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# HANFORD TANK WASTE REMEDIATION SYSTEM FAMILIARIZATION REPORT

*Prepared for*

**Nuclear Regulatory Commission**
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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

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# GLOSSARY (Cont'd)

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 TPlant.

**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 1977–1980. AW-102 was feed from 1981–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 1973–80. S-102 was feed from 1973–1977. SY-102 was feed 1977–1981.

# GLOSSARY (Cont'd)

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

**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 3rd 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 4th 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.

# GLOSSARY (Cont'd)

**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.

**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.

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# GLOSSARY (Cont'd)

**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.

**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.

**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 Airlift Circulators (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 roll over 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 below a value 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.

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# GLOSSARY (Cont'd)

**Confirmed or Declared Leaker**—The designation of any underground waste storage tank where the data is 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.

# GLOSSARY (Cont'd)

**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 has adopted a different definition for reactor site criteria in 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

# GLOSSARY (Cont'd)

complexed waste in the double-shell tanks system are salt well liquid inventory. See also EDTA, HEDTA, and IDA.

**DCG**—Derived Concentration Guide.

**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

# GLOSSARY (Cont'd)

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.

**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**—Ethylenediaminetetraacetic acid. See also, DC, HEDTA, and IDA.

**EF**—Evaporator Feed.

**EFD**—Evaporator Feed Dilute.

**EGR**—Episodic Gas Release.

# GLOSSARY (Cont'd)

**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.

**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.

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# GLOSSARY (Cont'd)

**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. (term located Tank and Surveillance and Waste Status Summary Report).

**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.

# GLOSSARY (Cont'd)

**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.

**HDRL**—Hanford Defense Residual Liquid.

**HDW**—Hanford Defined Waste.

**HEDL**—Dilute sulfate waste.

**HEDTA**—N-(2-hydroxyethyl)ethylenediaminetetraacetate.

**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.

# GLOSSARY (Cont'd)

**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.

**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.

# GLOSSARY (Cont'd)

**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 (IX) removal efficiency for radionuclides (i.e., americium, strontium, cesium, and technetium). Ion Exchange 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

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# GLOSSARY (Cont'd)

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.

**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.

# GLOSSARY (Cont'd)

**MCL**—Maximum Contaminant Level.

**MDW**—Miscellaneous Dilute Waste.

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

**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 liquors not identified as complexed. See also NCPL and NCPLEX.

# GLOSSARY (Cont'd)

**NCRW**—Neutralized Cladding Removal Waste.

**NEPA**—National Environmental Policy Act.

**NESHAP**—National Emission standard for Hazardous Air Pollutants.

**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. (Term obtained from LA-UR-92-3196 Revised.)

**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. Off-gas 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.

# GLOSSARY (Cont'd)

**ORR**—Operational Readiness Review.

**OSD**—Operational Safety Document.

**OSHA**—Occupational Safety and Health Administration.

**OSR**—Operational Safety Requirement.

**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.

# GLOSSARY (Cont'd)

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

**PFM**—Process Facility Modification (PFM) 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.

**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.

# GLOSSARY (Cont'd)

**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.

**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.

# GLOSSARY (Cont'd)

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

**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.)

**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.

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# GLOSSARY (Cont'd)

**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.

**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 or 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.

# GLOSSARY (Cont'd)

**TEDF**—Treated Effluent Disposal Facility.

**Terminal Liquor (TL)**—The liquid product from the Evaporation-Crystallization Process which, 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).

**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.

# GLOSSARY (Cont'd)

**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.

**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.)

# GLOSSARY (Cont'd)

**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.)

**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

This document is an initial contribution to the Hanford Tank Waste Remediation System (TWRS) Familiarization Report. The executive summary will be revised as more information is gathered for the final report and after incorporating the Nuclear Regulatory Commission (NRC) staff comments on the draft report.

Chapter 2 summarizes the large volume of information available regarding the Hanford site, tank farms, and ongoing activities pertaining to the TWRS. Of greatest immediate interest to the NRC are those ongoing activities related to selection of tanks for Phase I solidification operations, construction of cross-transfer piping, and characterization of wastes in the various tanks. The information presently available on plugging of cross-transfer piping system is rather scarce. It is recommended that further information be obtained on this subject in order to understand potential safety issues concerning future use of existing transfer piping as well as the new transfer piping system that is currently under construction.

Chapter 3 describes the state of knowledge of tank waste contents and chemistry. The tank waste inventory data can be accessed through the Tank Waste Inventory Network System (TWINS) database. A method to describe the geographic location of various components of the TWRS and link the geographic information to other types of information (e.g., radionuclide inventory) is described. Examples of the use of the desktop system, ArcView, in conjunction with the Geographical Information System (GIS) database are provided. The GIS currently contains information on waste tank status, characteristics, and waste chemistry. The information in the database was collected from reports prepared by the U.S. Department of Energy (DOE) contractors. Display, examination, and analysis of the GIS data were performed by the ArcView desktop mapping software package.

The hazards posed by the waste tanks and TWRS are described in Chapter 4. The four watch list categories used to identify tanks with potential safety concerns are flammable gas, ferrocyanide, high organic content, and high-heat generation. An additional safety concern includes criticality.

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# 1 INTRODUCTION

During 1991, the U.S. Department of Energy (DOE) established the Tank Waste Remediation System (TWRS) program at the Hanford Site to meet the requirements and commitments for cleanup established in the Hanford Federal Facilities Agreement and Consent Order, 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 (MOU) has been reached between the DOE and the Nuclear Regulatory Commission (NRC)[1] for Phase I activities, which provides for 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 Areas 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 Geographical Information System (GIS). 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 Hanford 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 Department of Energy, January 29, 1997.

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# 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 and 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 for national defense purposes. The site occupies approximately 1450 square km (560 square miles) 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 (LLW) site, licensed by the state of Washington and operated by U.S. Ecology, is also located near the 200 Areas.

- 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 that mainly provide vehicle maintenance and administrative support to site activities.

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

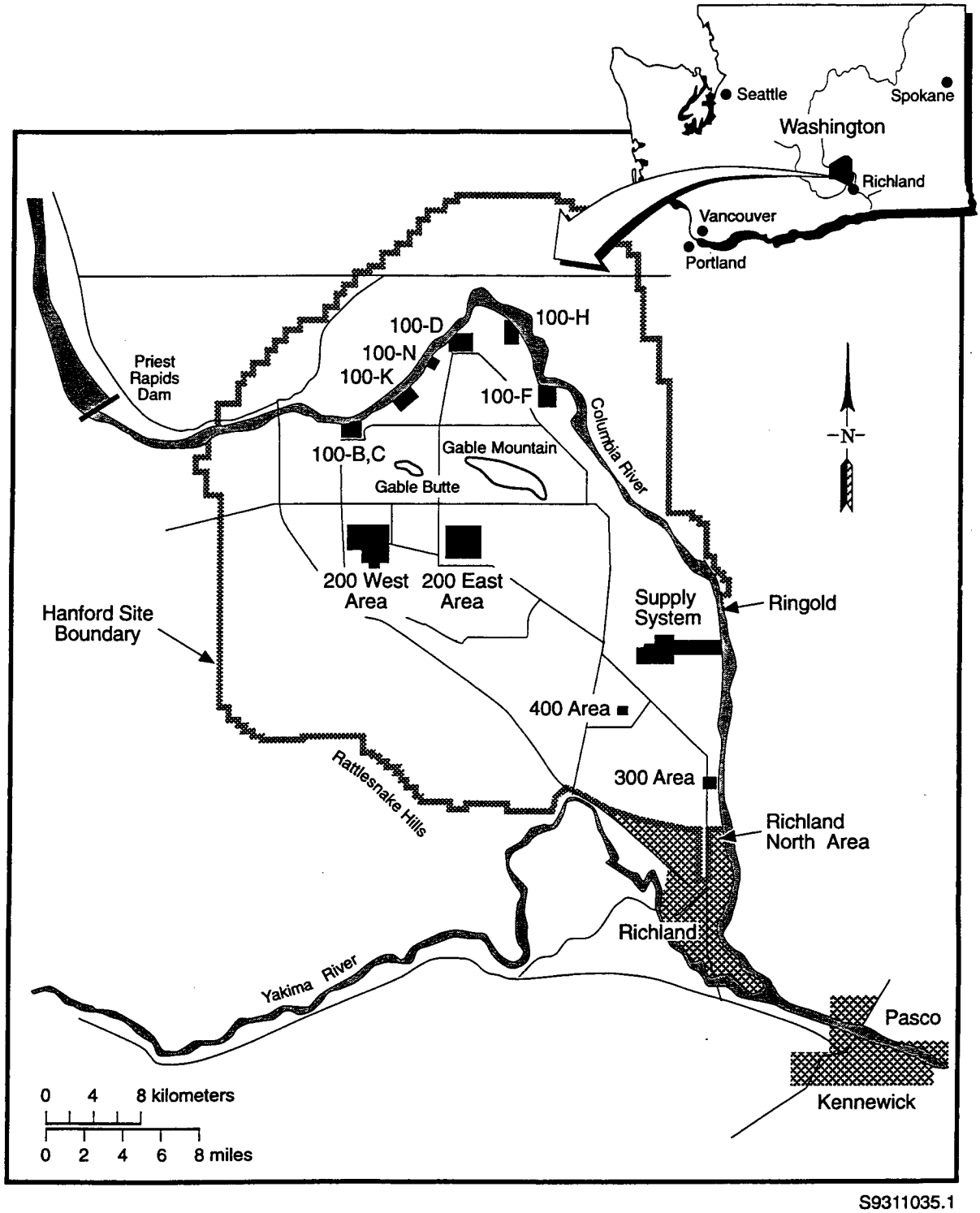


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**Figure 2-1. Hanford Site Location map**

## 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 Reservation 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 individually cover areas of thousands of square km and are stacked up to several km thick. The Pasco Basin is an area of limited topographic relief bounded by a monocline on the east and anticlinal ridges elsewhere. 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 flat Central Plateau in the central part of the Hanford site.

The CRBs at Hanford 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 Hanford, and the waste tank farms are located between the Gable Mountain anticline on the north and the Cold Creek syncline on the south. These geologic structures have important controls on topography, suprabasalt sedimentation, and 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.

Suprabasalt sediments up to 230 m thick at Hanford 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.

The Hanford Formation, which is exposed at the ground surface over most of the Hanford Reservation, is composed of unconsolidated sand, gravel, boulders, and silt deposited by floodwaters of the Columbia River. This formation is about 20 to 65 m thick in the vicinity of the waste tank farms. (Note, however, that the thickness of the Hanford Formation represented in the cross section in Figure 2-3 ranges over 100 m; either the cross section or the reported 65 m maximum thickness, which

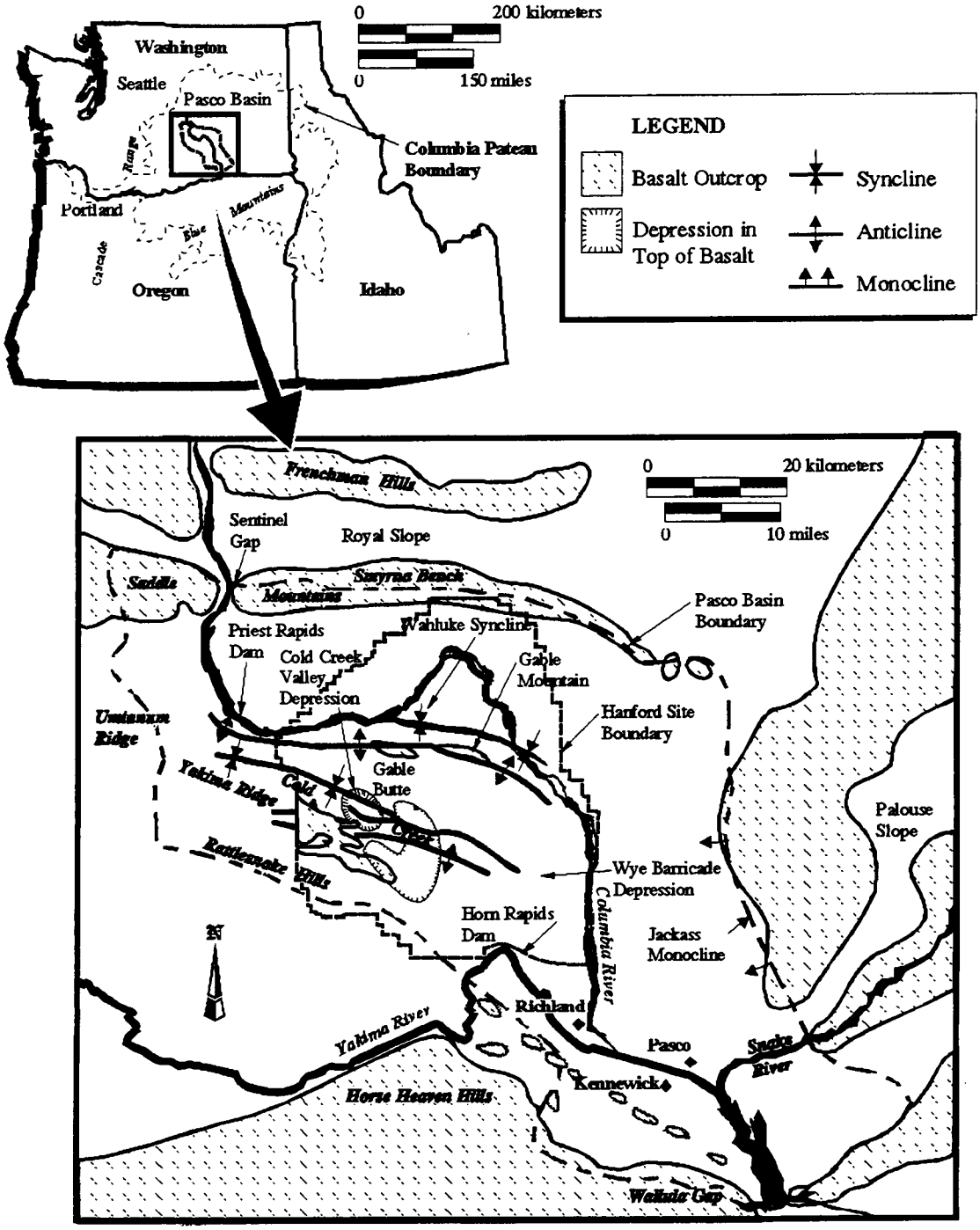


**Figure 2-2. Geologic setting of the Hanford site. The 200-West and 200-East Areas are located south of Gable Butte and Gable Mountain, respectively, and north of the Cold Creek Syncline. [Figure adapted from the Tank Waste Remediation System Environmental Impact Statement (U.S. Department of Energy, 1996a)].**

