04	2.72E-03
Eu-155	4.01E-03	2.90	3.47E+03	4.00E-03	4.01E-03	4.01E-03	4.01E-03
Ra-226	4.45E-09	3.21E-06	3.85E-03	3.02E-09	3.37E-09	5.52E-09	6.55E-09
Ra-228	3.48E-10	2.51E-07	3.02E-04	3.48E-10	3.48E-10	3.48E-10	3.48E-10
Ac-227	2.20E-08	1.59E-05	1.90E-02	1.58E-08	1.58E-08	2.82E-08	3.42E-08
Pa-231	2.18E-08	1.57E-05	1.89E-02	1.24E-09	8.22E-09	3.53E-08	5.66E-08
Th-229	1.64E-10	1.18E-07	1.42E-04	1.64E-10	1.64E-10	1.64E-10	1.64E-10
Th-232	3.75E-11	2.71E-08	3.25E-05	3.72E-11	3.73E-11	3.77E-11	3.81E-11
U-232	2.21E-08	1.60E-05	1.92E-02	1.99E-08	2.10E-08	2.32E-08	2.43E-08
U-233	8.52E-08	6.16E-05	7.39E-02	7.67E-08	8.09E-08	8.96E-08	9.38E-08
U-234	1.68E-06	1.21E-03	1.46	1.55E-06	1.62E-06	1.73E-06	1.77E-06
U-235	7.16E-08	5.18E-05	6.21E-02	6.60E-08	6.90E-08	7.38E-08	7.55E-08
U-236	2.99E-08	2.16E-05	2.59E-02	2.76E-08	2.88E-08	3.07E-08	3.14E-08
U-238	1.72E-06	1.24E-03	1.49	1.58E-06	1.65E-06	1.77E-06	1.81E-06
Np-237	1.10E-07	7.98E-05	9.57E-02	1.08E-07	1.09E-07	1.11E-07	1.14E-07
Pu-238	6.14E-05	4.44E-02	53.2	4.15E-05	5.40E-05	6.85E-05	7.51E-05
Pu-239	1.25E-03	0.907	1.09E+03	9.06E-04	1.10E-03	1.41E-03	1.55E-03
Pu-240	2.56E-04	0.185	222	1.81E-04	2.26E-04	2.87E-04	3.16E-04
Pu-241	4.32E-03	3.12	3.74E+03	2.92E-03	3.80E-03	4.82E-03	5.28E-03
Pu-242	2.73E-08	1.98E-05	2.37E-02	1.82E-08	2.40E-08	3.05E-08	3.34E-08
Am-241	1.63E-03	1.18	1.41E+03	7.08E-04	1.11E-03	2.15E-03	2.65E-03
Am-243	8.56E-08	6.19E-05	7.42E-02	1.59E-08	4.86E-08	1.18E-07	1.46E-07
Cm-242	2.56E-06	1.85E-03	2.22	2.56E-06	2.56E-06	2.56E-06	2.57E-06
Cm-243	2.35E-07	1.70E-04	0.204	2.35E-07	2.35E-07	2.36E-07	2.36E-07
Cm-244	5.51E-06	3.99E-03	4.78	1.49E-06	4.19E-06	6.84E-06	8.11E-06
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	2.09E-02 (g/L)	----	18.1	1.50E-02	1.84E-02	2.35E-02	2.60E-02
U	2.16E-02	3.72E+03	4.46E+03	1.99E-02	2.08E-02	2.22E-02	2.28E-02

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

†Volume average for density, mass average Water wt% and TOC wt% C.

A-6. Tank SY-101

HDW Model Rev. 4

Double-Shell Tank 241-SY-101							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	0 (kg)	(0 kgal)	----	----	----	----	----
Heat Load	0 (kW)	(0 BTU/hr)	----	0	0	0	0
Bulk Density	0 (g/cc)	----	----	0	0	0	0
Void Fraction	0	----	----	0	0	0	0
Water wt%	0	----	----	0	0	0	0
TOC wt% C (wet)	0	----	----	0	0	0	0
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	0	0	0	0	0	0	0
Al^{3+}	0	0	0	0	0	0	0
Fe^{3+} (total Fe)	0	0	0	0	0	0	0
Cr^{3+}	0	0	0	0	0	0	0
Bi^{3+}	0	0	0	0	0	0	0
La^{3+}	0	0	0	0	0	0	0
Hg^{2+}	0	0	0	0	0	0	0
Zr (as $ZrO(OH)_2$)	0	0	0	0	0	0	0
Pb^{2+}	0	0	0	0	0	0	0
Ni^{2+}	0	0	0	0	0	0	0
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	0	0	0	0	0	0	0
Ca^{2+}	0	0	0	0	0	0	0
K^+	0	0	0	0	0	0	0
OH^-	0	0	0	0	0	0	0
$NO3^-$	0	0	0	0	0	0	0
$NO2^-$	0	0	0	0	0	0	0
$CO3^{2-}$	0	0	0	0	0	0	0
$PO4^{3-}$	0	0	0	0	0	0	0
$SO4^{2-}$	0	0	0	0	0	0	0
Si (as SiO_3^{2-})	0	0	0	0	0	0	0
F^-	0	0	0	0	0	0	0
Cl^-	0	0	0	0	0	0	0
$C_6H_5O_7^{3-}$	0	0	0	0	0	0	0
$EDTA^{4-}$	0	0	0	0	0	0	0
$HEDTA^{3-}$	0	0	0	0	0	0	0
$glycolate^-$	0	0	0	0	0	0	0
$acetate^-$	0	0	0	0	0	0	0
$oxalate^{2-}$	0	0	0	0	0	0	0
DBP	0	0	0	0	0	0	0
butanol	0	0	0	0	0	0	0
NH_3	0	0	0	0	0	0	0
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

HDW Model Rev. 4

Double-Shell Tank 241-SY-101							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	7.45E+06 (kg)	(1.10E+03 kgal)	----	----	----	----	----
Heat Load	11.8 (kW)	(4.04E+04 BTU/hr)	----	11.1	11.5	12.2	12.6
Bulk Density*	1.79 (g/cc)	----	----	1.73	1.76	1.82	1.84
Water wt%	21.3	----	----	18.5	19.7	22.9	24.9
TOC wt% C (wet)	1.04	----	----	0.638	0.835	1.24	1.44
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	18.5	2.38E+05	1.77E+06	16.9	17.7	19.2	19.9
Al^{3+}	2.13	3.21E+04	2.39E+05	1.97	2.05	2.21	2.29
Fe^{3+} (total Fe)	1.48E-02	461	3.43E+03	1.21E-02	1.34E-02	1.61E-02	1.74E-02
Cr^{3+}	0.186	5.40E+03	4.03E+04	0.157	0.173	0.191	0.196
Bi^{3+}	1.82E-03	212	1.58E+03	1.66E-03	1.74E-03	1.90E-03	1.98E-03
La^{3+}	6.15E-05	4.77	35.6	4.46E-05	5.28E-05	7.02E-05	7.86E-05
Hg^{2+}	1.23E-05	1.38	10.3	1.14E-05	1.19E-05	1.25E-05	1.26E-05
Zr (as $ZrO(OH)_2$)	3.36E-04	17.1	128	3.06E-04	3.17E-04	3.48E-04	3.65E-04
Pb^{2+}	1.35E-03	156	1.16E+03	1.09E-03	1.21E-03	1.48E-03	1.61E-03
Ni^{2+}	8.58E-03	282	2.10E+03	8.19E-03	8.38E-03	8.68E-03	8.78E-03
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	5.22E-03	160	1.19E+03	3.95E-03	4.57E-03	5.87E-03	6.50E-03
Ca^{2+}	4.53E-02	1.02E+03	7.57E+03	4.15E-02	4.34E-02	4.73E-02	4.92E-02
K^+	8.68E-02	1.90E+03	1.41E+04	7.90E-02	8.27E-02	9.11E-02	9.51E-02
OH^-	12.8	1.21E+05	9.04E+05	11.9	12.3	13.3	13.6
$NO3^-$	6.54	2.27E+05	1.69E+06	6.02	6.33	6.63	6.72
$NO2^-$	3.16	8.12E+04	6.05E+05	2.62	2.87	3.44	3.71
$CO3^{2-}$	0.602	2.02E+04	1.50E+05	0.544	0.570	0.642	0.651
$PO4^{3-}$	0.123	6.54E+03	4.87E+04	0.106	0.112	0.126	0.129
$SO4^{2-}$	0.333	1.79E+04	1.33E+05	0.262	0.296	0.371	0.404
Si (as SiO_3^{2-})	0.105	1.65E+03	1.23E+04	8.68E-02	9.57E-02	0.114	0.123
F^-	8.95E-02	950	7.08E+03	7.54E-02	8.13E-02	9.64E-02	0.102
Cl^-	0.321	6.35E+03	4.73E+04	0.290	0.302	0.335	0.348
$C_6H_5O_7^{3-}$	3.79E-02	4.00E+03	2.98E+04	3.46E-02	3.62E-02	3.96E-02	4.12E-02
$EDTA^{4-}$	2.53E-02	4.08E+03	3.04E+04	7.48E-03	1.62E-02	3.45E-02	4.35E-02
$HEDTA^{3-}$	4.78E-02	7.32E+03	5.45E+04	1.21E-02	2.95E-02	6.62E-02	8.41E-02
glycolate$^-$	0.134	5.61E+03	4.18E+04	9.02E-02	0.112	0.156	0.178
acetate$^-$	9.25E-03	305	2.27E+03	7.62E-03	8.42E-03	1.01E-02	1.09E-02
oxalate^{2-}	8.06E-05	3.96	29.5	7.14E-05	7.59E-05	8.53E-05	8.98E-05
DBP	2.55E-02	2.99E+03	2.23E+04	2.10E-02	2.32E-02	2.77E-02	2.99E-02
butanol	2.55E-02	1.06E+03	7.87E+03	2.10E-02	2.32E-02	2.77E-02	2.99E-02
NH_3	0.113	1.08E+03	8.01E+03	9.27E-02	0.101	0.129	0.148
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