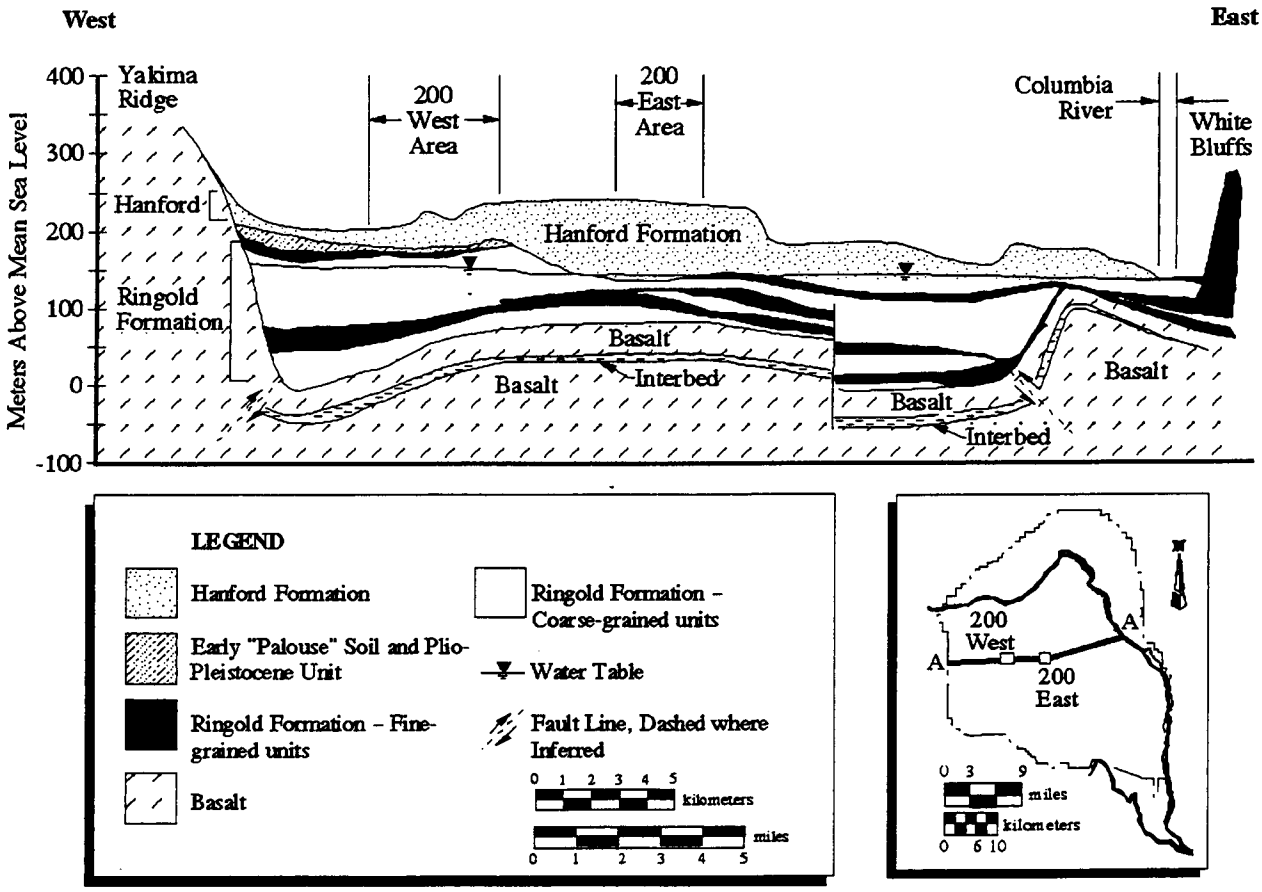


**Figure 2-3. Geologic cross section across the central part of the Hanford Reservation. Waste tanks are located in the Hanford Formation. [Figure adapted from the Tank Waste Remediation System Environmental Impact Statement (U.S. Department of Energy, 1996a)].**

are both taken from U.S. Department of Energy, 1996a, is in error.) 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.

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.

Groundwater flow in the unconfined aquifer under natural conditions is from west to east in the central part of the Hanford Reservation. 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 Hanford, the water table was about 90 m below the ground surface in the present vicinity of the waste tank farms. 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.

Surface water and groundwater in the unconfined aquifer at Hanford are dilute, oxidizing, and have near neutral pH. The oxidation state diminishes and pH increases with depth in the 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 operations elevated the water table and modified the groundwater chemistry, particularly in the vicinity of the 200 Areas. Recharge of the unconfined aquifer 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. Present hydrologic and hydrochemical conditions 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 Hanford 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. The most prevalent wind speed class, 6 to 11 km/hr, occurs about 36 percent of the time. Peak gusts occur from south-southwest, southwest, and west-southwest. Severe wind conditions occur about ten times a year, most commonly during May through August. There were no reported incidents of violent tornadoes in the region surrounding Hanford from 1945 through

1980. The annual probability of a tornado striking the region has been estimated to be $2.7 \times 10^{-5}$ to $3.7 \times 10^{-5}$ (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. Flow in the Columbia River is presently controlled by numerous dams above and below Hanford. During the Pleistocene, however, repeated failures of glacial dams released huge volumes of water into the Columbia Plateau and created floods at Hanford hundreds of meters deep. These immense floods eroded the channelled scablands north of Hanford and deposited the sediments of the Hanford Formation.

The Cascade Range to the west of Hanford has active continental margin stratovolcanoes. Ash from the 1980 eruption of Mount St. Helens fell at Hanford. A major eruption of a Cascade volcano could potentially deposit centimeters of ash at Hanford. 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.

## 2.3 SITE CONTAMINATION

### 2.3.1 Overview

This subsection presents a description of contamination at the Hanford Site (Hanford). 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 Hanford, which is present in different media and in many areas onsite and offsite. Site conditions, contamination, and affected environment at Hanford 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 monitoring programs is to verify compliance with DOE, U.S. Environmental Protection Agency (EPA), and Washington State standards for 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 | Tritium, $^{60}Co$, $^{90}Sr$, $^{99}Tc$, $^{125}Sb$, $Cr^{+6}$, $SO_4^{-2}$, $NO_3^-$, U |
| Plutonium purification | 200 | Pu, $^{241}Am$, carbon tetrachloride, chloroform, $NO_3^-$ |
| Irradiated fuel processing—fission products | 200, 600 | Tritium, $^{90}Sr$, $^{99}Tc$, $^{129}I$, $^{137}Cs$, Pu, U, $CN^-$, $Cr^{+6}$, $F^-$, $NO_3^-$ |
| Fuel fabrication | 300 | $^{99}Tc$, U, $Cr^{+6}$, Cu, trichloroethylene, |

## 2.3.2 Soil Contamination

Hanford 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 Hanford 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, strontium-90, cesium-137, plutonium-239, plutonium-240, and uranium, 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 strontium-90, which has declined due to radiological decay and has shown downward migration (U.S. Department of Energy, 1996a). Strontium-90 and cesium-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 cesium has reached greater depths than previously determined beneath the 200-West Area, recorded at a depth of at least 38 m (125 feet) which is the top of a low-permeability confining bed with underlying groundwater levels at about 64 m (210 feet) (Pacific Northwest National Laboratories, 1996b).

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 plutonium-238, plutonium-239, plutonium-240, tritium, strontium-90, uranium, and gamma-emitting radionuclides, as well as pH, temperature, and nitrate. 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 Resource Conservation and Recovery Act (RCRA) standards.

Contaminant transport through springs to the Columbia River from the past operations of the N-Reactor is a major concern at Hanford. 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 uranium, the total uranium concentration in the proposed EPA Drinking Water Standard was exceeded in the 300 Area spring. Washington State ambient surface water quality criteria levels for strontium-90 and tritium 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 Hanford contain radionuclides at concentrations well below regulatory standards. As expected, highest tritium and total uranium concentrations were detected along shorelines located near operational facilities, groundwater seepage areas, irrigation return canals, and downstream of Hanford, with lowest concentrations recorded at upstream locations. Since 1990, tritium 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 lower analytical method detection limits 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 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 uranium 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 plutonium-239 and -240, strontium-90, uranium, 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-7, strontium-90, plutonium-239 and -240, cobalt-60, uranium-235 and -238, and europium-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 Hanford 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 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 Hanford. 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 Hanford 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 Hanford.

Annual monitoring of the Hanford drinking water system indicated elevated tritium 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 tritium 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 2-4a and 2-4b, 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 cesium-137, cobalt-60, iodine-129, plutonium, strontium-90, technetium-99, total alpha, total beta, tritium, and uranium. DOE Derived Concentration Guide groundwater limits for tritium, strontium-90, plutonium, and uranium were also exceeded.

Tritium 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. Tritium 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 iodine-129 and tritium were released from the same sources, migration and subsequent discharge of iodine-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 iodine-129 concentrations greater than Drinking Water Standards.

Strontium-90, uranium, and technetium-99 plumes are present in the 100, 200-East and -West, and 600 Areas (uranium is also in the 300 Area) with reported concentrations above the Drinking Water Standards and/or DOE Derived Concentration Guide limits. Discharge of strontium-90 from these plumes into the Columbia River is known. Uranium 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 technetium-99 into the Columbia River is occurring. Cobalt-60, cesium-137, and plutonium 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.

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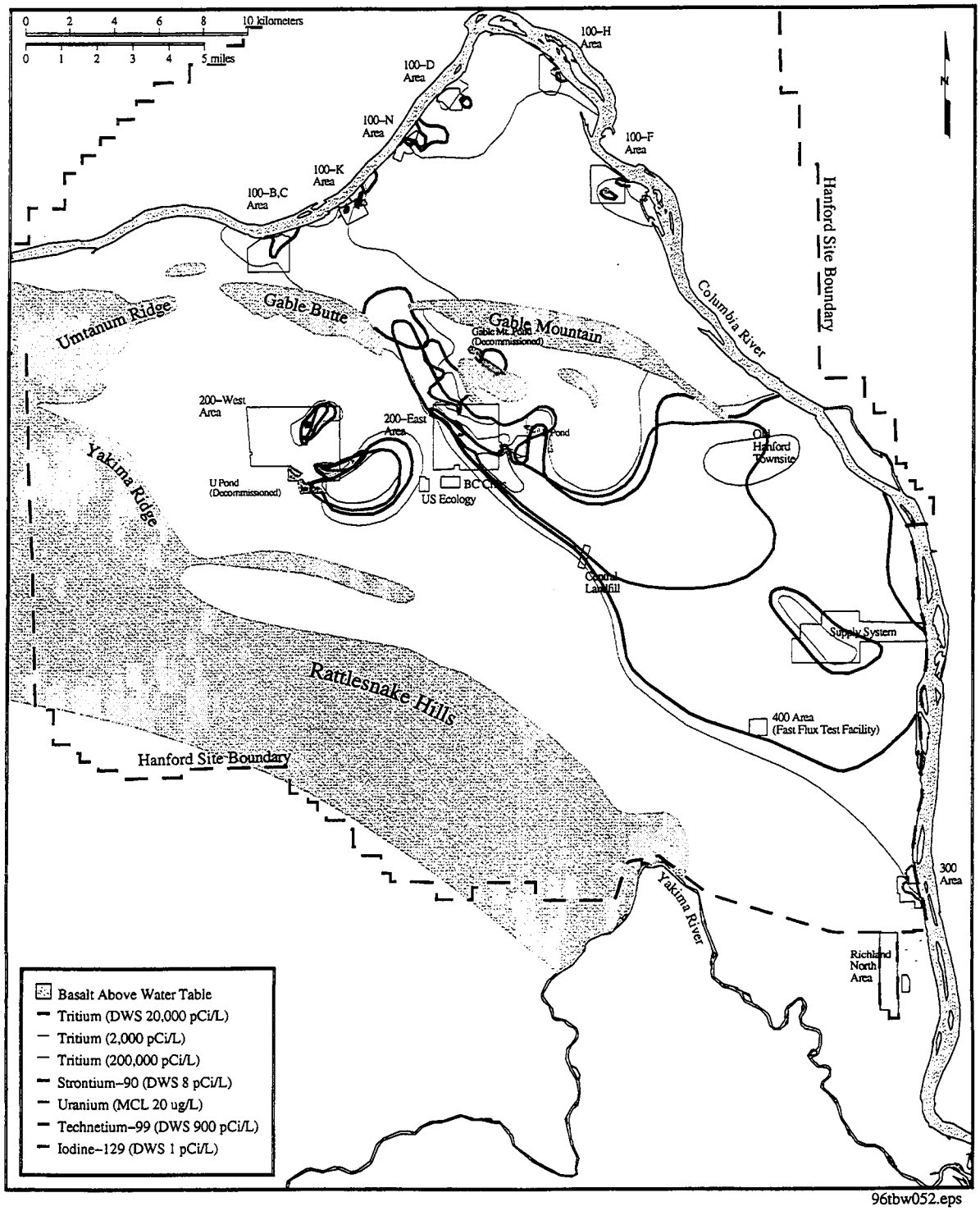


**Figure 2-4a. Distribution of major radionuclides in groundwater at concentrations above the maximum contaminant level or interim drinking water standard (Pacific Northwest National Laboratory, 1996a.)**

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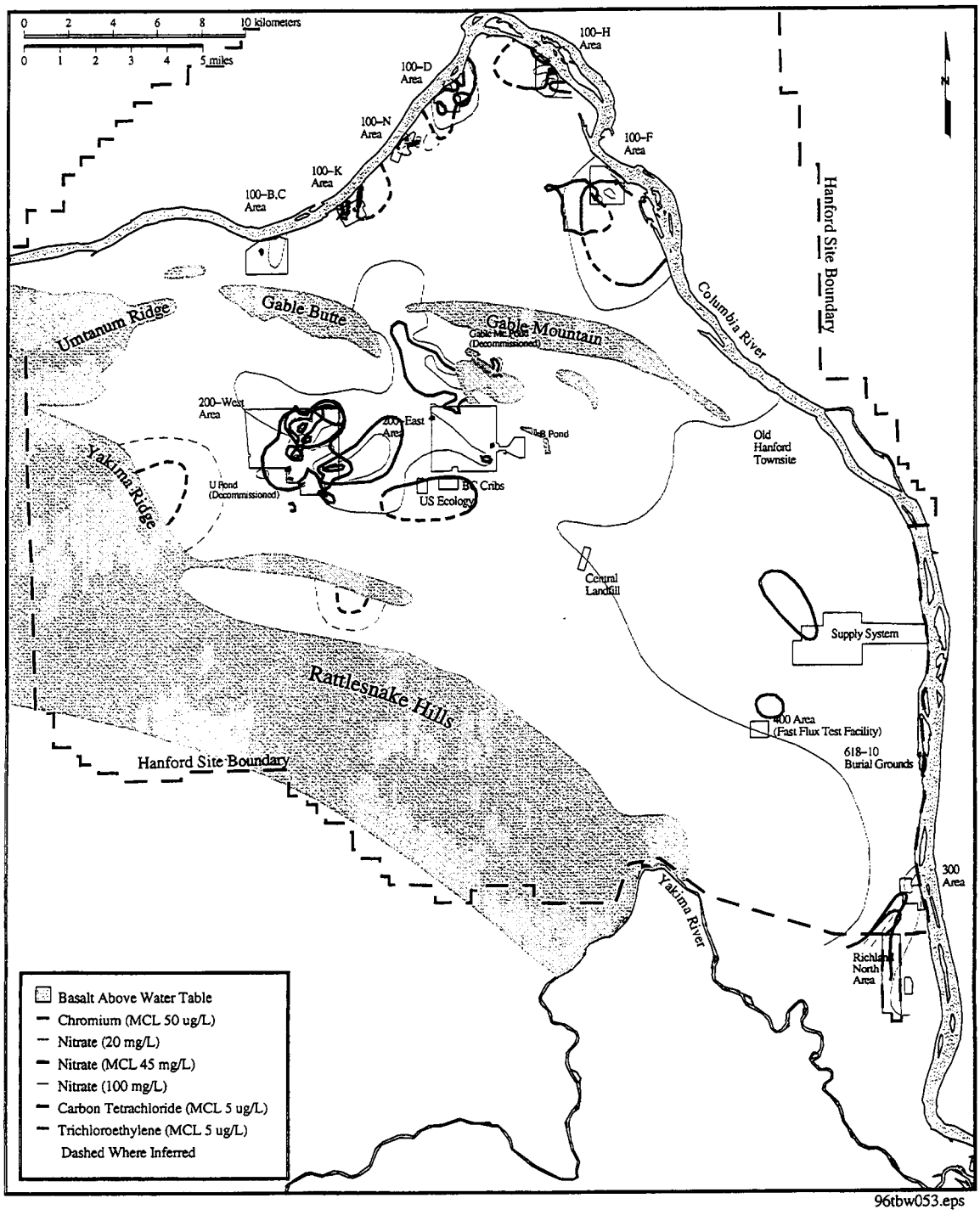



**Figure 2-4b. Distribution of major hazardous chemicals in groundwater at concentrations above the maximum contaminant level (Pacific Northwest National Laboratory, 1996a.)**

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 Hanford. Nitrate plumes extend throughout the site at the 100, 200-East, 200-West, 600, 1100 and North Richland 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.

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, have 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 yr.

### 2.3.5 Air Contamination

Under the Clean Air Act amendments of 1990, Hanford is a designated major source for one or more criteria pollutants and for hazardous air pollutants. Presently, Hanford 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 cesium-137, plutonium-239 and 240, strontium-90, and uranium, and for the 100-N Area cobalt-60 and infrequently plutonium-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 Hanford were consistently detected.

Specific radionuclides detected during the 1995 air surveillance program include tritium, iodine-129, strontium-90, and plutonium-239 and plutonium-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 tritium and iodine-129 were slightly elevated compared to distant locations. However, the elevated tritium concentrations were not statistically significant, and concentrations of iodine-129 measured only 0.000002 percent of the DOE Derived Concentration Guide of 70 pCi/m$^3$. Strontium-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 plutonium-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 $1 \times 10^{-6}$ 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 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 Hanford 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 plutonium production operations.

Elevated strontium-90 and cesium-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. Strontium-90 was detected in goose eggshells and fish while cesium-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 concentrations that were slightly elevated above background conditions. These samples were from milk (collected at downwind locations from the Site) containing iodine-129 levels that indicate a steady decline in concentration over the last 6 yr; wine containing tritium levels below hazardous consumption levels, and alfalfa with strontium-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 micro/rem 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 the previous year. 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 2-5 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.

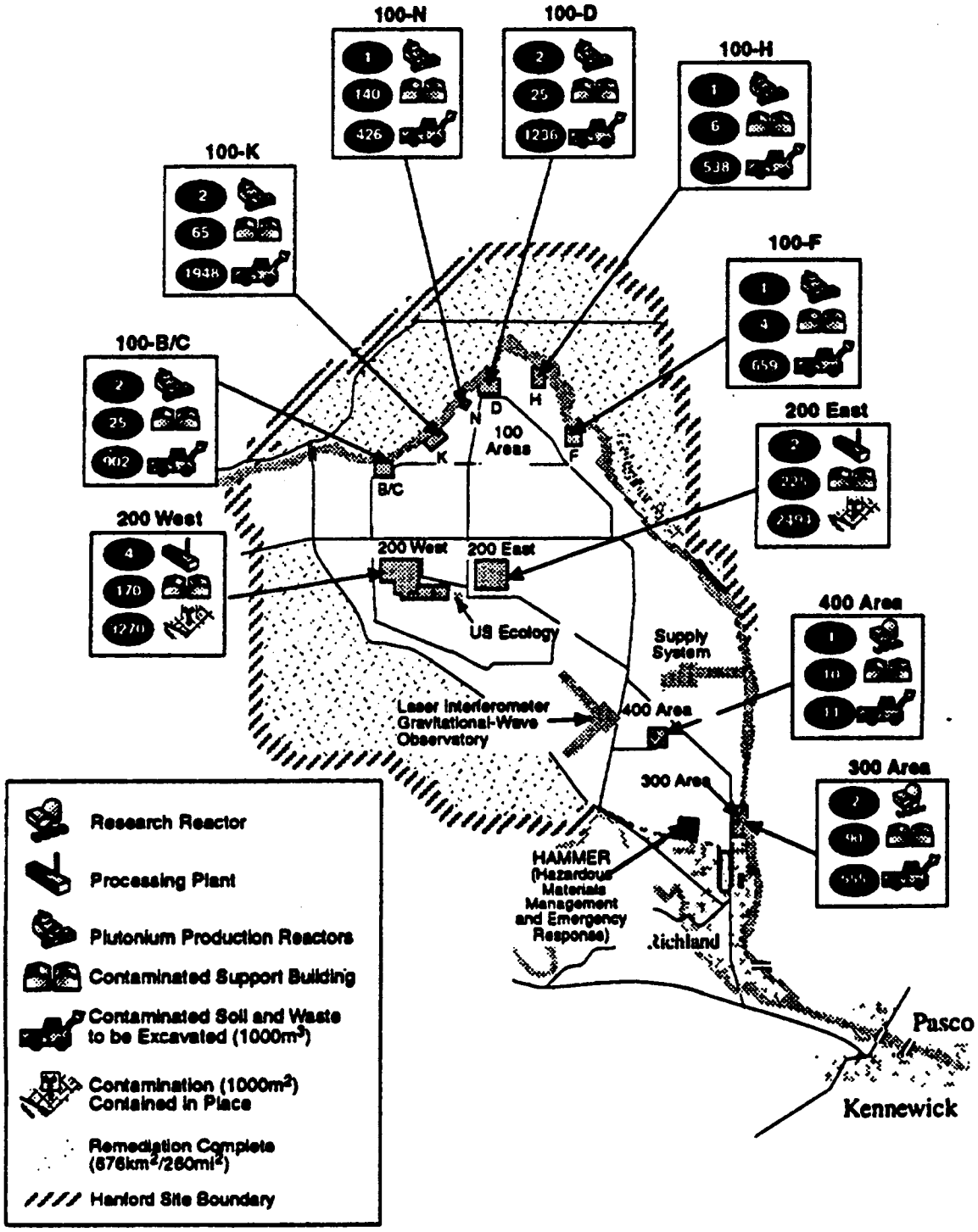



Figure 2-5. Proposed environmental restoration (U.S. Department of Energy, 1996e.)

#### 2.4.1.1 100 Area

Approximately 640 acres of property have been identified as contaminated in the 100 Area, 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 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) tritium contaminants reinjected up-gradient 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 uranium. 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 in the Waste Management program. 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 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 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 Hanford 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 facility is the historical irradiation and processing of uranium fuel to extract plutonium. The fuels consisted of Al-Si clad metallic uranium fuel (B, D, F reactors) as well as the zirconium-clad metallic uranium fuel (N and K reactors) (Wodrich, 1996). A total of about 100,000 metric tons of uranium (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, 1992; Wodrich, 1996), as shown in Figure 2-6. 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 2-7 (Agnew, 1997).