HDW Model Rev. 4

Double-Shell Tank 241-SY-101							
Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	7.45E+06 (kg)	(1.10E+03 kgal)	----	----	----	----	----
Heat Load	11.8 (kW)	(4.04E+04 BTU/hr)	----	11.1	11.5	12.2	12.6
Bulk Density†	1.79 (g/cc)	----	----	1.73	1.76	1.82	1.84
Water wt%†	21.3	----	----	18.5	19.7	22.9	24.9
TOC wt% C (wet)†	1.04	----	----	0.638	0.835	1.24	1.44
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	18.5	2.38E+05	1.77E+06	16.9	17.7	19.2	19.9
Al^{3+}	2.13	3.21E+04	2.39E+05	1.97	2.05	2.21	2.29
Fe^{3+} (total Fe)	1.48E-02	461	3.43E+03	1.21E-02	1.34E-02	1.61E-02	1.74E-02
Cr^{3+}	0.186	5.40E+03	4.03E+04	0.157	0.173	0.191	0.196
Bi^{3+}	1.82E-03	212	1.58E+03	1.66E-03	1.74E-03	1.90E-03	1.98E-03
La^{3+}	6.15E-05	4.77	35.6	4.46E-05	5.28E-05	7.02E-05	7.86E-05
Hg^{2+}	1.23E-05	1.38	10.3	1.14E-05	1.19E-05	1.25E-05	1.26E-05
Zr (as $ZrO(OH)_2$)	3.36E-04	17.1	128	3.06E-04	3.17E-04	3.48E-04	3.65E-04
Pb^{2+}	1.35E-03	156	1.16E+03	1.09E-03	1.21E-03	1.48E-03	1.61E-03
Ni^{2+}	8.58E-03	282	2.10E+03	8.19E-03	8.38E-03	8.68E-03	8.78E-03
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	5.22E-03	160	1.19E+03	3.95E-03	4.57E-03	5.87E-03	6.50E-03
Ca^{2+}	4.53E-02	1.02E+03	7.57E+03	4.15E-02	4.34E-02	4.73E-02	4.92E-02
K^+	8.68E-02	1.90E+03	1.41E+04	7.90E-02	8.27E-02	9.11E-02	9.51E-02
OH^-	12.8	1.21E+05	9.04E+05	11.9	12.3	13.3	13.6
$NO3^-$	6.54	2.27E+05	1.69E+06	6.02	6.33	6.63	6.72
$NO2^-$	3.16	8.12E+04	6.05E+05	2.62	2.87	3.44	3.71
$CO3^{2-}$	0.602	2.02E+04	1.50E+05	0.544	0.570	0.642	0.651
$PO4^{3-}$	0.123	6.54E+03	4.87E+04	0.106	0.112	0.126	0.129
$SO4^{2-}$	0.333	1.79E+04	1.33E+05	0.262	0.296	0.371	0.404
Si (as SiO_3^{2-})	0.105	1.65E+03	1.23E+04	8.68E-02	9.57E-02	0.114	0.123
F^-	8.95E-02	950	7.08E+03	7.54E-02	8.13E-02	9.64E-02	0.102
Cl^-	0.321	6.35E+03	4.73E+04	0.290	0.302	0.335	0.348
$C_6H_5O_7^{3-}$	3.79E-02	4.00E+03	2.98E+04	3.46E-02	3.62E-02	3.96E-02	4.12E-02
$EDTA^{4-}$	2.53E-02	4.08E+03	3.04E+04	7.48E-03	1.62E-02	3.45E-02	4.35E-02
$HEDTA^{3-}$	4.78E-02	7.32E+03	5.45E+04	1.21E-02	2.95E-02	6.62E-02	8.41E-02
$glycolate^-$	0.134	5.61E+03	4.18E+04	9.02E-02	0.112	0.156	0.178
$acetate^-$	9.25E-03	305	2.27E+03	7.62E-03	8.42E-03	1.01E-02	1.09E-02
$oxalate^{2-}$	8.06E-05	3.96	29.5	7.14E-05	7.59E-05	8.53E-05	8.98E-05
DBP	2.55E-02	2.99E+03	2.23E+04	2.10E-02	2.32E-02	2.77E-02	2.99E-02
butanol	2.55E-02	1.06E+03	7.87E+03	2.10E-02	2.32E-02	2.77E-02	2.99E-02
NH_3	0.113	1.08E+03	8.01E+03	9.27E-02	0.101	0.129	0.148
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

†Water wt% derived from the difference of density and total dissolved species.

A-6. Tank SY-101 (cont'd)

HDW Model Rev. 4

Double-Shell Tank 241-SY-101							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	0 (kg)	(0 kgal)	----	----	----	----	----
Heat Load	0 (kW)	(0 BTU/hr)	----	0	0	0	0
Bulk Density	0 (g/cc)	----	----	0	0	0	0
Void Fraction	0	----	----	0	0	0	0
Water wt%	0	----	----	0	0	0	0
TOC wt% C (wet)	0	----	----	0	0	0	0
Radiological Constituents	**CI/L**	**pCI/g**	**CI**	**-95 CI (CI/L)**	**-67 CI (CI/L)**	**+67 CI (CI/L)**	**+95 CI (CI/L)**
H-3	0	0	0	0	0	0	0
C-14	0	0	0	0	0	0	0
Ni-59	0	0	0	0	0	0	0
Ni-63	0	0	0	0	0	0	0
Co-60	0	0	0	0	0	0	0
Se-79	0	0	0	0	0	0	0
Sr-90	0	0	0	0	0	0	0
Y-90	0	0	0	0	0	0	0
Zr-93	0	0	0	0	0	0	0
Nb-93m	0	0	0	0	0	0	0
Tc-99	0	0	0	0	0	0	0
Ru-106	0	0	0	0	0	0	0
Cd-113m	0	0	0	0	0	0	0
Sb-125	0	0	0	0	0	0	0
Sn-126	0	0	0	0	0	0	0
I-129	0	0	0	0	0	0	0
Cs-134	0	0	0	0	0	0	0
Cs-137	0	0	0	0	0	0	0
Ba-137m	0	0	0	0	0	0	0
Sm-151	0	0	0	0	0	0	0
Eu-152	0	0	0	0	0	0	0
Eu-154	0	0	0	0	0	0	0
Eu-155	0	0	0	0	0	0	0
Ra-226	0	0	0	0	0	0	0
Ra-228	0	0	0	0	0	0	0
Ac-227	0	0	0	0	0	0	0
Pa-231	0	0	0	0	0	0	0
Th-229	0	0	0	0	0	0	0
Th-232	0	0	0	0	0	0	0
U-232	0	0	0	0	0	0	0
U-233	0	0	0	0	0	0	0
U-234	0	0	0	0	0	0	0
U-235	0	0	0	0	0	0	0
U-236	0	0	0	0	0	0	0
U-238	0	0	0	0	0	0	0
Np-237	0	0	0	0	0	0	0
Pu-238	0	0	0	0	0	0	0
Pu-239	0	0	0	0	0	0	0
Pu-240	0	0	0	0	0	0	0
Pu-241	0	0	0	0	0	0	0
Pu-242	0	0	0	0	0	0	0
Am-241	0	0	0	0	0	0	0
Am-243	0	0	0	0	0	0	0
Cm-242	0	0	0	0	0	0	0
Cm-243	0	0	0	0	0	0	0
Cm-244	0	0	0	0	0	0	0
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	0 (g/L)	----	0	0	0	0	0
U	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