### 2.5.1 Bismuth Phosphate (BP) Process

The history of the process chemistry development and details of the chemistry have been described by Thompson and Seaborg (1956). The process utilized the ability of bismuth to coprecipitate

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

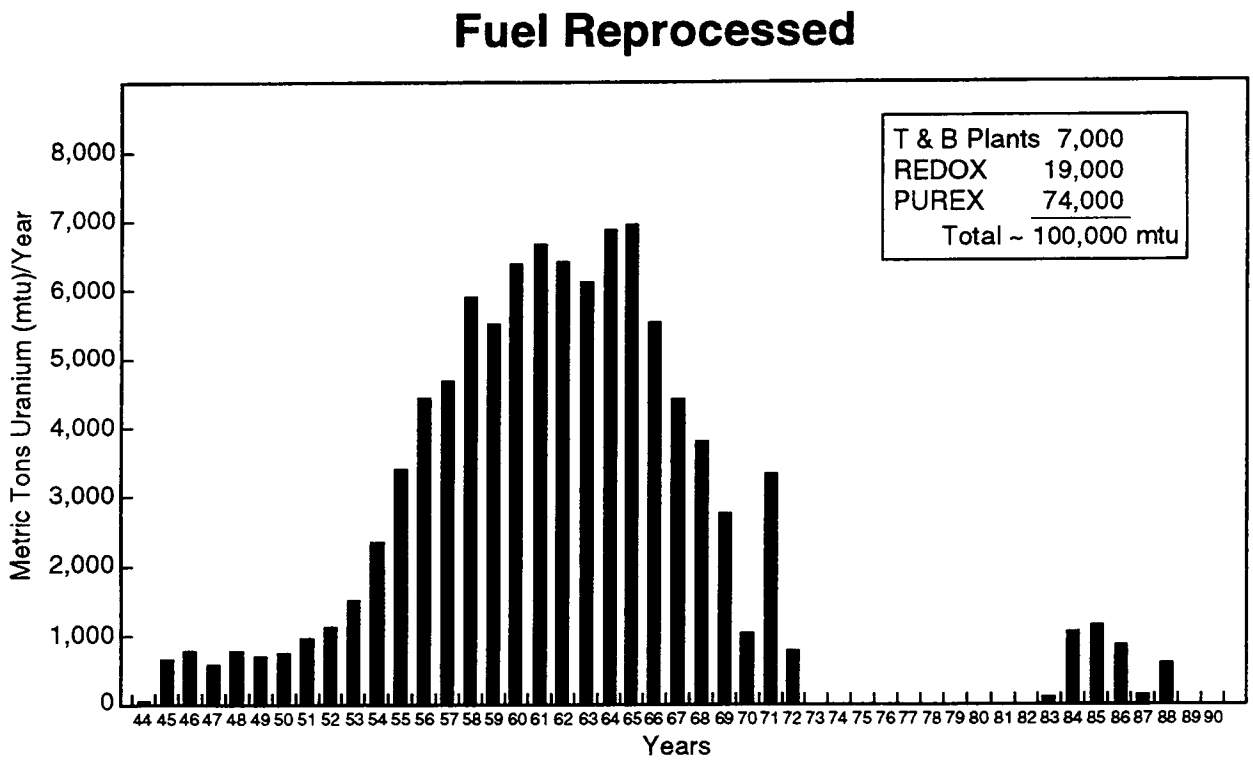



**Figure 2-6. Annual estimates of fuel processed at the Hanford site using various processes (Wodrich, 1996)**

plutonium in the +4 state in phosphoric acid [referred to as Pu (IV)] with bismuth phosphate (BP), while uranium 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 2-8 (Agnew, 1997). The fuel, containing uranium, plutonium and fission products, is dissolved in nitric acid. Phosphoric acid and bismuth are added and the Pu(IV) in the solution is precipitated as $Bi(Pu)PO_4$, while most of the uranium 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 uranium and fission products precipitate, 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 plutonium is achieved by coprecipitating the Pu(IV) with a small concentration of lanthanum fluoride.

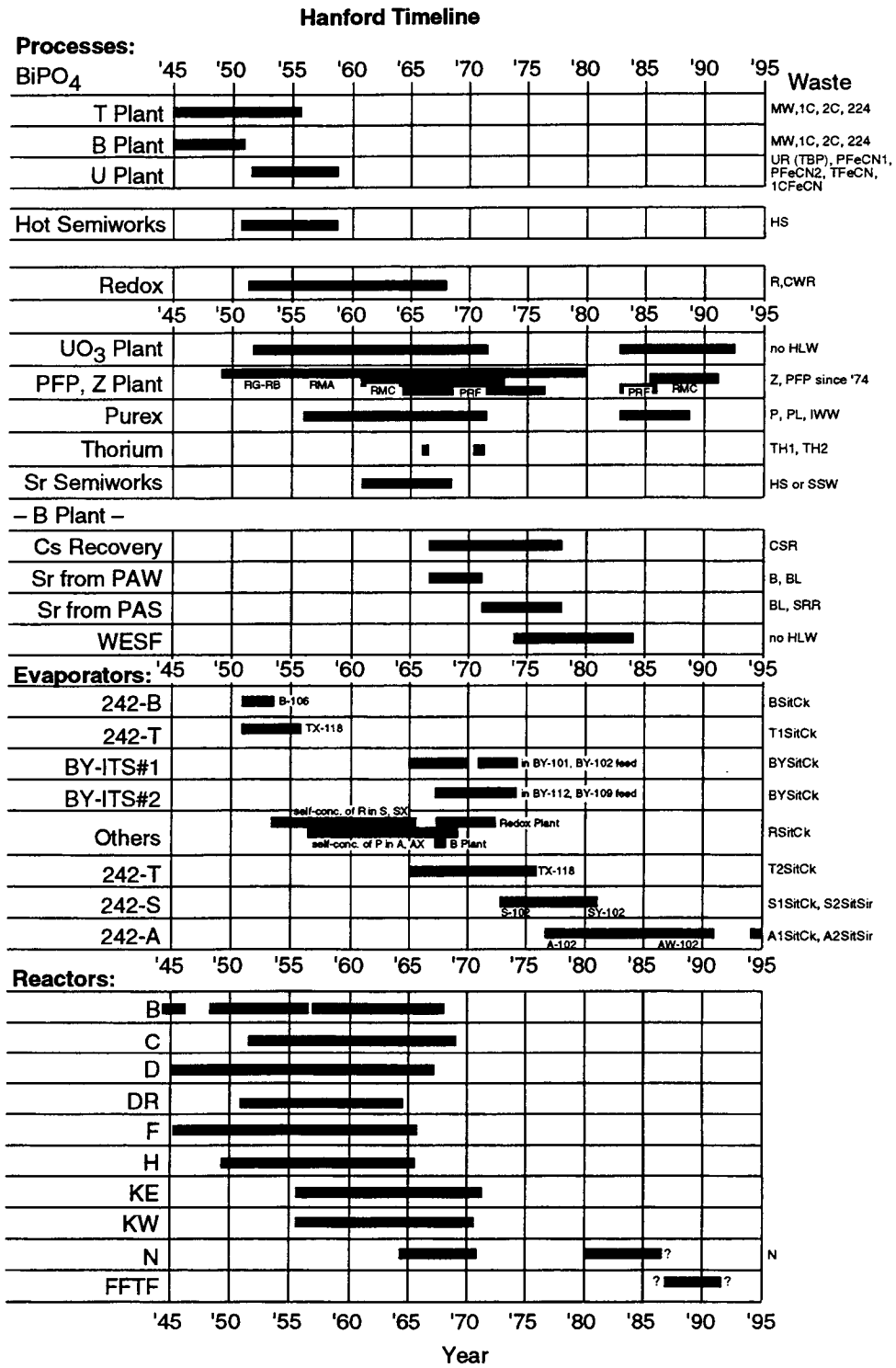



**Figure 2-7. The timeline for various processes at Hanford site and their associated wastes (Agnew, 1994). (The abbreviations for the wastes are indicated in the front matter of the report.)**

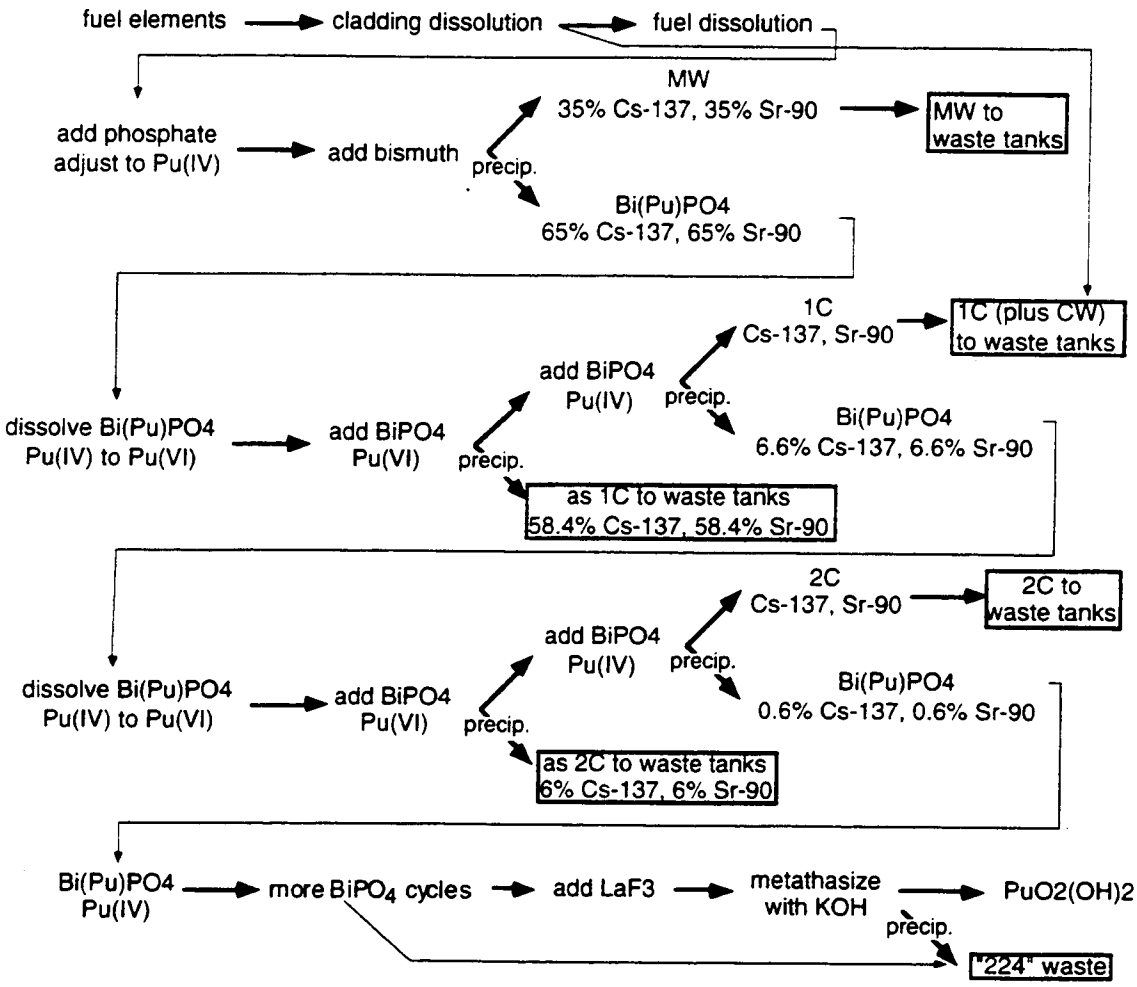



**Figure 2-8. A synopsis of the bismuth phosphate (BP) process and associated waste streams (Agnew, 1997)**

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 fuel from the B, D, and F reactors were processed to dissolve and remove the cladding using a caustic solution. Prior to 1952, the fuel was fabricated by encasing the uranium metal in a cladding (or jacket) using the triple dip method (Gerber, 1993). This process consisted of cleaning the bare uranium 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 uranium 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). The 1C, 2C, and 224 wastes referred to in Figure 2-8 are from the first cycle, second cycle, and plutonium finishing operation, respectively. The tank farms T, TX, and TY were used for wastes from the T plant and to 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,b)

### 2.5.2 Uranium Recovery Process

In order to recycle the uranium MW generated in the waste stream by the BP process, the U plant (221-U building) was converted to a uranium 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 uranium recovery process took advantage of the fact that the actinides, notably uranium and plutonium, 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 tributyl phosphate (TBP) or methyl isobutyl ketone (MIBK). So 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 process at Hanford 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 uranium as U(VI) with nitric acid, and solvent extraction of U(VI) in a mixture of TBP and kerosene. A synopsis of the process is shown in Figure 2-9. The uranium was recovered in the organic phase from which it was stripped by repeated carbonate wash and organic extraction. 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 uranium carbonate phase. Agnew (1997) assumes that 80 percent of the plutonium and 95 percent of the cesium associated with the MW waste were removed during the uranium recovery process and ended up in the waste streams, while the remainder of the Pu and Cs ended up in the heel.

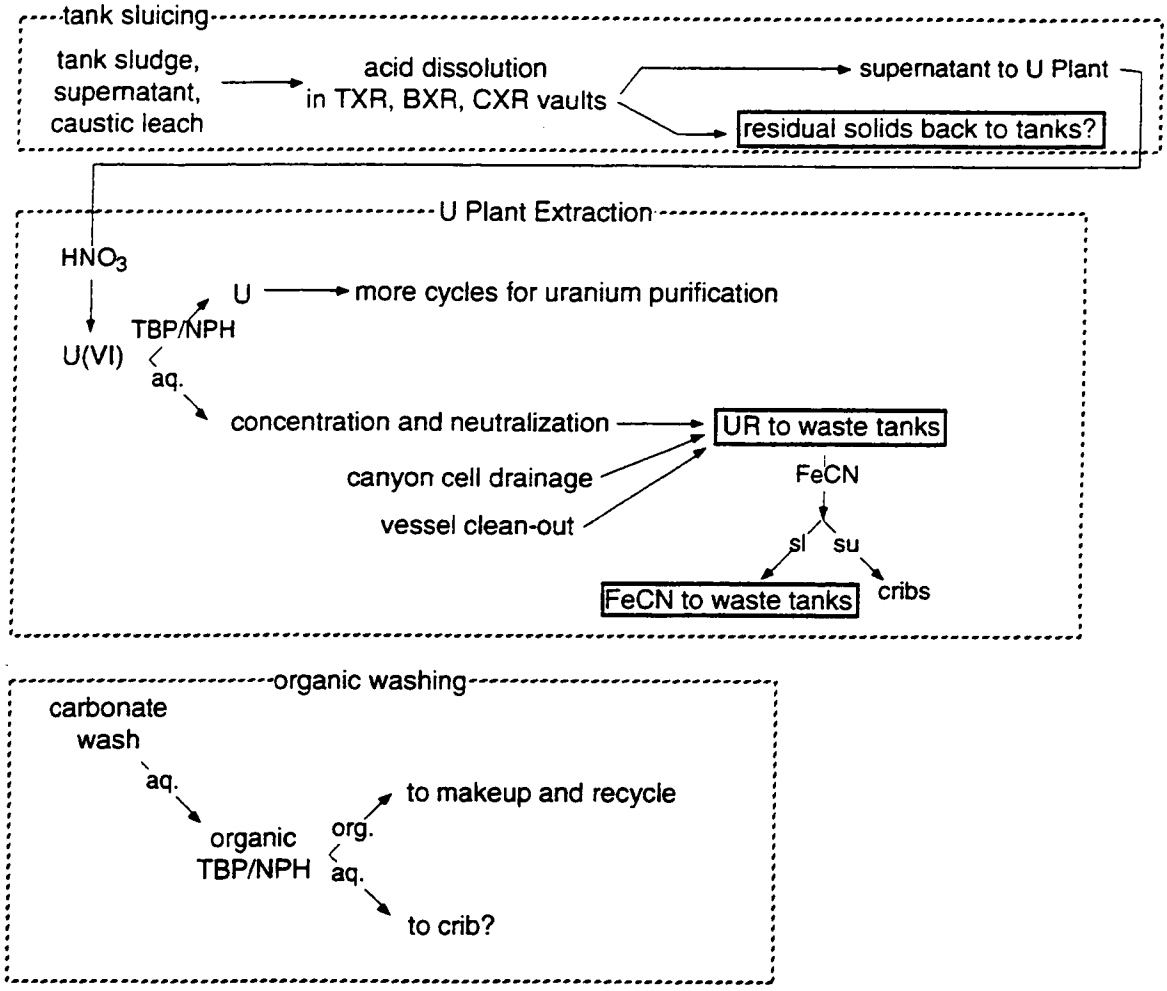



**Figure 2-9. A synopsis of the uranium recovery process and associated waste streams (Agnew, 1997)**

## 2.5.3 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 2-10. 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 uranium was present as U(VI) and plutonium was present as Pu(IV). Intimate mixing with hexone extracted the actinides into the 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

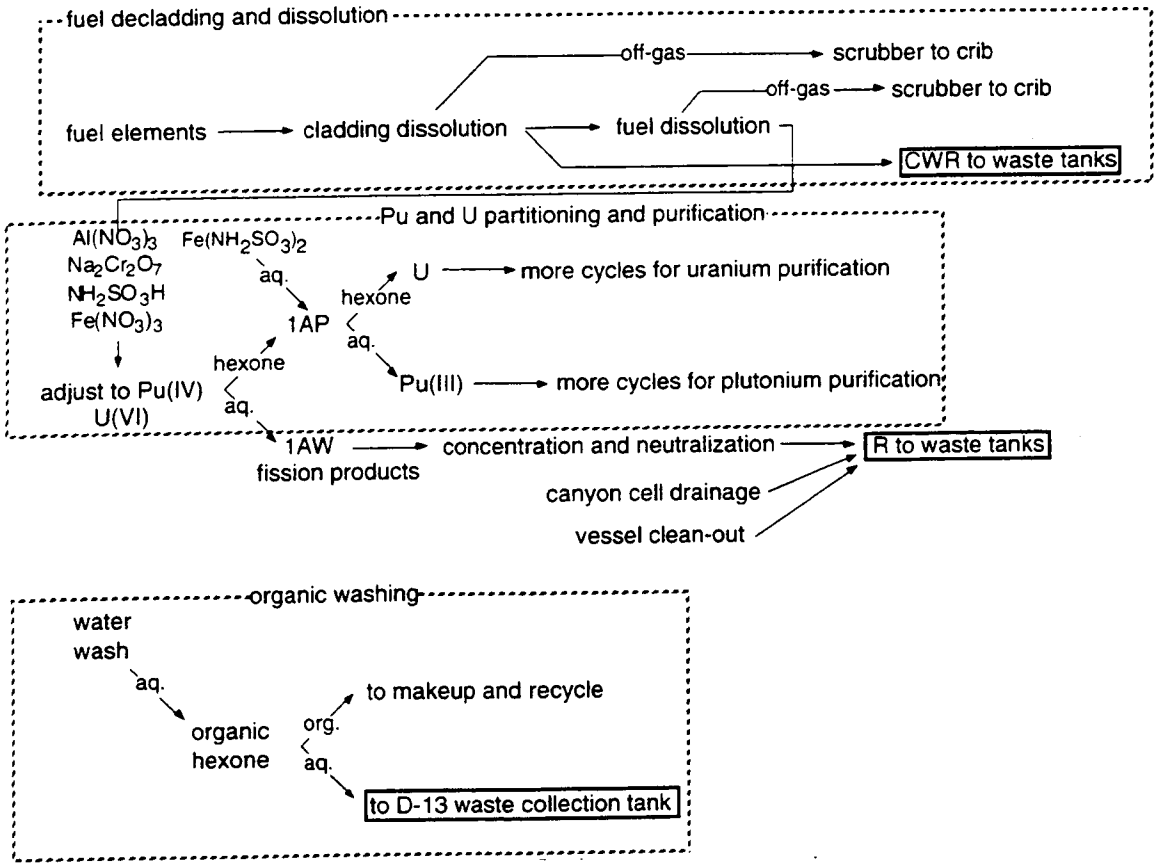



**Figure 2-10. A synopsis of the REDOX process and associated waste streams (Agnew, 1997)**

reduce the plutonium to Pu(III) which then partitioned to the aqueous phase. The plutonium can be oxidized again to the tetravalent state to separate it from other actinides such as americium.

## 2.5.4 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, zirconium clad was treated to dissolve the zirconium 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 plutonium and uranium 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 2-11. The redox condition prior to solvent extraction of uranium and plutonium is adjusted using ferric nitrate instead of a mixture of nitrates, bisulfites and dichromates as in the case of the REDOX process. The ferric nitrate also acts as a salting agent to enhance the partitioning of the actinides to the organic phase. From 1959 to 1961, the PUREX wastes were sent to the A and AX tank farms.

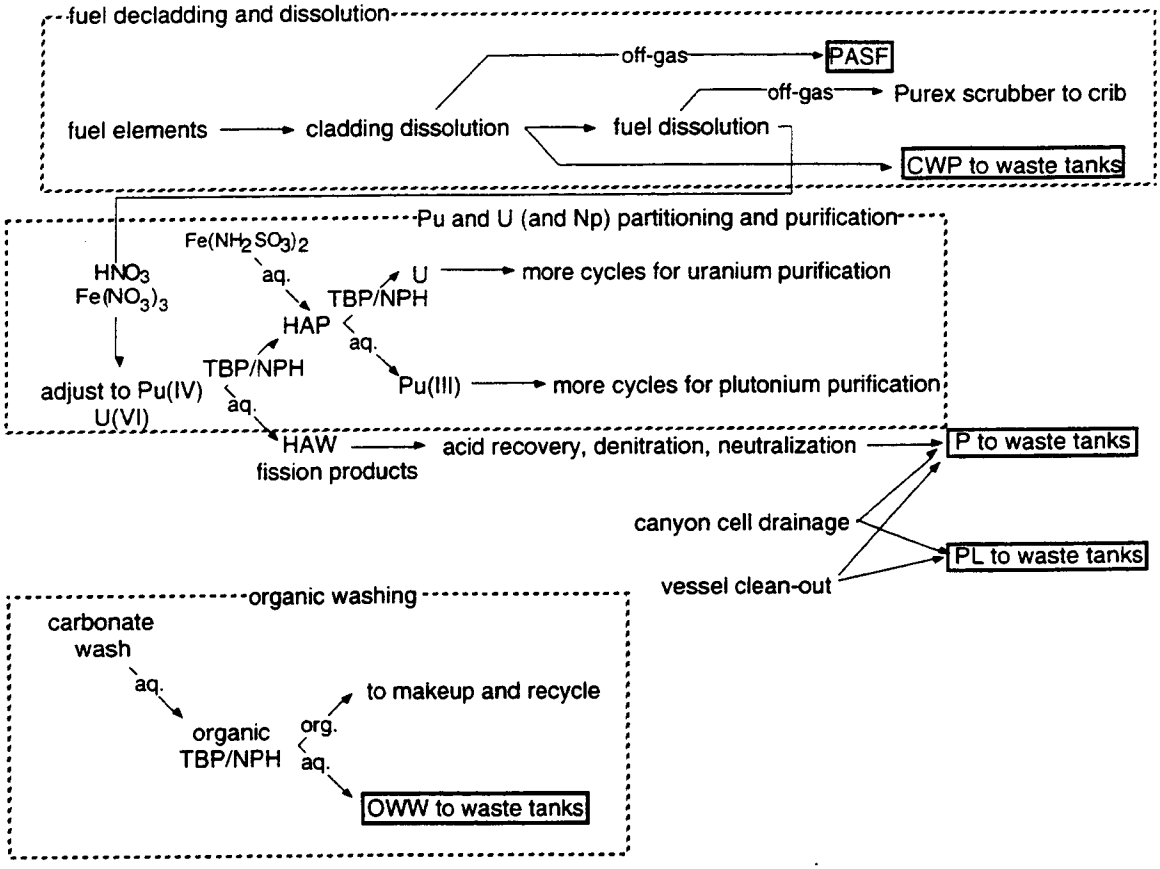



**Figure 2-11. A synopsis of the PUREX process and associated waste streams (Agnew, 1997)**

## 2.5.5 Cesium and Strontium Recovery

From 1962 forward, the strontium 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 cesium and strontium recovery process synopsis is shown in Figure 2-12. 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 strontium was recovered using solvent extraction into an organic phase containing TBP. The Cs was converted to a cesium 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

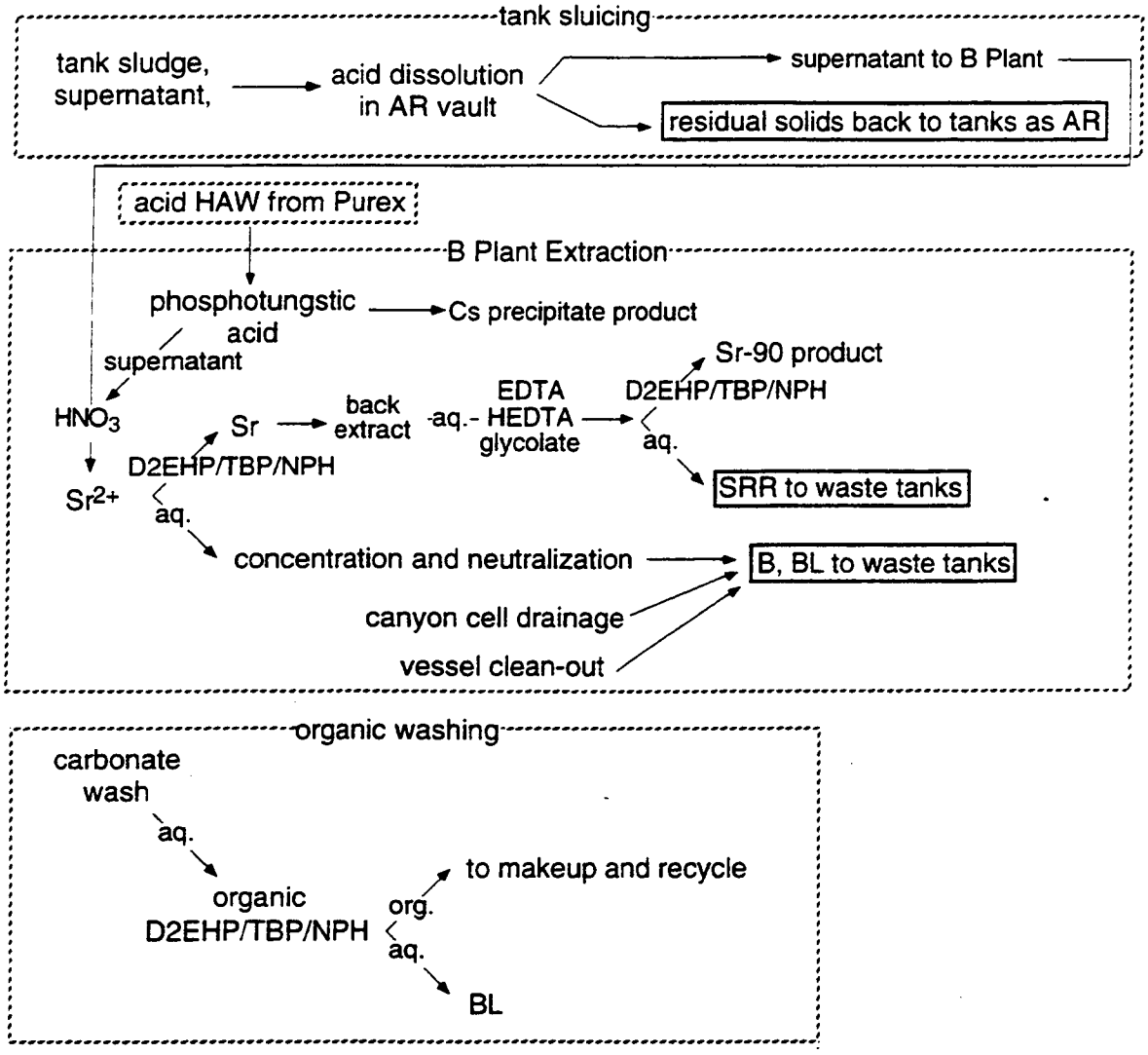



**Figure 2-12. A synopsis of the strontium recovery process and associated waste streams. Cs recovery from acidic waste is also shown (Agnew, 1997).**