HDW Model Rev. 4

Double-Shell Tank 241-SY-101							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	7.45E+06 (kg)	(1.10E+03 kgal)	----	----	----	----	----
Heat Load	11.8 (kW)	(4.04E+04 BTU/hr)	----	11.1	11.5	12.2	12.6
Bulk Density*	1.79 (g/cc)	----	----	1.73	1.76	1.82	1.84
Water wt%†	21.3	----	----	18.5	19.7	22.9	24.9
TOC wt% C (wet)	1.04	----	----	0.638	0.835	1.24	1.44
Radiological Constituents	**CI/L**	**pCI/g**	**CI**	**-95 CI (CI/L)**	**-67 CI (CI/L)**	**+67 CI (CI/L)**	**+95 CI (CI/L)**
H-3	3.31E-04	0.185	1.38E+03	1.69E-04	1.69E-04	3.45E-04	3.63E-04
C-14	4.89E-05	2.73E-02	204	1.49E-05	1.49E-05	4.96E-05	5.03E-05
Ni-59	3.13E-06	1.75E-03	13.0	1.53E-06	1.53E-06	3.21E-06	3.29E-06
Ni-63	3.07E-04	0.172	1.28E+03	1.49E-04	1.49E-04	3.15E-04	3.23E-04
Co-60	5.48E-05	3.06E-02	228	1.59E-05	1.59E-05	5.59E-05	5.69E-05
Sc-79	4.87E-06	2.72E-03	20.3	2.70E-06	2.70E-06	5.66E-06	6.41E-06
Sr-90	0.164	91.6	6.83E+05	0.153	0.158	0.169	0.175
Y-90	0.164	91.6	6.83E+05	8.89E-02	8.89E-02	0.169	0.175
Zr-93	2.39E-05	1.34E-02	99.5	1.30E-05	1.30E-05	2.78E-05	3.16E-05
Nb-93m	1.73E-05	9.68E-03	72.1	9.72E-06	9.72E-06	2.01E-05	2.27E-05
Tc-99	3.48E-04	0.194	1.45E+03	2.21E-04	2.83E-04	4.13E-04	4.76E-04
Ru-106	1.00E-08	5.59E-06	4.16E-02	4.96E-09	4.96E-09	1.11E-08	1.21E-08
Cd-113m	1.26E-04	7.06E-02	526	6.13E-05	6.13E-05	1.50E-04	1.73E-04
Sb-125	2.38E-04	0.133	989	6.90E-05	6.90E-05	2.43E-04	2.49E-04
Sn-126	7.36E-06	4.11E-03	30.6	4.10E-06	4.10E-06	8.54E-06	9.67E-06
I-129	6.71E-07	3.75E-04	2.79	4.26E-07	5.46E-07	7.98E-07	9.20E-07
Cs-134	4.05E-06	2.26E-03	16.8	2.70E-06	3.36E-06	4.74E-06	5.42E-06
Cs-137	0.371	207	1.54E+06	0.334	0.352	0.390	0.409
Ba-137m	0.351	196	1.46E+06	0.282	0.282	0.369	0.387
Sm-151	1.71E-02	9.58	7.14E+04	9.54E-03	9.54E-03	1.99E-02	2.25E-02
Eu-152	5.91E-06	3.30E-03	24.6	3.22E-06	3.22E-06	6.41E-06	6.89E-06
Eu-154	8.96E-04	0.501	3.73E+03	3.53E-04	3.53E-04	1.09E-03	1.17E-03
Eu-155	3.51E-04	0.196	1.46E+03	1.91E-04	1.91E-04	3.81E-04	4.11E-04
Ra-226	2.05E-10	1.15E-07	8.54E-04	1.38E-10	1.38E-10	2.30E-10	2.53E-10
Ra-228	2.08E-07	1.16E-04	0.865	8.88E-08	1.47E-07	2.78E-07	3.53E-07
Ac-227	1.30E-09	7.27E-07	5.42E-03	9.10E-10	9.10E-10	1.44E-09	1.58E-09
Pa-231	6.00E-09	3.35E-06	2.50E-02	3.83E-09	3.83E-09	6.79E-09	7.54E-09
Th-229	4.87E-09	2.72E-06	2.03E-02	2.26E-09	3.54E-09	6.42E-09	8.06E-09
Th-232	1.40E-08	7.84E-06	5.84E-02	7.45E-09	1.07E-08	1.74E-08	2.06E-08
U-232	1.06E-06	5.91E-04	4.40	5.81E-07	8.14E-07	1.34E-06	1.64E-06
U-233	4.05E-06	2.26E-03	16.9	2.23E-06	3.12E-06	5.13E-06	6.29E-06
U-234	1.14E-06	6.37E-04	4.75	1.10E-06	1.12E-06	1.16E-06	1.18E-06
U-235	4.62E-08	2.58E-05	0.192	4.44E-08	4.53E-08	4.71E-08	4.77E-08
U-236	3.59E-08	2.00E-05	0.149	3.45E-08	3.53E-08	3.64E-08	3.70E-08
U-238	1.34E-06	7.46E-04	5.56	1.29E-06	1.32E-06	1.36E-06	1.37E-06
Np-237	1.26E-06	7.03E-04	5.24	8.44E-07	1.05E-06	1.47E-06	1.68E-06
Pu-238	2.07E-06	1.15E-03	8.60	1.58E-06	1.82E-06	2.31E-06	2.55E-06
Pu-239	7.02E-05	3.92E-02	292	5.77E-05	6.38E-05	7.65E-05	8.26E-05
Pu-240	1.20E-05	6.68E-03	49.8	9.63E-06	1.08E-05	1.31E-05	1.43E-05
Pu-241	1.40E-04	7.84E-02	584	1.07E-04	1.23E-04	1.57E-04	1.74E-04
Pu-242	7.72E-10	4.31E-07	3.21E-03	5.74E-10	6.71E-10	8.73E-10	9.70E-10
Am-241	8.29E-05	4.63E-02	345	5.98E-05	7.11E-05	9.47E-05	1.06E-04
Am-243	2.96E-09	1.65E-06	1.23E-02	2.24E-09	2.58E-09	3.38E-09	3.74E-09
Cm-242	2.25E-07	1.26E-04	0.938	1.15E-07	1.15E-07	2.44E-07	2.63E-07
Cm-243	2.09E-08	1.17E-05	8.70E-02	1.04E-08	1.04E-08	2.26E-08	2.42E-08
Cm-244	2.02E-07	1.13E-04	0.841	9.34E-08	9.34E-08	2.39E-07	2.62E-07
Totals	**M**	**pg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	8.59E-04 (g/L)	----	3.58	6.23E-04	7.39E-04	9.79E-04	1.09E-03
U	1.30E-02	1.73E+03	1.29E+04	1.25E-02	1.28E-02	1.33E-02	1.35E-02

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

A-6. Tank SY-101 (cont'd)

HDW Model Rev. 4

Double-Shell Tank 241-SY-101 Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	7.45E+06 (kg)	(1.10E+03 kgal)		----	----	----	----
Heat Load	11.8 (kW)	(4.04E+04 BTU/hr)	----	11.1	11.5	12.2	12.6
Bulk Density†	1.79 (g/cc)	----	----	1.73	1.76	1.82	1.84
Water wt%†	21.3	----	----	18.5	19.7	22.9	24.9
TOC wt% C (wet)†	1.04	----	----	0.638	0.835	1.24	1.44
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	3.31E-04	0.185	1.38E+03	1.69E-04	1.69E-04	3.45E-04	3.63E-04
C-14	4.89E-05	2.73E-02	204	1.49E-05	1.49E-05	4.96E-05	5.03E-05
Ni-59	3.13E-06	1.75E-03	13.0	1.53E-06	1.53E-06	3.21E-06	3.29E-06
Ni-63	3.07E-04	0.172	1.28E+03	1.49E-04	1.49E-04	3.15E-04	3.23E-04
Co-60	5.48E-05	3.06E-02	228	1.59E-05	1.59E-05	5.59E-05	5.69E-05
Se-79	4.87E-06	2.72E-03	20.3	2.70E-06	2.70E-06	5.66E-06	6.41E-06
Sr-90	0.164	91.6	6.83E+05	0.153	0.158	0.169	0.175
Y-90	0.164	91.6	6.83E+05	8.89E-02	8.89E-02	0.169	0.175
Zr-93	2.39E-05	1.34E-02	99.5	1.30E-05	1.30E-05	2.78E-05	3.16E-05
Nb-93m	1.73E-05	9.68E-03	72.1	9.72E-06	9.72E-06	2.01E-05	2.27E-05
Tc-99	3.48E-04	0.194	1.45E+03	2.21E-04	2.83E-04	4.13E-04	4.76E-04
Ru-106	1.00E-08	5.59E-06	4.16E-02	4.96E-09	4.96E-09	1.11E-08	1.21E-08
Cd-113m	1.26E-04	7.06E-02	526	6.13E-05	6.13E-05	1.50E-04	1.73E-04
Sb-125	2.38E-04	0.133	989	6.90E-05	6.90E-05	2.43E-04	2.49E-04
Sn-126	7.36E-06	4.11E-03	30.6	4.10E-06	4.10E-06	8.54E-06	9.67E-06
I-129	6.71E-07	3.75E-04	2.79	4.26E-07	5.46E-07	7.98E-07	9.20E-07
Cs-134	4.05E-06	2.26E-03	16.8	2.70E-06	3.36E-06	4.74E-06	5.42E-06
Cs-137	0.371	207	1.54E+06	0.334	0.352	0.390	0.409
Ba-137m	0.351	196	1.46E+06	0.282	0.282	0.369	0.387
Sm-151	1.71E-02	9.58	7.14E+04	9.54E-03	9.54E-03	1.99E-02	2.25E-02
Eu-152	5.91E-06	3.30E-03	24.6	3.22E-06	3.22E-06	6.41E-06	6.89E-06
Eu-154	8.96E-04	0.501	3.73E+03	3.53E-04	3.53E-04	1.09E-03	1.17E-03
Eu-155	3.51E-04	0.196	1.46E+03	1.91E-04	1.91E-04	3.81E-04	4.11E-04
Ra-226	2.05E-10	1.15E-07	8.54E-04	1.38E-10	1.38E-10	2.30E-10	2.53E-10
Ra-228	2.08E-07	1.16E-04	0.865	8.88E-08	1.47E-07	2.78E-07	3.53E-07
Ac-227	1.30E-09	7.27E-07	5.42E-03	9.10E-10	9.10E-10	1.44E-09	1.58E-09
Pa-231	6.00E-09	3.35E-06	2.50E-02	3.83E-09	3.83E-09	6.79E-09	7.54E-09
Th-229	4.87E-09	2.72E-06	2.03E-02	2.26E-09	3.54E-09	6.42E-09	8.06E-09
Th-232	1.40E-08	7.84E-06	5.84E-02	7.45E-09	1.07E-08	1.74E-08	2.06E-08
U-232	1.06E-06	5.91E-04	4.40	5.81E-07	8.14E-07	1.34E-06	1.64E-06
U-233	4.05E-06	2.26E-03	16.9	2.23E-06	3.12E-06	5.13E-06	6.29E-06
U-234	1.14E-06	6.37E-04	4.75	1.10E-06	1.12E-06	1.16E-06	1.18E-06
U-235	4.62E-08	2.58E-05	0.192	4.44E-08	4.53E-08	4.71E-08	4.77E-08
U-236	3.59E-08	2.00E-05	0.149	3.45E-08	3.53E-08	3.64E-08	3.70E-08
U-238	1.34E-06	7.46E-04	5.56	1.29E-06	1.32E-06	1.36E-06	1.37E-06
Np-237	1.26E-06	7.03E-04	5.24	8.44E-07	1.05E-06	1.47E-06	1.68E-06
Pu-238	2.07E-06	1.15E-03	8.60	1.58E-06	1.82E-06	2.31E-06	2.55E-06
Pu-239	7.02E-05	3.92E-02	292	5.77E-05	6.38E-05	7.65E-05	8.26E-05
Pu-240	1.20E-05	6.68E-03	49.8	9.63E-06	1.08E-05	1.31E-05	1.43E-05
Pu-241	1.40E-04	7.84E-02	584	1.07E-04	1.23E-04	1.57E-04	1.74E-04
Pu-242	7.72E-10	4.31E-07	3.21E-03	5.74E-10	6.71E-10	8.73E-10	9.70E-10
Am-241	8.29E-05	4.63E-02	345	5.98E-05	7.11E-05	9.47E-05	1.06E-04
Am-243	2.96E-09	1.65E-06	1.23E-02	2.24E-09	2.58E-09	3.38E-09	3.74E-09
Cm-242	2.25E-07	1.26E-04	0.938	1.15E-07	1.15E-07	2.44E-07	2.63E-07
Cm-243	2.09E-08	1.17E-05	8.70E-02	1.04E-08	1.04E-08	2.26E-08	2.42E-08
Cm-244	2.02E-07	1.13E-04	0.841	9.34E-08	9.34E-08	2.39E-07	2.62E-07
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	8.59E-04 (g/L)	----	3.58	6.23E-04	7.39E-04	9.79E-04	1.09E-03
U	1.30E-02	1.73E+03	1.29E+04	1.25E-02	1.28E-02	1.33E-02	1.35E-02

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).
†Volume average for density, mass average Water wt% and TOC wt% C.

A-7. Tank SY-102

HDW Model Rev. 4

Double-Shell Tank 241-SY-102							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	4.94E+05 (kg)	(70.9 kgal)	----	----	----	----	----
Heat Load	0.514 (kW)	(1.76E+03 BTU/hr)	----	0.285	0.392	0.621	0.729
Bulk Density	1.84 (g/cc)	----	----	1.62	1.72	1.93	2.01
Void Fraction	0.545	----	----	0.452	0.491	0.610	0.666
Water wt%	25.5	----	----	17.8	21.2	31.7	38.0
TOC wt% C (wet)	0.820	----	----	0.416	0.620	1.00	1.17
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	13.8	1.72E+05	8.50E+04	8.42	10.9	16.1	18.1
Al^{3+}	5.53	8.11E+04	4.01E+04	4.98	5.27	5.77	6.01
Fe^{3+} (total Fe)	0.873	2.65E+04	1.31E+04	0.830	0.860	0.880	0.887
Cr^{3+}	0.136	3.86E+03	1.90E+03	0.112	0.123	0.144	0.149
Bi^{3+}	3.36E-03	382	189	2.84E-03	3.10E-03	3.63E-03	3.88E-03
La^{3+}	9.88E-06	0.746	0.368	6.70E-06	8.22E-06	1.14E-05	1.30E-05
Hg^{2+}	1.42E-05	1.55	0.765	1.28E-05	1.35E-05	1.49E-05	1.55E-05
Zr (as $ZrO(OH)_2$)	3.76E-04	18.6	9.20	2.50E-04	3.07E-04	4.36E-04	4.99E-04
Pb^{2+}	1.29E-03	145	71.8	7.05E-04	9.92E-04	1.59E-03	1.88E-03
Ni^{2+}	6.43E-02	2.05E+03	1.01E+03	3.03E-02	5.25E-02	6.57E-02	6.70E-02
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	1.39E-03	41.5	20.5	9.83E-04	1.18E-03	1.60E-03	1.80E-03
Ca^{2+}	0.220	4.79E+03	2.37E+03	7.62E-02	0.161	0.247	0.273
K^+	7.84E-02	1.67E+03	823	4.50E-02	5.96E-02	9.84E-02	0.116
OH^-	24.7	2.29E+05	1.13E+05	21.3	23.0	26.3	27.9
$NO3^-$	3.60	1.21E+05	5.98E+04	2.39	3.00	4.60	4.05
$NO2^-$	2.43	6.08E+04	3.00E+04	1.26	1.78	3.03	3.58
$CO3^{2-}$	0.656	2.14E+04	1.06E+04	0.470	0.550	0.762	0.807
$PO4^{3-}$	0.199	1.02E+04	5.06E+03	0.137	0.165	0.209	0.218
$SO4^{2-}$	0.383	2.00E+04	9.87E+03	0.174	0.261	0.516	0.609
Si (as SiO_3^{2-})	4.33E-02	661	326	2.38E-02	3.34E-02	5.26E-02	6.08E-02
F^-	7.08E-02	730	361	4.04E-02	5.45E-02	8.47E-02	8.84E-02
Cl^-	9.56E-02	1.84E+03	909	5.82E-02	7.45E-02	0.115	0.127
$C_6H_5O_7^{3-}$	3.22E-02	3.30E+03	1.63E+03	2.46E-02	2.82E-02	3.56E-02	3.89E-02
$EDTA^{4-}$	1.94E-02	3.04E+03	1.50E+03	4.93E-03	1.18E-02	2.70E-02	3.45E-02
$HEDTA^{3-}$	3.64E-02	5.43E+03	2.68E+03	8.05E-03	2.15E-02	5.13E-02	6.59E-02
glycolate$^-$	0.105	4.27E+03	2.11E+03	3.67E-02	6.89E-02	0.140	0.174
acetate$^-$	7.82E-03	251	124	5.83E-03	6.75E-03	8.84E-03	1.01E-02
oxalate^{2-}	1.29E-05	0.619	0.306	1.15E-05	1.22E-05	1.37E-05	1.44E-05
DBP	2.33E-02	2.67E+03	1.32E+03	1.65E-02	1.97E-02	2.65E-02	2.98E-02
butanol	2.33E-02	940	464	1.65E-02	1.97E-02	2.65E-02	2.98E-02
NH_3	4.86E-02	449	222	2.31E-02	3.44E-02	6.42E-02	8.15E-02
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

HDW Model Rev. 4

Double-Shell Tank 241-SY-102							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	2.62E+06 (kg)	(676 kgal)	----	----	----	----	----
Heat Load	1.43E-03 (kW)	(4.87 BTU/hr)	----	1.32E-03	1.38E-03	1.47E-03	1.54E-03
Bulk Density*	1.03 (g/cc)	----	----	1.01	1.02	1.03	1.03
Water wt%	94.9	----	----	94.9	94.9	96.2	97.4
TOC wt% C (wet)	5.74E-04	----	----	3.84E-04	4.77E-04	6.71E-04	7.67E-04
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	0.629	1.41E+04	3.70E+04	0.315	0.468	0.629	0.629
Al^{3+}	3.81E-02	1.00E+03	2.63E+03	1.59E-02	2.67E-02	3.82E-02	3.81E-02
Fe^{3+} (total Fe)	1.24E-03	67.5	177	8.19E-04	1.02E-03	1.45E-03	1.66E-03
Cr^{3+}	5.21E-03	264	693	4.38E-03	4.78E-03	5.21E-03	5.21E-03
Bi^{3+}	3.67E-07	7.49E-02	0.196	3.42E-07	3.54E-07	3.80E-07	3.92E-07
La^{3+}	3.79E-09	5.13E-04	1.35E-03	2.81E-09	3.29E-09	4.29E-09	4.78E-09
Hg^{2+}	2.78E-09	5.44E-04	1.43E-03	2.65E-09	2.73E-09	2.83E-09	2.87E-09
Zr (as $ZrO(OH)_2$)	9.97E-08	8.87E-03	2.33E-02	7.58E-08	9.67E-08	1.03E-07	1.06E-07
Pb^{2+}	3.49E-07	7.04E-02	0.185	2.83E-07	3.15E-07	3.82E-07	4.15E-07
Ni^{2+}	1.11E-03	63.8	167	1.03E-03	1.07E-03	1.16E-03	1.20E-03
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	3.50E-06	0.188	0.492	2.07E-06	2.77E-06	4.23E-06	4.73E-06
Ca^{2+}	5.57E-03	218	572	3.93E-03	4.73E-03	6.41E-03	7.22E-03
K^+	2.25E-03	85.8	225	1.13E-03	1.68E-03	2.26E-03	2.25E-03
OH^-	0.222	3.67E+03	9.64E+03	0.108	0.163	0.222	0.223
$NO3^-$	0.461	2.79E+04	7.32E+04	0.234	0.345	0.461	0.462
$NO2^-$	1.40E-02	628	1.65E+03	1.28E-02	1.34E-02	1.41E-02	1.41E-02
$CO3^{2-}$	2.98E-02	1.74E+03	4.58E+03	1.35E-02	2.16E-02	3.06E-02	3.14E-02
$PO4^{3-}$	7.75E-05	7.18	18.8	6.09E-05	6.90E-05	8.60E-05	9.41E-05
$SO4^{2-}$	2.98E-03	279	733	2.38E-03	2.67E-03	2.99E-03	2.99E-03
Si (as SiO_3^{2-})	2.47E-05	0.675	1.77	2.05E-05	2.25E-05	2.68E-05	2.86E-05
F^-	2.29E-05	0.424	1.11	1.94E-05	2.16E-05	2.43E-05	2.64E-05
Cl^-	1.50E-02	517	1.36E+03	7.08E-03	1.09E-02	1.50E-02	1.50E-02
$C_6H_5O_7^{3-}$	1.03E-05	1.90	4.99	8.26E-06	9.26E-06	1.14E-05	1.24E-05
$EDTA^{4-}$	7.10E-06	1.99	5.23	2.33E-06	4.66E-06	9.55E-06	1.20E-05
$HEDTA^{3-}$	1.27E-05	3.39	8.90	3.14E-06	7.80E-06	1.76E-05	2.24E-05
glycolate$^-$	6.52E-05	4.77	12.5	3.78E-05	5.12E-05	7.92E-05	9.25E-05
acetate$^-$	4.82E-06	0.277	0.728	3.79E-06	4.23E-06	5.45E-06	6.42E-06
oxalate^{2-}	4.96E-09	4.26E-04	1.12E-03	4.43E-09	4.69E-09	5.23E-09	5.49E-09
DBP	7.55E-06	1.55	4.06	6.59E-06	7.01E-06	8.14E-06	9.02E-06
butanol	7.55E-06	0.546	1.43	6.59E-06	7.01E-06	8.14E-06	9.02E-06
NH_3	2.90E-05	0.481	1.26	1.74E-05	2.30E-05	3.51E-05	4.11E-05
$Fe(CN)_6^{4-}$	0	0	0	0	0	0	0