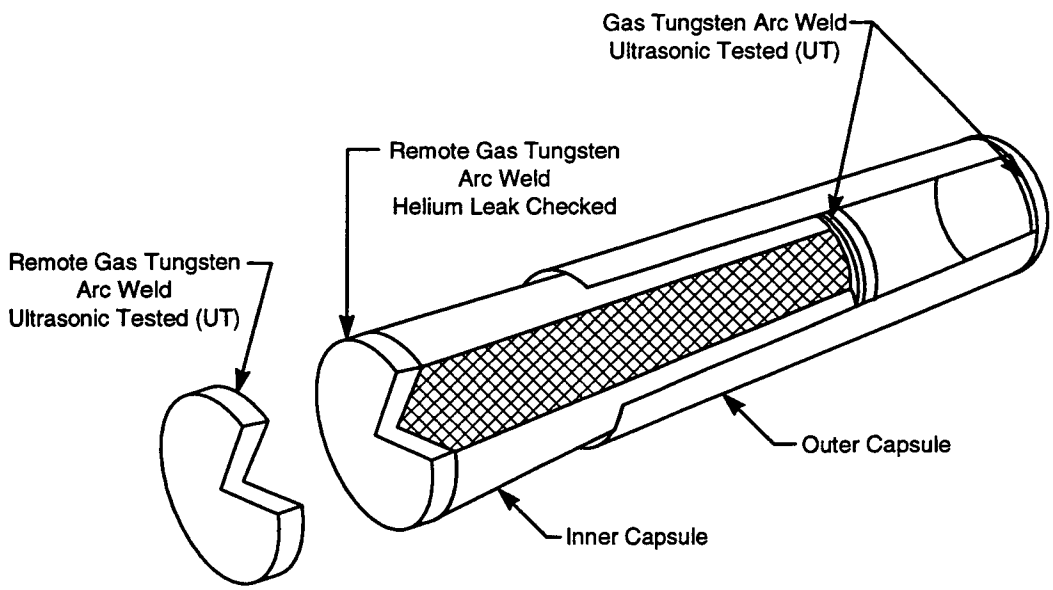
of similar design to the Cs capsules. However, for the Sr capsules, the inner wall was made of a Ni-base alloy, Alloy C-276, and the outer wall was made of Type 316L stainless steel. A schematic of the capsule design is shown in Figure 2-13. There are at present 601 Sr and 1328 Cs capsules with a total 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. Various alternatives for the long-term storage and disposal of these capsules are being pursued (U.S. Department of Energy, 1996b).

## 2.5.6 Other Processes

Various other processes were initiated in the production of plutonium in the Z plant (also known as the Plutonium Finishing Plant, PFP), located in 200-West. The plant started by concentrating the

| 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 2-13. A schematic view of the Cs and Sr capsules (U.S. Department of Energy, 1996b)**

plutonium nitrate from the B and T plants into a paste, which took place from 1945 to 1949. In 1949, production of plutonium 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). 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 Americium 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.

### 2.5.7 Solidification Technologies

The history of various solidification processes at Hanford and other DOE sites has been described by McElroy and Platt (1996). Prior to 1965, solidification experiments were carried out in the 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 Pacific Northwest National Laboratories (PNNL) in the 324 building. In the following 5 yr, 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 were 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 Building 324 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.

## 2.6 DESCRIPTION OF OPERATING FACILITIES

### 2.6.1 Overview of 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 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 2-14). In addition to the tank farms, there are miscellaneous underground storage tanks (MUSTs), most of which are inactive.

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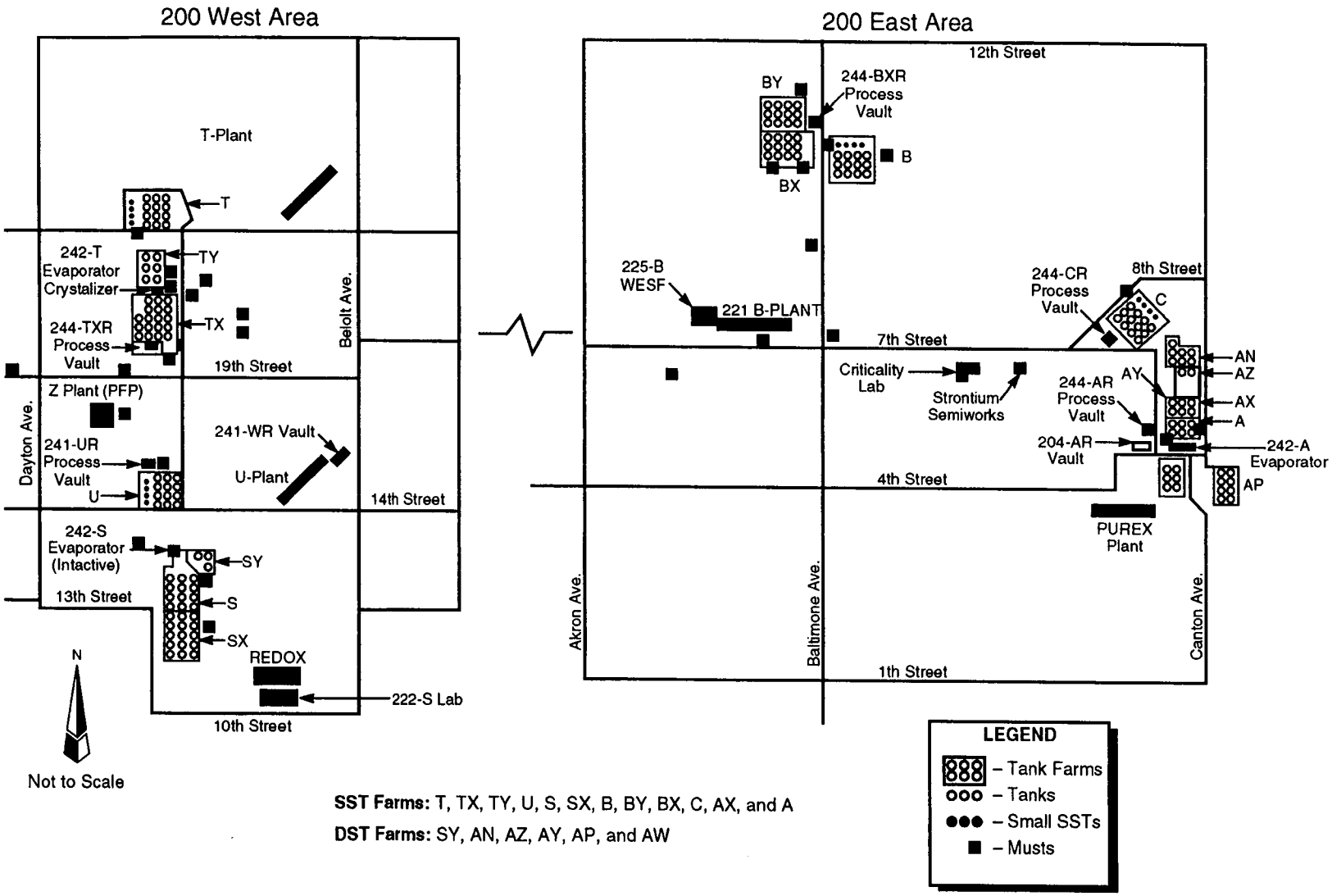
**Table 2-2. Tank waste remediation system facilities and components**

| 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 2-14. 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)**



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The first 149 tanks constructed at Hanford, 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 2-15, 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 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 et al., 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 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 Hanford 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 Hanford, 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

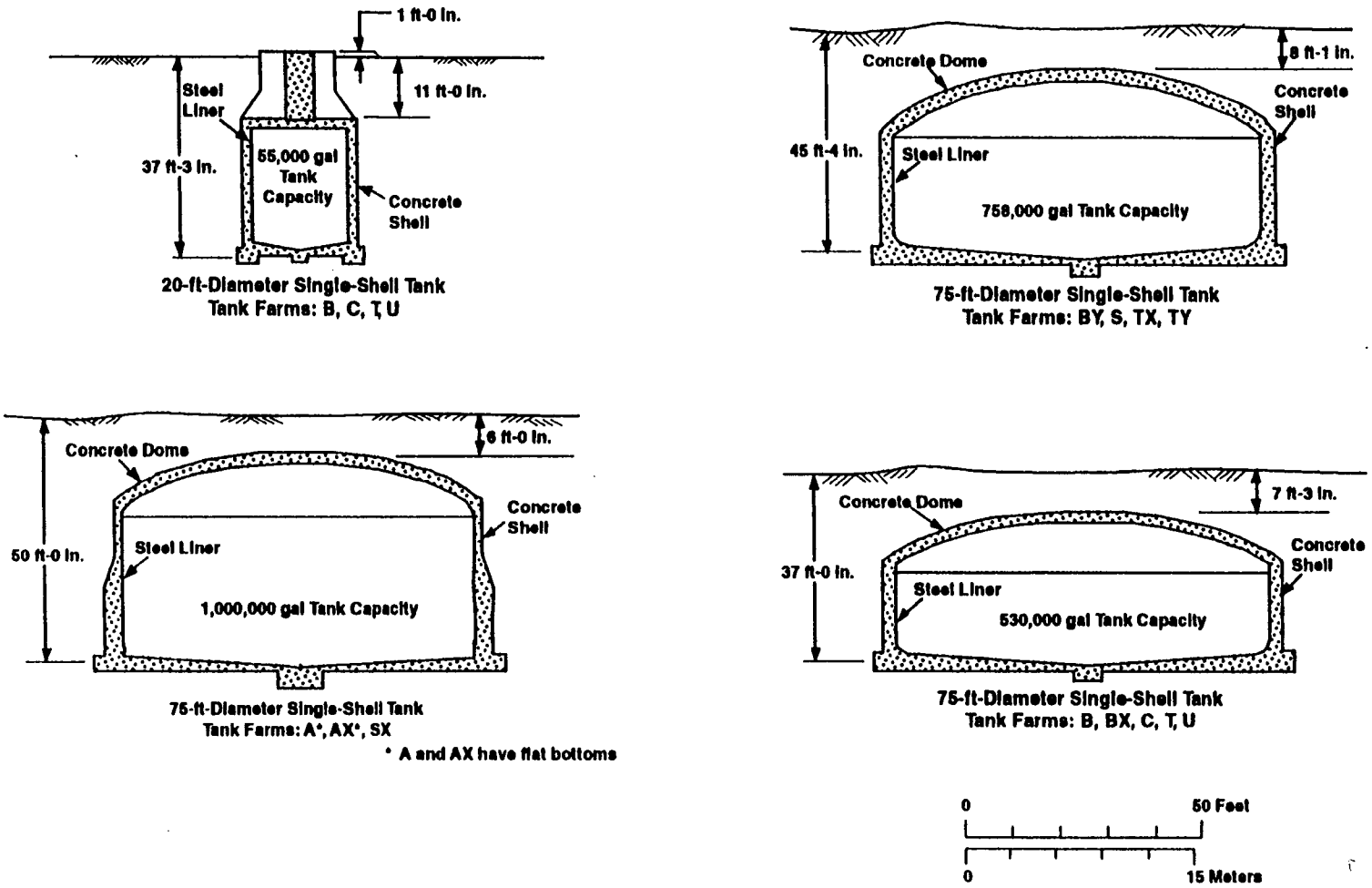


Figure 2-15. Schematic cross sections of various types of single-shell tanks



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**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



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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 2-16 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 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. This tank is located inside a reinforced concrete shell and dome with the walls covered with a steel liner, as shown in Figure 2-17. The liner is 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