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

HDW Model Rev. 4

Double-Shell Tank 241-SY-102							
Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	3.12E+06 (kg)	(747 kgal)	----	----	----	----	----
Heat Load	0.516 (kW)	(1.76E+03 BTU/hr)	----	0.286	0.394	0.622	0.731
Bulk Density†	1.10 (g/cc)	----	----	1.08	1.09	1.11	1.12
Water wt%†	84.0	----	----	81.8	82.8	85.5	86.9
TOC wt% C (wet)†	0.130	----	----	5.95E-02	9.34E-02	0.166	0.200
Chemical Constituents	**mole/L**	**ppm**	**kg**	**-95 CI (mole/L)**	**-67 CI (mole/L)**	**+67 CI (mole/L)**	**+95 CI (mole/L)**
Na^+	1.88	3.91E+04	1.22E+05	1.37	1.61	2.10	2.29
Al^{3+}	0.560	1.37E+04	4.27E+04	0.507	0.535	0.582	0.604
Fe^{3+} (total Fe)	8.40E-02	4.25E+03	1.33E+04	7.99E-02	8.28E-02	8.46E-02	8.52E-02
Cr^{3+}	1.77E-02	833	2.60E+03	1.53E-02	1.64E-02	1.84E-02	1.89E-02
Bi^{3+}	3.19E-04	60.5	189	2.70E-04	2.94E-04	3.45E-04	3.69E-04
La^{3+}	9.41E-07	0.119	0.370	6.39E-07	7.84E-07	1.09E-06	1.23E-06
Hg^{2+}	1.35E-06	0.246	0.767	1.22E-06	1.28E-06	1.42E-06	1.48E-06
Zr (as $ZrO(OH)_2$)	3.58E-05	2.96	9.22	2.38E-05	2.93E-05	4.15E-05	4.75E-05
Pb^{2+}	1.23E-04	23.1	72.0	6.72E-05	9.45E-05	1.51E-04	1.78E-04
Ni^{2+}	7.11E-03	379	1.18E+03	3.87E-03	5.99E-03	7.23E-03	7.34E-03
Sr^{2+}	0	0	0	0	0	0	0
Mn^{4+}	1.35E-04	6.73	21.0	9.64E-05	1.15E-04	1.55E-04	1.74E-04
Ca^{2+}	2.59E-02	942	2.94E+03	1.21E-02	2.04E-02	2.82E-02	3.04E-02
K^+	9.48E-03	336	1.05E+03	6.31E-03	7.69E-03	1.14E-02	1.31E-02
OH^-	2.55	3.93E+04	1.23E+05	2.22	2.39	2.70	2.85
$NO3^-$	0.759	4.27E+04	1.33E+05	0.527	0.640	0.845	0.802
$NO2^-$	0.244	1.02E+04	3.17E+04	0.132	0.181	0.301	0.352
$CO3^{2-}$	8.92E-02	4.85E+03	1.51E+04	5.89E-02	7.52E-02	9.93E-02	0.104
$PO4^{3-}$	1.89E-02	1.63E+03	5.08E+03	1.31E-02	1.57E-02	1.99E-02	2.08E-02
$SO4^{2-}$	3.90E-02	3.40E+03	1.06E+04	1.92E-02	2.75E-02	5.17E-02	6.04E-02
Si (as SiO_3^{2-})	4.13E-03	105	328	2.28E-03	3.20E-03	5.01E-03	5.79E-03
F^-	6.74E-03	116	362	3.85E-03	5.19E-03	8.06E-03	8.41E-03
Cl^-	2.26E-02	727	2.27E+03	1.46E-02	1.85E-02	2.44E-02	2.56E-02
$C_6H_5O_7^{3-}$	3.06E-03	525	1.64E+03	2.35E-03	2.69E-03	3.38E-03	3.70E-03
$EDTA^4$	1.85E-03	484	1.51E+03	4.75E-04	1.13E-03	2.57E-03	3.28E-03
$HEDTA^3$	3.47E-03	863	2.69E+03	7.76E-04	2.05E-03	4.88E-03	6.27E-03
glycolate	1.00E-02	680	2.12E+03	3.54E-03	6.60E-03	1.34E-02	1.66E-02
acetate	7.47E-04	40.0	125	5.58E-04	6.45E-04	8.43E-04	9.58E-04
oxalate^{2-}	1.23E-06	9.84E-02	0.307	1.09E-06	1.16E-06	1.30E-06	1.37E-06
DBP	2.22E-03	423	1.32E+03	1.57E-03	1.88E-03	2.53E-03	2.84E-03
butanol	2.22E-03	149	466	1.57E-03	1.88E-03	2.53E-03	2.84E-03
NH_3	4.64E-03	71.5	223	2.22E-03	3.29E-03	6.12E-03	7.76E-03
$Fe(CN)_6^4$	0	0	0	0	0	0	0

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).
†Water wt% derived from the difference of density and total dissolved species.

A-7. Tank SY-102 (cont'd)

HDW Model Rev. 4

Double-Shell Tank 241-SY-102							
TLM Solids Composite Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total TLM Waste	4.94E+05 (kg)	(70.9 kgal)	----	----	----	----	----
Heat Load	0.514 (kW)	(1.76E+03 BTU/hr)	----	0.285	0.392	0.621	0.729
Bulk Density	1.84 (g/cc)	----	----	1.62	1.72	1.93	2.01
Void Fraction	0.545	----	----	0.452	0.491	0.610	0.666
Water wt%	25.5	----	----	17.8	21.2	31.7	38.0
TOC wt% C (wet)	0.820	----	----	0.416	0.620	1.00	1.17
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	2.76E-04	0.150	74.0	0	0	2.80E-04	2.84E-04
C-14	3.57E-05	1.94E-02	9.59	0	0	3.60E-05	3.61E-05
Ni-59	6.11E-07	3.32E-04	0.164	0	0	6.39E-07	6.65E-07
Ni-63	6.01E-05	3.27E-02	16.1	0	0	6.29E-05	6.55E-05
Co-60	2.55E-05	1.39E-02	6.84	0	0	2.57E-05	2.57E-05
Se-79	2.27E-06	1.23E-03	0.609	0	0	2.81E-06	3.27E-06
Sr-90	4.47E-02	24.3	1.20E+04	3.40E-02	4.09E-02	4.83E-02	5.12E-02
Y-90	4.48E-02	24.3	1.20E+04	0	0	4.73E-02	4.98E-02
Zr-93	1.11E-05	6.05E-03	2.99	0	0	1.38E-05	1.60E-05
Nb-93m	8.13E-06	4.42E-03	2.18	0	0	1.00E-05	1.16E-05
Tc-99	3.17E-04	0.172	85.1	1.46E-04	2.26E-04	4.07E-04	4.95E-04
Ru-106	4.29E-09	2.33E-06	1.15E-03	0	0	5.38E-09	6.39E-09
Cd-113m	5.77E-05	3.13E-02	15.5	0	0	7.10E-05	8.21E-05
Sb-125	1.12E-04	6.09E-02	30.1	0	0	1.13E-04	1.13E-04
Sn-126	3.43E-06	1.87E-03	0.921	0	0	4.24E-06	4.94E-06
I-129	6.12E-07	3.33E-04	0.164	2.82E-07	4.37E-07	7.85E-07	9.56E-07
Cs-134	3.27E-06	1.78E-03	0.879	0	0	3.30E-06	3.31E-06
Cs-137	0.345	187	9.25E+04	0.178	0.253	0.424	0.506
Ba-137m	0.326	177	8.75E+04	0	0	0.328	0.329
Sm-151	8.00E-03	4.35	2.15E+03	0	0	9.90E-03	1.15E-02
Eu-152	2.76E-06	1.50E-03	0.741	0	0	2.78E-06	2.78E-06
Eu-154	4.02E-04	0.218	108	0	0	4.97E-04	5.39E-04
Eu-155	1.64E-04	8.91E-02	44.0	0	0	1.65E-04	1.65E-04
Ra-226	1.01E-10	5.51E-08	2.72E-05	0	0	1.33E-10	1.60E-10
Ra-228	7.21E-08	3.92E-05	1.94E-02	0	0	7.27E-08	7.33E-08
Ac-227	6.23E-10	3.39E-07	1.67E-04	0	0	8.23E-10	9.68E-10
Pa-231	2.79E-09	1.52E-06	7.49E-04	0	0	3.40E-09	3.93E-09
Th-229	1.75E-09	9.52E-07	4.70E-04	0	0	1.76E-09	1.78E-09
Th-232	7.98E-09	4.33E-06	2.14E-03	0	0	9.70E-09	1.14E-08
U-232	1.74E-07	9.45E-05	4.67E-02	1.09E-07	1.37E-07	2.15E-07	2.58E-07
U-233	6.68E-07	3.63E-04	0.179	4.17E-07	5.28E-07	8.23E-07	9.90E-07
U-234	3.74E-07	2.03E-04	0.100	3.29E-07	3.53E-07	3.93E-07	4.10E-07
U-235	1.57E-08	8.51E-06	4.20E-03	1.39E-08	1.48E-08	1.64E-08	1.71E-08
U-236	8.99E-09	4.89E-06	2.41E-03	7.80E-09	8.46E-09	9.44E-09	9.85E-09
U-238	4.61E-07	2.50E-04	0.124	4.22E-07	4.40E-07	4.79E-07	4.94E-07
Np-237	1.16E-06	6.29E-04	0.311	5.69E-07	8.44E-07	1.47E-06	1.77E-06
Pu-238	5.62E-07	3.06E-04	0.151	2.78E-07	4.17E-07	7.09E-07	8.51E-07
Pu-239	9.84E-03	5.34	2.64E+03	9.65E-03	9.78E-03	9.88E-03	9.93E-03
Pu-240	2.46E-03	1.33	659	2.41E-03	2.44E-03	2.47E-03	2.48E-03
Pu-241	3.78E-05	2.05E-02	10.1	1.93E-05	2.83E-05	4.73E-05	5.66E-05
Pu-242	2.04E-10	1.11E-07	5.48E-05	9.96E-11	1.51E-10	2.59E-10	3.12E-10
Am-241	1.04E-02	5.63	2.78E+03	9.71E-03	1.02E-02	1.05E-02	1.07E-02
Am-243	2.50E-09	1.36E-06	6.70E-04	7.24E-10	1.59E-09	3.47E-09	4.41E-09
Cm-242	2.28E-10	1.24E-07	6.11E-05	0	0	2.30E-10	2.33E-10
Cm-243	4.65E-12	2.53E-09	1.25E-06	0	0	4.70E-12	4.76E-12
Cm-244	1.35E-10	7.36E-08	3.63E-05	0	0	1.37E-10	1.38E-10
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	0.172 (g/L)	----	46.1	0.169	0.171	0.173	0.173
U	4.46E-03	577	285	3.95E-03	4.22E-03	4.68E-03	4.87E-03

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

HDW Model Rev. 4

Double-Shell Tank 241-SY-102							
SMM Composite Inventory Estimate							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total SMM Waste	2.62E+06 (kg)	(676 kgal)	----	----	----	----	----
Heat Load	1.43E-03 (kW)	(4.87 BTU/hr)	----	1.32E-03	1.38E-03	1.47E-03	1.54E-03
Bulk Density*	1.03 (g/cc)	----	----	1.01	1.02	1.03	1.03
Water wt%†	94.9	----	----	94.9	94.9	96.2	97.4
TOC wt% C (wet)	5.74E-04	----	----	3.84E-04	4.77E-04	6.71E-04	7.67E-04
Radiological Constituents	**Ci/L**	**pCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	6.77E-08	6.60E-05	0.173	4.84E-08	4.84E-08	7.16E-08	7.61E-08
C-14	9.28E-09	9.05E-06	2.37E-02	5.25E-09	5.25E-09	9.43E-09	9.58E-09
Ni-59	5.29E-10	5.16E-07	1.35E-03	3.40E-10	3.40E-10	5.39E-10	5.48E-10
Ni-63	5.21E-08	5.08E-05	0.133	3.33E-08	3.33E-08	5.30E-08	5.39E-08
Co-60	1.19E-08	1.16E-05	3.04E-02	7.27E-09	7.27E-09	1.22E-08	1.24E-08
Se-79	1.09E-09	1.06E-06	2.79E-03	8.34E-10	8.34E-10	1.18E-09	1.27E-09
Sr-90	3.40E-05	3.32E-02	87.0	3.21E-05	3.34E-05	3.47E-05	3.53E-05
Y-90	3.40E-05	3.32E-02	87.1	2.51E-05	2.51E-05	3.47E-05	3.53E-05
Zr-93	5.29E-09	5.16E-06	1.35E-02	4.00E-09	4.00E-09	5.75E-09	6.20E-09
Nb-93m	3.88E-09	3.78E-06	9.93E-03	2.98E-09	2.98E-09	4.21E-09	4.52E-09
Tc-99	6.98E-08	6.81E-05	0.179	5.48E-08	6.21E-08	7.79E-08	8.90E-08
Ru-106	2.93E-12	2.86E-09	7.51E-06	2.05E-12	2.34E-12	3.38E-12	3.82E-12
Cd-113m	2.69E-08	2.62E-05	6.87E-02	1.91E-08	1.91E-08	2.97E-08	3.23E-08
Sb-125	6.19E-08	6.04E-05	0.159	4.20E-08	4.20E-08	6.44E-08	6.68E-08
Sn-126	1.66E-09	1.62E-06	4.25E-03	1.28E-09	1.28E-09	1.80E-09	1.94E-09
I-129	1.35E-10	1.32E-07	3.45E-04	1.06E-10	1.20E-10	1.51E-10	1.72E-10
Cs-134	8.88E-09	8.66E-06	2.27E-02	6.67E-09	7.75E-09	1.00E-08	1.11E-08
Cs-137	7.01E-05	6.84E-02	179	6.29E-05	6.59E-05	7.38E-05	7.94E-05
Ba-137m	6.63E-05	6.47E-02	170	5.59E-05	5.59E-05	6.95E-05	7.26E-05
Sm-151	3.86E-06	3.76E-03	9.88	2.96E-06	2.96E-06	4.19E-06	4.50E-06
Eu-152	1.34E-09	1.31E-06	3.44E-03	1.02E-09	1.02E-09	1.48E-09	1.60E-09
Eu-154	1.95E-07	1.90E-04	0.498	1.30E-07	1.30E-07	2.18E-07	2.27E-07
Eu-155	8.23E-08	8.02E-05	0.211	6.33E-08	6.33E-08	9.04E-08	9.83E-08
Ra-226	4.66E-14	4.55E-11	1.19E-07	3.57E-14	3.86E-14	5.22E-14	5.24E-14
Ra-228	8.95E-11	8.72E-08	2.29E-04	3.01E-11	3.01E-11	1.00E-10	1.12E-10
Ac-227	2.87E-13	2.79E-10	7.33E-07	2.23E-13	2.40E-13	3.19E-13	3.19E-13
Pa-231	1.23E-12	1.20E-09	3.14E-06	9.71E-13	9.71E-13	1.32E-12	1.41E-12
Th-229	2.07E-12	2.02E-09	5.31E-06	7.03E-13	7.03E-13	2.31E-12	2.57E-12
Th-232	9.25E-12	9.02E-09	2.37E-05	1.91E-12	1.91E-12	1.13E-11	1.32E-11
U-232	2.84E-10	2.77E-07	7.26E-04	2.11E-10	2.46E-10	3.27E-10	3.73E-10
U-233	1.09E-09	1.06E-06	2.78E-03	8.07E-10	9.44E-10	1.25E-09	1.43E-09
U-234	3.89E-10	3.79E-07	9.95E-04	3.00E-10	3.68E-10	3.98E-10	4.08E-10
U-235	1.51E-11	1.47E-08	3.87E-05	1.17E-11	1.43E-11	1.55E-11	1.58E-11
U-236	2.24E-11	2.19E-08	5.74E-05	1.51E-11	2.07E-11	2.32E-11	2.40E-11
U-238	3.92E-10	3.83E-07	1.00E-03	3.31E-10	3.78E-10	3.99E-10	4.05E-10
Np-237	2.47E-10	2.41E-07	6.32E-04	1.98E-10	2.22E-10	2.74E-10	3.10E-10
Pu-238	8.79E-10	8.57E-07	2.25E-03	5.76E-10	7.24E-10	1.03E-09	1.18E-09
Pu-239	1.28E-06	1.24E-03	3.27	3.83E-07	8.21E-07	1.73E-06	2.17E-06
Pu-240	3.18E-07	3.10E-04	0.815	9.50E-08	2.04E-07	4.32E-07	5.42E-07
Pu-241	7.53E-08	7.34E-05	0.193	4.44E-08	5.95E-08	9.11E-08	1.06E-07
Pu-242	3.40E-13	3.31E-10	8.69E-07	2.24E-13	2.81E-13	3.99E-13	4.55E-13
Am-241	4.48E-06	4.37E-03	11.5	1.32E-06	2.87E-06	6.10E-06	7.65E-06
Am-243	1.04E-12	1.01E-09	2.65E-06	6.16E-13	8.09E-13	1.30E-12	1.52E-12
Cm-242	4.99E-11	4.86E-08	1.28E-04	3.68E-11	3.68E-11	5.49E-11	5.98E-11
Cm-243	4.90E-12	4.77E-09	1.25E-05	3.65E-12	3.65E-12	5.35E-12	5.79E-12
Cm-244	4.99E-11	4.86E-08	1.28E-04	3.22E-11	3.70E-11	5.89E-11	6.75E-11
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	2.23E-05 (g/L)	----	5.69E-02	6.64E-06	1.43E-05	3.02E-05	3.79E-05
U	3.86E-06	0.895	2.35	3.09E-06	3.67E-06	3.94E-06	4.02E-06

*Density is calculated based on Na, OH-, and AlO2-.