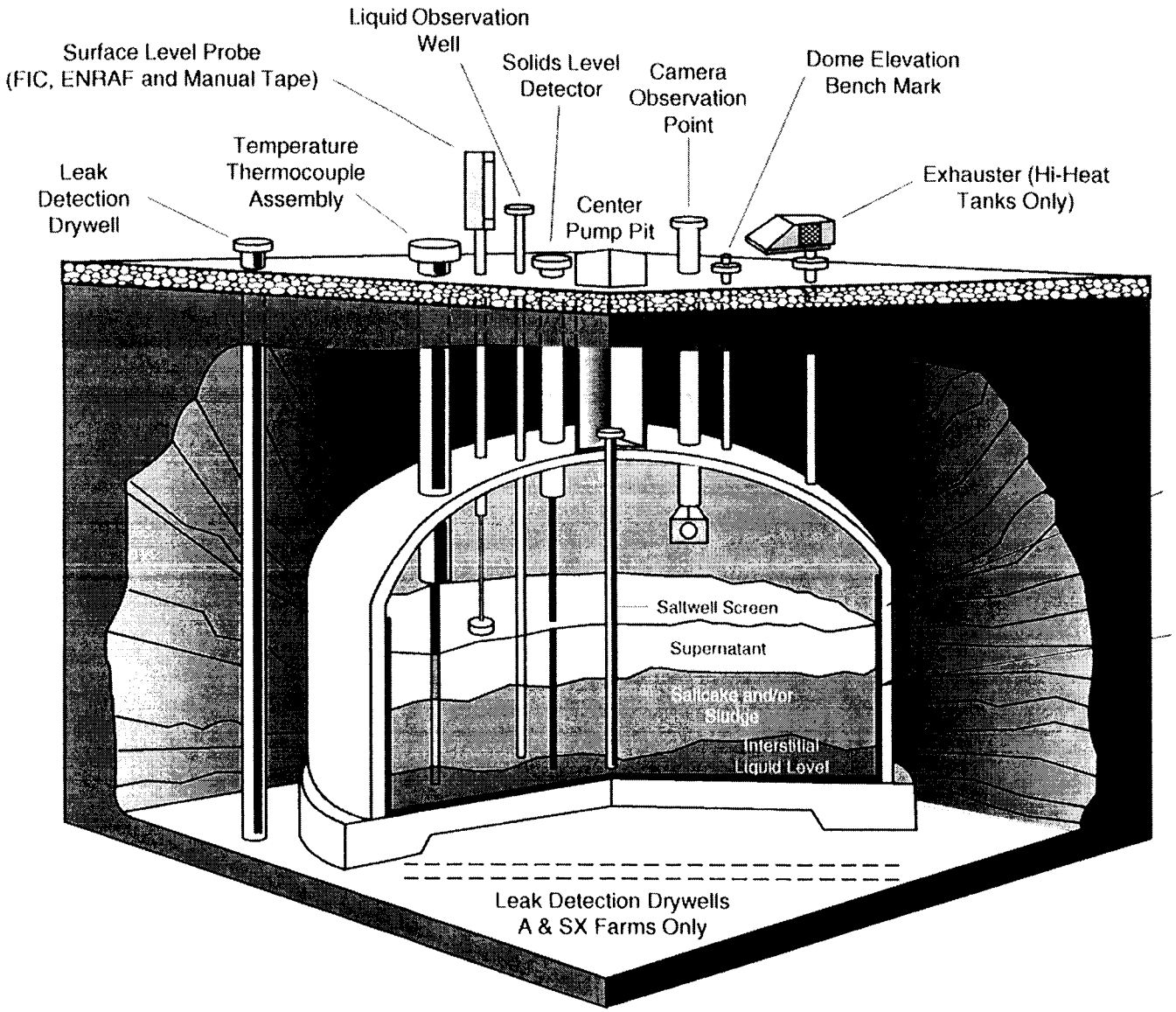


**Figure 2-16. Single-shell tank instrumentation configuration**



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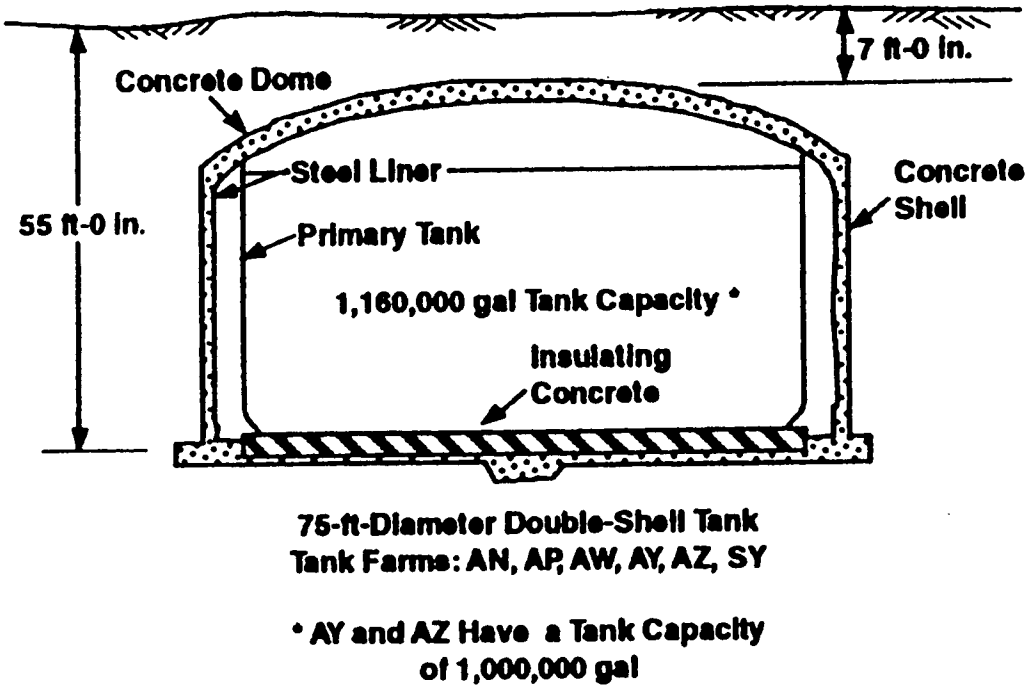


**Figure 2-17. Schematic cross-section of a double-shell tank showing the inner (primary) tank that is a completely enclosed steel tank surrounded by an open topped steel liner and encased in concrete**

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 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 tanks, the DSTs were grouped into different categories (Ohl et al., 1996), according to their potential propensity to pitting corrosion and SCC taking into account CF and an index of SCC susceptibility (Ondrejcin, 1978), respectively.

**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 (1,100,000) | A515-1965, Gr 60 | N |
| 1971–77 | 200E | AZ | 2 | 3,785 (1,100,000) | A515-1969, Gr 65 | N |
| 1974–78 | 200W | SY | 3 | 3,785 (1,160,000) | A516-1972, Gr 65 | N |
| 1978-80 | 200E | AW | 6 | 3,785 (1,160,000) | A537-1974a, Cl 1 | N |
| 1980–81 | 200E | AN | 7 | 3,785 (1,160,000) | A537-1975, Cl 1 | N |
| 1983–86 | 200E | AP | 8 | 3,785 (1,160,000) | A537-1979, Cl 1 | N |

N normalized

Figure 2-18 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.

### 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 2-19. It must be noted that Figure 2-19 does not show all the pipes in this area (Gephart and Lundgren, 1996). 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 is a disadvantage. 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 composite 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 2-20.

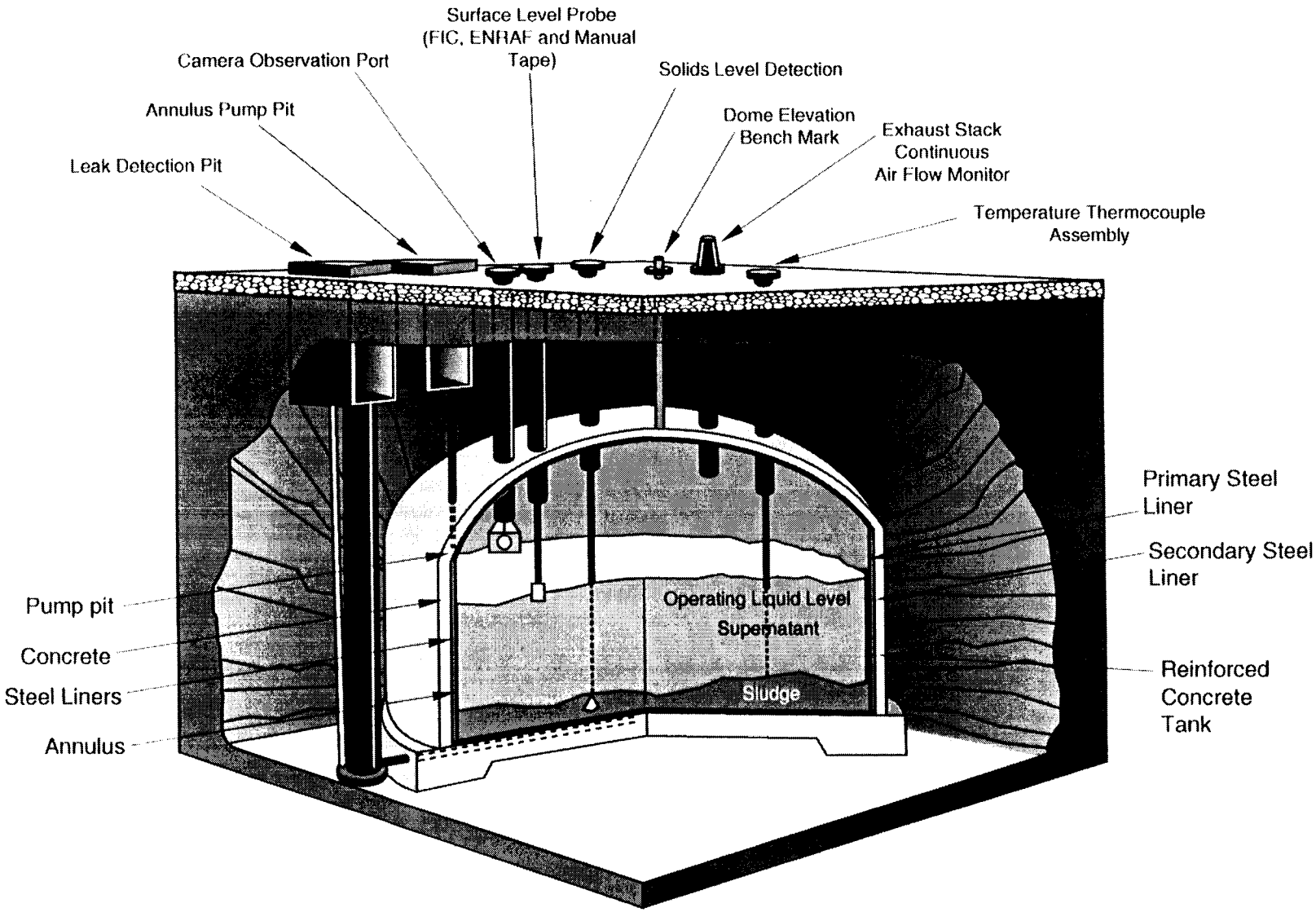


**Figure 2-18. Double-shell tank instrumentation configuration**



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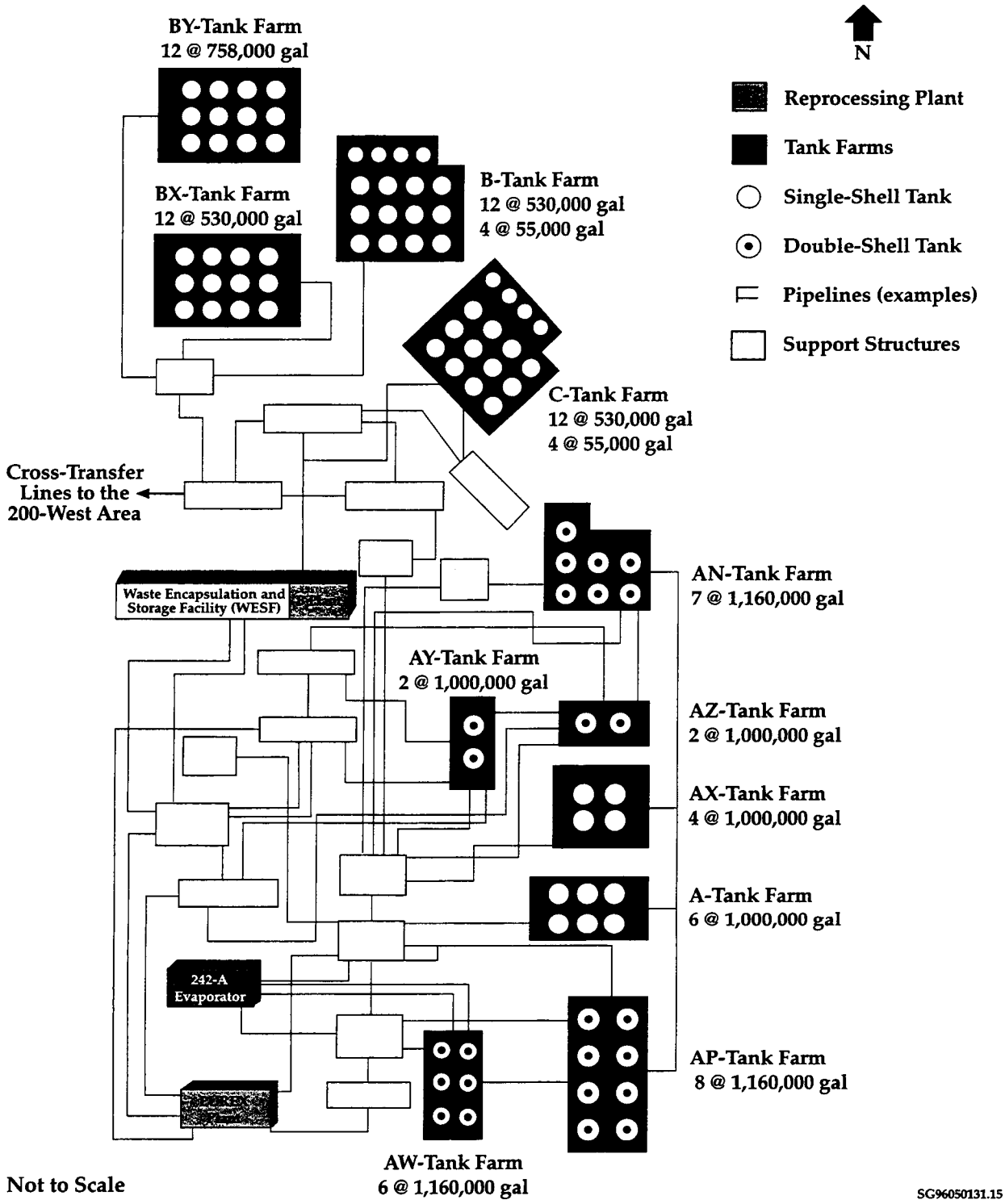