†Water wt% derived from the difference of density and total dissolved species.

HDW Model Rev. 4

Double-Shell Tank 241-SY-102							
Total Inventory Estimate*							
Physical Properties				**-95 CI**	**-67 CI**	**+67 CI**	**+95 CI**
Total Waste	3,121,446 (kg)	(747 kgal)	----	----	----	---	----
Heat Load	0.516 (kW)	(1.76E+03 BTU/hr)	----	0.286	0.394	0.622	0.731
Bulk Density†	1.10 (g/cc)	----	----	1.08	1.09	1.11	1.12
Water wt%†	84.0	----	----	81.8	82.8	85.5	86.9
TOC wt% C (wet)†	0.130	----	----	5.95E-02	9.34E-02	0.166	0.200
Radiological Constituents	**Ci/L**	**µCi/g**	**Ci**	**-95 CI (Ci/L)**	**-67 CI (Ci/L)**	**+67 CI (Ci/L)**	**+95 CI (Ci/L)**
H-3	2.62E-05	2.38E-02	74.1	6.13E-08	6.13E-08	2.66E-05	2.66E-05
C-14	3.40E-06	3.08E-03	9.61	8.40E-09	8.40E-09	3.42E-06	3.43E-06
Ni-59	5.85E-08	5.30E-05	0.165	4.79E-10	4.79E-10	6.11E-08	6.36E-08
Ni-63	5.75E-06	5.22E-03	16.3	4.71E-08	4.71E-08	6.01E-06	6.26E-06
Co-60	2.43E-06	2.20E-03	6.87	1.08E-08	1.08E-08	2.45E-06	2.45E-06
Se-79	2.16E-07	1.96E-04	0.612	9.88E-10	9.88E-10	2.68E-07	3.11E-07
Sr-90	4.28E-03	3.88	1.21E+04	3.26E-03	3.91E-03	4.61E-03	4.89E-03
Y-90	4.28E-03	3.88	1.21E+04	3.08E-05	3.08E-05	4.52E-03	4.76E-03
Zr-93	1.06E-06	9.63E-04	3.00	4.79E-09	4.79E-09	1.32E-06	1.52E-06
Nb-93m	7.75E-07	7.02E-04	2.19	3.51E-09	3.51E-09	9.56E-07	1.11E-06
Tc-99	3.02E-05	2.74E-02	85.3	1.39E-05	2.16E-05	3.87E-05	4.71E-05
Ru-106	4.10E-10	3.72E-07	1.16E-03	2.65E-12	2.65E-12	5.13E-10	6.09E-10
Cd-113m	5.50E-06	4.99E-03	15.5	2.43E-08	2.43E-08	6.76E-06	7.81E-06
Sb-125	1.07E-05	9.70E-03	30.2	5.61E-08	5.61E-08	1.08E-05	1.08E-05
Sn-126	3.27E-07	2.97E-04	0.925	1.50E-09	1.50E-09	4.04E-07	4.70E-07
I-129	5.82E-08	5.28E-05	0.165	2.69E-08	4.16E-08	7.47E-08	9.09E-08
Cs-134	3.19E-07	2.89E-04	0.901	8.03E-09	8.03E-09	3.21E-07	3.22E-07
Cs-137	3.28E-02	29.7	9.27E+04	1.69E-02	2.41E-02	4.03E-02	4.81E-02
Ba-137m	3.10E-02	28.1	8.77E+04	6.00E-05	6.00E-05	3.12E-02	3.13E-02
Sm-151	7.63E-04	0.692	2.16E+03	3.49E-06	3.49E-06	9.43E-04	1.10E-03
Eu-152	2.63E-07	2.39E-04	0.744	1.22E-09	1.22E-09	2.65E-07	2.65E-07
Eu-154	3.83E-05	3.47E-02	108	1.76E-07	1.76E-07	4.73E-05	5.13E-05
Eu-155	1.56E-05	1.42E-02	44.2	7.45E-08	7.45E-08	1.57E-05	1.58E-05
Ra-226	9.67E-12	8.77E-09	2.73E-05	4.22E-14	4.22E-14	1.27E-11	1.53E-11
Ra-228	6.93E-09	6.28E-06	1.96E-02	8.10E-11	8.10E-11	6.98E-09	7.03E-09
Ac-227	5.94E-11	5.39E-08	1.68E-04	2.59E-13	2.59E-13	7.83E-11	9.21E-11
Pa-231	2.66E-10	2.41E-07	7.53E-04	1.11E-12	1.11E-12	3.24E-10	3.74E-10
Th-229	1.68E-10	1.52E-07	4.75E-04	1.88E-12	1.88E-12	1.69E-10	1.70E-10
Th-232	7.66E-10	6.94E-07	2.16E-03	8.37E-12	8.37E-12	9.29E-10	1.09E-09
U-232	1.68E-08	1.52E-05	4.74E-02	1.06E-08	1.33E-08	2.06E-08	2.47E-08
U-233	6.43E-08	5.83E-05	0.182	4.06E-08	5.11E-08	7.91E-08	9.49E-08
U-234	3.58E-08	3.25E-05	0.101	3.16E-08	3.38E-08	3.76E-08	3.92E-08
U-235	1.50E-09	1.36E-06	4.24E-03	1.33E-09	1.42E-09	1.57E-09	1.64E-09
U-236	8.74E-10	7.92E-07	2.47E-03	7.60E-10	8.23E-10	9.16E-10	9.55E-10
U-238	4.41E-08	4.00E-05	0.125	4.04E-08	4.21E-08	4.58E-08	4.73E-08
Np-237	1.10E-07	9.98E-05	0.311	5.42E-08	8.03E-08	1.40E-07	1.68E-07
Pu-238	5.42E-08	4.91E-05	0.153	2.72E-08	4.04E-08	6.81E-08	8.16E-08
Pu-239	9.35E-04	0.847	2.64E+03	9.17E-04	9.29E-04	9.39E-04	9.42E-04
Pu-240	2.33E-04	0.212	660	2.29E-04	2.32E-04	2.34E-04	2.35E-04
Pu-241	3.65E-06	3.31E-03	10.3	1.90E-06	2.75E-06	4.56E-06	5.44E-06
Pu-242	1.97E-11	1.79E-08	5.57E-05	9.76E-12	1.46E-11	2.49E-11	2.99E-11
Am-241	9.87E-04	0.895	2.79E+03	9.25E-04	9.68E-04	1.00E-03	1.01E-03
Am-243	2.38E-10	2.16E-07	6.72E-04	6.96E-11	1.51E-10	3.31E-10	4.20E-10
Cm-242	6.67E-11	6.05E-08	1.89E-04	4.51E-11	4.51E-11	7.13E-11	7.57E-11
Cm-243	4.87E-12	4.42E-09	1.38E-05	3.74E-12	3.74E-12	5.28E-12	5.68E-12
Cm-244	5.80E-11	5.26E-08	1.64E-04	4.20E-11	4.51E-11	6.61E-11	7.40E-11
Totals	**M**	**µg/g**	**kg**	**-95 CI (M or g/L)**	**-67 CI (M or g/L)**	**+67 CI (M or g/L)**	**+95 CI (M or g/L)**
Pu	1.63E-02 (g/L)	----	46.2	1.60E-02	1.62E-02	1.64E-02	1.65E-02
U	4.27E-04	92.1	287	3.78E-04	4.04E-04	4.48E-04	4.66E-04

*Unknowns in tank solids inventory are assigned by Tank Layering Model (TLM).

†Volume average for density, mass average Water wt% and TOC wt% C.

Table A-8. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for nonradioactive species in metric tons (10^6 g). Data from Golberg and Guberski (1995). Lack of values indicates that the species was not measured and/or estimated.

Chemical Species	Single-Shell Tanks				Double-Shell Tanks			Grand Total
	Sludge	Saltcake	Int. Liq.	Total	Soluble	Insoluble	Total	
Ag^+					3.28E-01	1.38E+00	1.7E+00	1.7E+00
$Al(OH)_4^-$	6.25E+02	1.25E+03	4.57E+02	2.33E+03	5.09E+03		5.09E+03	7.43E+03
Al^{3+}	1.99E+03			1.99E+03		6.78E+01	6.78E+01	2.06E+03
As^{5+}					7.70E-01	4.98E-01	1.27E+00	1.27E+00
B^{3+}					5.19E-01	9.94E-01	1.51E+00	1.51E+00
Ba^{2+}					7.91E-01	3.09E+00	3.88E+00	3.88E+00
Be^{2+}					8.19E-02	7.61E-03	8.95E-02	8.95E-02
Bi^{3+}	2.61E+02			2.61E+02	2.26E+00		2.26E+00	2.64E+02
Ca^{2+}	1.28E+02			1.28E+02	1.03E+01	1.15E+01	2.18E+01	1.50E+02
Cd^{2+}	3.84E+00			3.84E+00	1.67E-01	6.01E+00	6.18E+00	1.00E+01
Ce^{3+}	2.35E+02			2.35E+02	2.26E-02	3.04E+00	3.07E+00	2.38E+02
Cl^-	4.00E+01			4.00E+01	2.73E+02	1.49E+00	2.74E+02	3.14E+02
CO_3^{2-}	1.15E+03	4.13E+02	3.96E+01	1.61E+03	1.92E+03	5.83E+01	1.98E+03	3.59E+03
Cr^{+2}	8.63E+01			8.63E+01		3.41E+01	3.41E+01	1.20E+02
CrO_4^{2-}			2.14E+01	2.14E+01	1.20E+02		1.20E+02	1.41E+02
Cu^{2+}					1.77E-01	7.46E-01	9.23E-01	9.23E-01
F^-	8.00E+02		5.00E+01	8.05E+02	3.25E+02	1.91E+01	3.71E+02	1.18E+03
$Fe(CN)_6^{4-}$	3.22E+02			3.22E+02				3.22E+02
Fe^{3+}	6.27E+02			6.27E+02	8.09E+00	1.42E+02	1.50E+02	7.77E+02
Hg^+	9.00E-01			9.00E-01	5.84E-02		5.84E-02	9.58E-01
K^+					5.46E+02	2.02E+01	5.66E+02	5.66E+02
La^+					2.19E-01	2.10E+01	2.12E+01	2.12E+01
Li^+					5.77E-03	2.46E-02	3.04E-02	3.04E-02
Mg^{2+}					9.65E-01	1.10E+01	1.20E+01	1.20E+01
Mn^{4+}	1.20E+02			1.20E+02	7.69E+00	1.80E+01	2.57E+01	1.46E+02
Mo^{6+}					4.87E+00	8.01E-01	5.67E+00	5.67E+00
Na^+	1.58E+04	3.39E+04	2.30E+03	5.48E+04	1.40E+04	2.30E+02	1.43E+04	6.91E+04
Ni^{2+}	1.78E+02			1.78E+02	4.07E+00	6.57E+00	1.06E+01	1.89E+02
NO_2^-	2.00E+03	1.53E+03	1.27E+03	4.80E+03	4.80E+03	8.42E+00	4.81E+03	9.61E+03
NO_3^-	1.48E+04	8.03E+04	1.71E+03	9.68E+04	1.03E+04	3.91E+01	1.03E+04	1.07E+05
OH^-	4.22E+03	8.51E+02	3.15E+02	5.39E+03	2.33E+03	1.23E+02	2.45E+03	7.84E+03

Table A-8. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for nonradioactive species in metric tons (10^6 g). Data from Golberg and Guberski (1995). Lack of values indicates that the species was not measured and/or estimated. (cont'd)

Chemical Species	Single-Shell Tanks				Double-Shell Tanks			Grand Total
	Sludge	Saltcake	Int. Liq.	Total	Soluble	Insoluble	Total	
Pb^{4+}					1.96E+00	3.28E+00	5.24E+00	5.24E+00
PO_4^{3-}	3.89E+03	6.43E+02	8.58E+01	4.62E+03	3.29E+02	2.16E+01	3.51E+02	4.97E+03
SiO_3^{2-}	1.21E+03			1.21E+03	1.53E+01	2.14E+02	2.29E+02	1.44E+03
SO_4^{2-}	5.01E+02	1.15E+03		1.65E+03	3.86E+02	6.68E+00	3.93E+02	2.04E+03
Sr^{2+}	3.60E+01			3.60E+01				3.60E+01
TOC*			2.00E+02	2.00E+02	1.26E+03	6.84E+01	1.33E+03	1.53E+03
UO_2^{2+}					3.54E+00	2.68E+01	3.03E+01	3.03E+01
V^{5+}					6.20E-02	1.88E-01	2.50E-01	2.50E-01
W^{4+}	1.44E+01			1.44E+01	7.47E-01		7.47E-01	1.52E+01
Zn^{2+}					3.59E+00	9.45E-01	4.54E+00	4.54E+00
Zr^{4+}	2.46E+02			2.46E+02	4.48E-01	2.77E+02	2.77E+02	5.24E+02
Total w/o H_2O	4.93E+04	1.23E+05	6.40E+03	1.79E+05	4.18E+04	1.45E+03	4.32+04	2.22E+05
H_2O	2.62E+04	1.40E+04	5.16E+03	4.54E+04	8.59E+04		8.95+04	1.35E+05
TOTAL	7.55E+04	1.37E+05	1.16E+04	2.24E+05	1.31E+05	1.45E+03	1.33E+05	3.57E+05

* TOC: Total Organic Carbon

Table A-9. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for radionuclides in curies decayed to 1999. Data from Golberg and Guberski (1995). The letter "m" denotes the metastable isomer. For SSTs, Eu-154 was not calculated. For DSTs, data is included only for those radionuclides consistently reported in analytical work.

Radionuclides	Single-Shell Tank Total	Double-Shell Tanks		
		Soluble	Insoluble	Total
Ac-225	1.98E-05			
Ac-227	2.21E-02			
Am-241	3.30E+04	5.31E+03	6.54E+04	7.07E+04
Am-242	6.82E+01			
Am-242m	6.86E+01			
Am-243	3.32E+01			
At-217	1.98E-05			
Ba-137m	7.68E+06	2.48E+07	6.49E+05	2.54E+07
Bi-210	7.17E-08			
Bi-211	2.21E-02			
Bi-212	3.72E-14			
Bi-213	1.98E-05			
Bi-214	2.70E-07			
C-14	3.00E+03	3.45E+02	1.99E+03	2.34E+03
Cm-242	5.66E+01			
Cm-244	1.18E+02			
Cm-245	1.04E-02			
Cs-135	1.45E+02			
Cs-137	8.12E+06	2.61E+07	6.83E+05	2.68E+07
Eu-154		5.37E+04	1.44E+03	5.51E+04
Fr-221	1.98E-05			
Fr-223	3.06E-04			
I-129	1.60E+01	1.90E+01	3.30E+00	2.23E+01
Nb-93m	3.20E+03			
Ni-59	5.03E+03			

Table A-9. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for radionuclides in curies decayed to 1999. Data from Golberg and Guberski (1995). The letter "m" denotes the metastable isomer. For SSTs, Eu-154 was not calculated. For DSTs, data is included only for those radionuclides consistently reported in analytical work. (cont'd)

Radionuclides	Single-Shell Tank Total	Double-Shell Tanks		
		Soluble	Insoluble	Total
Ni-63	2.69E+05			
Np-237	6.97E+01			
Np-238	3.26E-01			
Np-239	3.32E+01			
Pa-231	3.80E-02			
Pa-233	6.97E+01			
Pa-234	7.69E-01			
Pa-234m	4.81E+02			
Pb-209	1.98E-05			
Pb-210	7.17E-08			
Pb-211	2.21E-02			
Pb-212	3.72E-14			
Pb-214	2.70E-07			
Pd-107	8.65E+01			
Po-210	7.17E-08			
Po-211	6.04E-05			
Po-212	2.38E-14			
Po-213	1.94E-05			
Po-214	2.70E-07			
Po-215	2.21E-02			
Po-216	3.72E-14			
Po-218	2.70E-07			
Pu-238	1.08E+03			
Pu-239	1.80E+04	1.31E+03	7.05E+03	8.36E+03
Pu-240	4.30E+03	3.28E+02	2.07E+03	2.40E+03

Table A-9. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for radionuclides in curies decayed to 1999. Data from Golberg and Guberski (1995). The letter "m" denotes the metastable isomer. For SSTs, Eu-154 was not calculated. For DSTs, data is included only for those radionuclides consistently reported in analytical work. (cont'd)

Radionuclides	Single-Shell Tank Total	Double-Shell Tanks		
		Soluble	Insoluble	Total
Pu-241	3.55E+04	7.76E+02	3.86E+04	3.94E+04
Pu-242	4.32E-04			
Ra-223	2.21E-02			
Ra-224	3.72E-14			
Ra-225	1.98E-05			
Ra-226	2.70E-07			
Ra-228	7.42E-14			
Rh-106	3.79E-02			
Rn-219	2.21E-02			
Rn-220	3.72E-14			
Rn-222	2.70E-07			
Ru-106	3.79E-02			
Sb-126	8.78E+01			
Sb-126m	6.27E+02			
Se-79	9.11E+02			
Sm-151	6.30E+05			
Sn-126	6.27E+02			
Sr-90	4.36E+07	6.15E+05	9.47E+06	1.01E+07
Tc-99	1.10E+04	2.07E+04	3.99E+02	2.11E+04
Th-227	2.18E-02			
Th-228	3.72E-14			
Th-229	1.98E-05			
Th-230	3.90E-05			
Th-231	2.06E+01			
Th-232	6.42E-13			

Table A-9. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for radionuclides in curies decayed to 1999. Data from Golberg and Guberski (1995). The letter "m" denotes the metastable isomer. For SSTs, Eu-154 was not calculated. For DSTs, data is included only for those radionuclides consistently reported in analytical work. (cont'd)

Radionuclides	Single-Shell Tank Total	Double-Shell Tanks		
		Soluble	Insoluble	Total
Th-234	4.81E+02			
Tl-207	2.21E-02			
Tl-208	1.34E-14			
Tl-209	4.28E-07			
U-233	1.21E-02			
U-234	2.12E-01			
U-235	2.06E+01			
U-236	2.88E-03			
U-237	8.69E-01			
U-238	4.81E+02			
Y-90	4.36E+07	6.15E+05	9.47E+06	1.01E+07
Zr-93	3.94E+03			
TOTAL	1.04E+08	5.23E+07	2.04E+07	7.27E+07