**Figure 2-19. A schematic description of tank farms, processing facilities and the interconnecting pipelines. Not all the pipelines are shown in this figure (Gephart and Lundgren, 1996).**

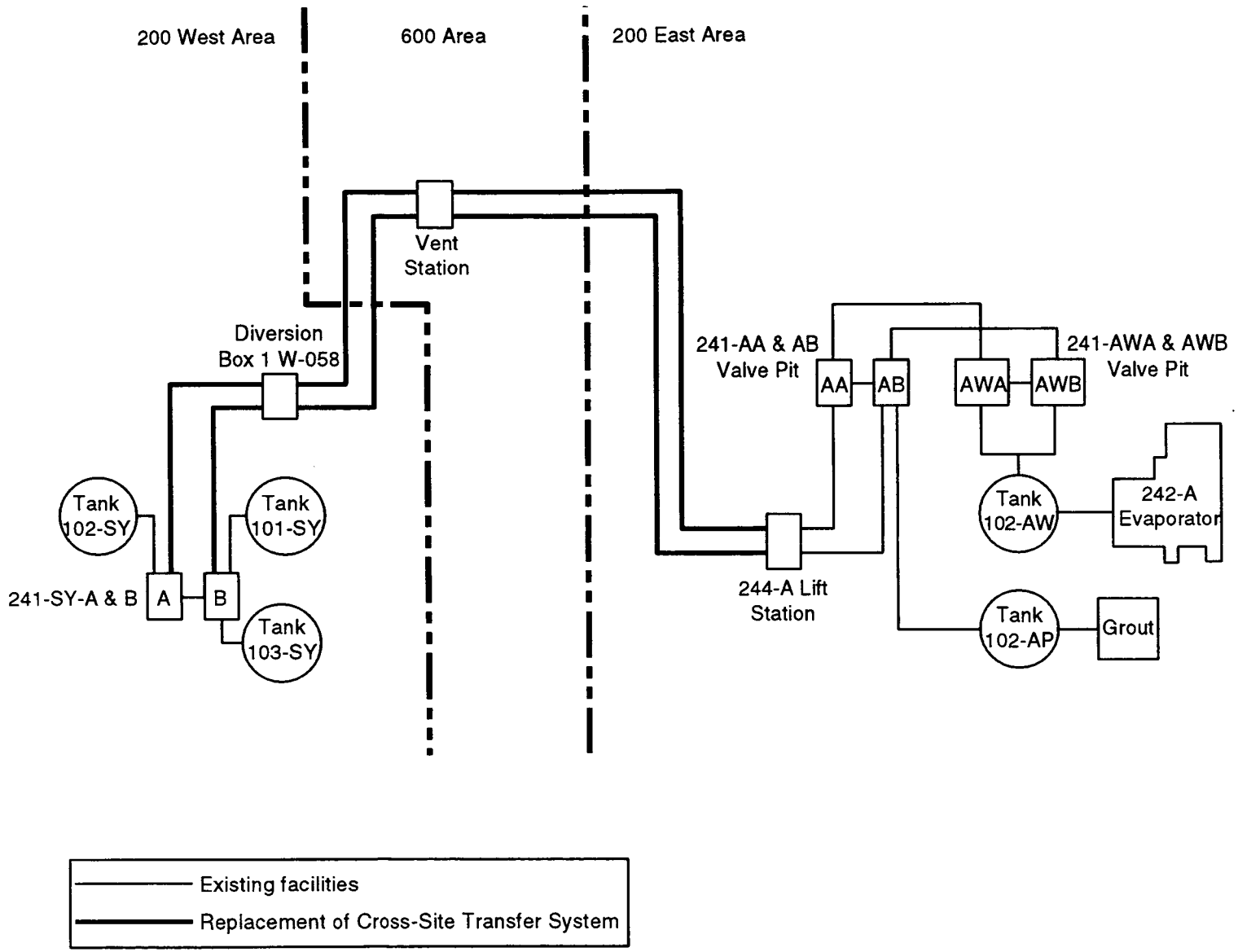


**Figure 2-20. Trace of the replacement cross-site transfer system (Brantley, 1996)**



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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 2-21. The transfer piping is made of a 8.62-cm (3-in) Schedule 40 AISI 304L stainless steel primary pipe encased in a 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 2-21, 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 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 (Parson, 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 2-21. 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

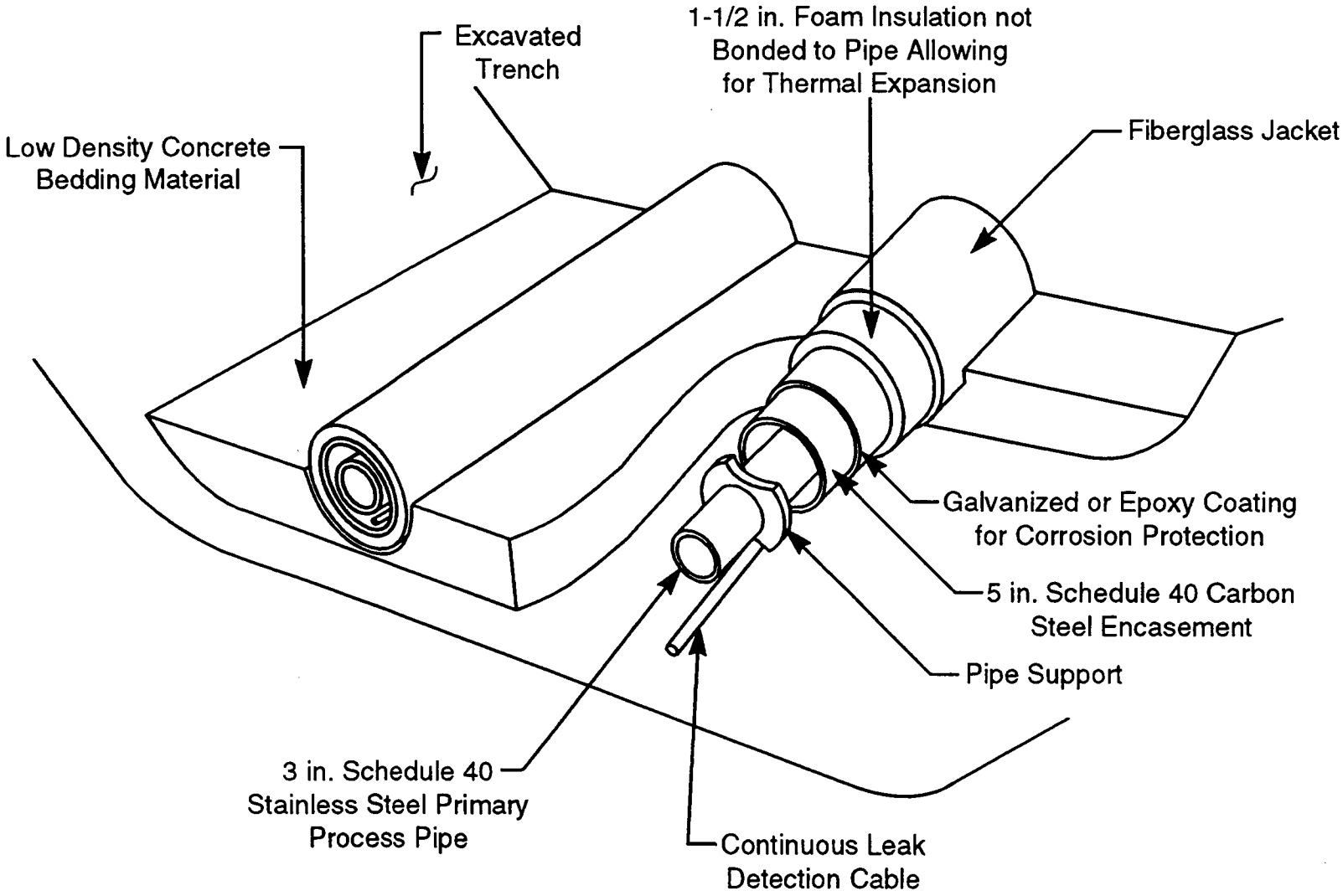


**Figure 2-21. Schematic diagram showing the components of the cross-site transfer piping (Kidder, 1996)**

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**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 site | 0.5 to 4,000 $\mu$m | 0.5 to 4,000 $\mu$m |
| Friction factor | 0.0404 | Newtonian flow |

**Table 2-6. Relative ranking of degradation mechanisms for transfer lines (Edgemon and Anantatmula, 1996)**

| 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 |

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.

**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)<br>Tube Sheet: ASTM A516, Grade 70 CS<br>Tubing: ASTM A53, Type E or S, Grade A or B CS |
| E-C-2 Condenser | Shell: ASTM A53, Grade B CS<br>Head: ASTM A515, Grade 300, CS<br>Tubing: ASTM A53, Type E or S, Grade A or B CS |
| E-C-3 Condenser | Shell: ASTM A53, Grade B CS<br>Head: ASTM A515, Grade 300, CS<br>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<br>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 |

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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.

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 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.

### 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 uranium or plutonium 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 meters 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 uranium 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

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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 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, uranium 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 LAW and 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. A possible layout of the phased implementation facility is shown in Figure 2-22 (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 activities for 200 Areas. 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

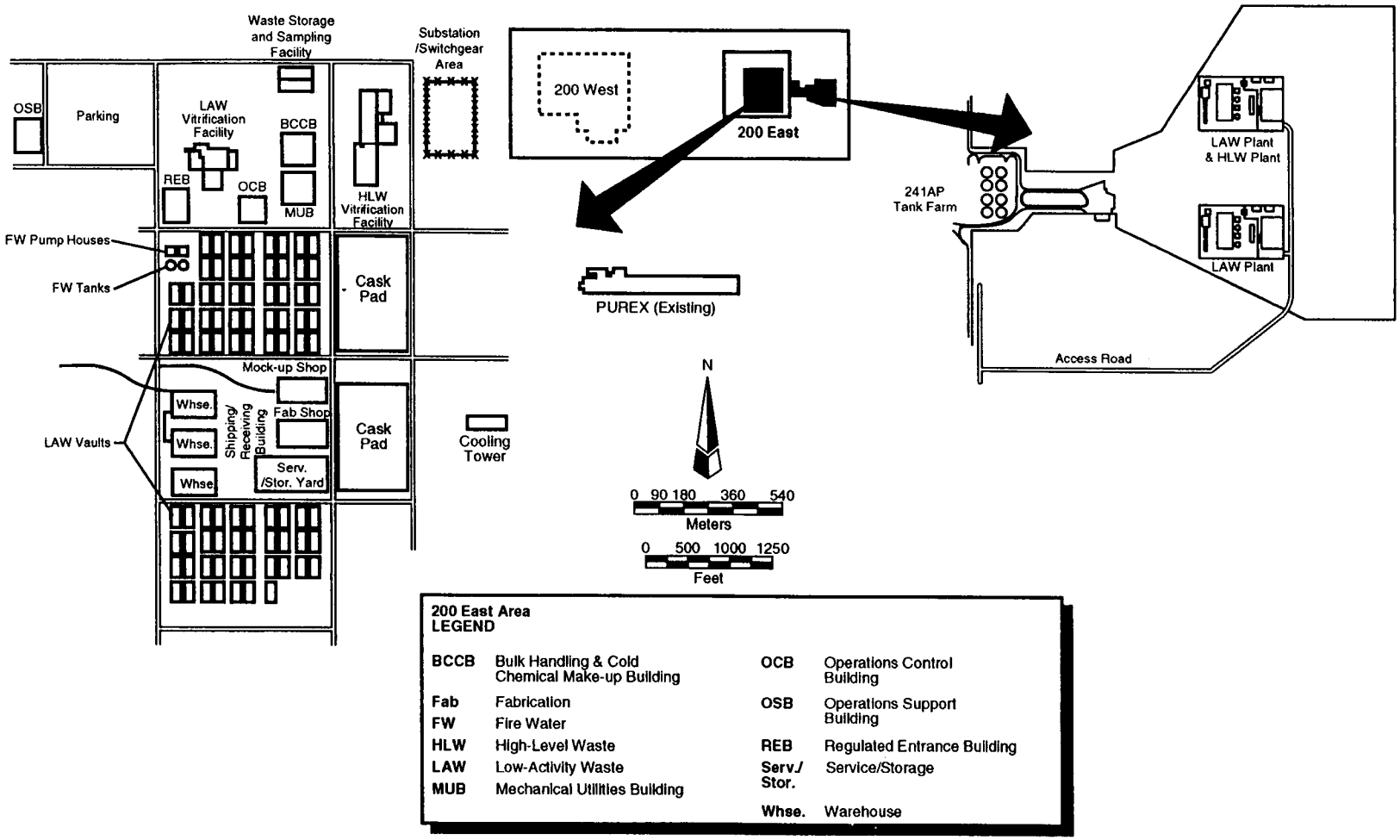


**Figure 2-22. Planned location of the vitrification/solidification facilities in the phased implementation approach of the tank waste remediation system (U.S. Department of Energy, 1996a)**



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**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 |

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 2-23, 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 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. 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 Hanford 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 activation products and sand from the

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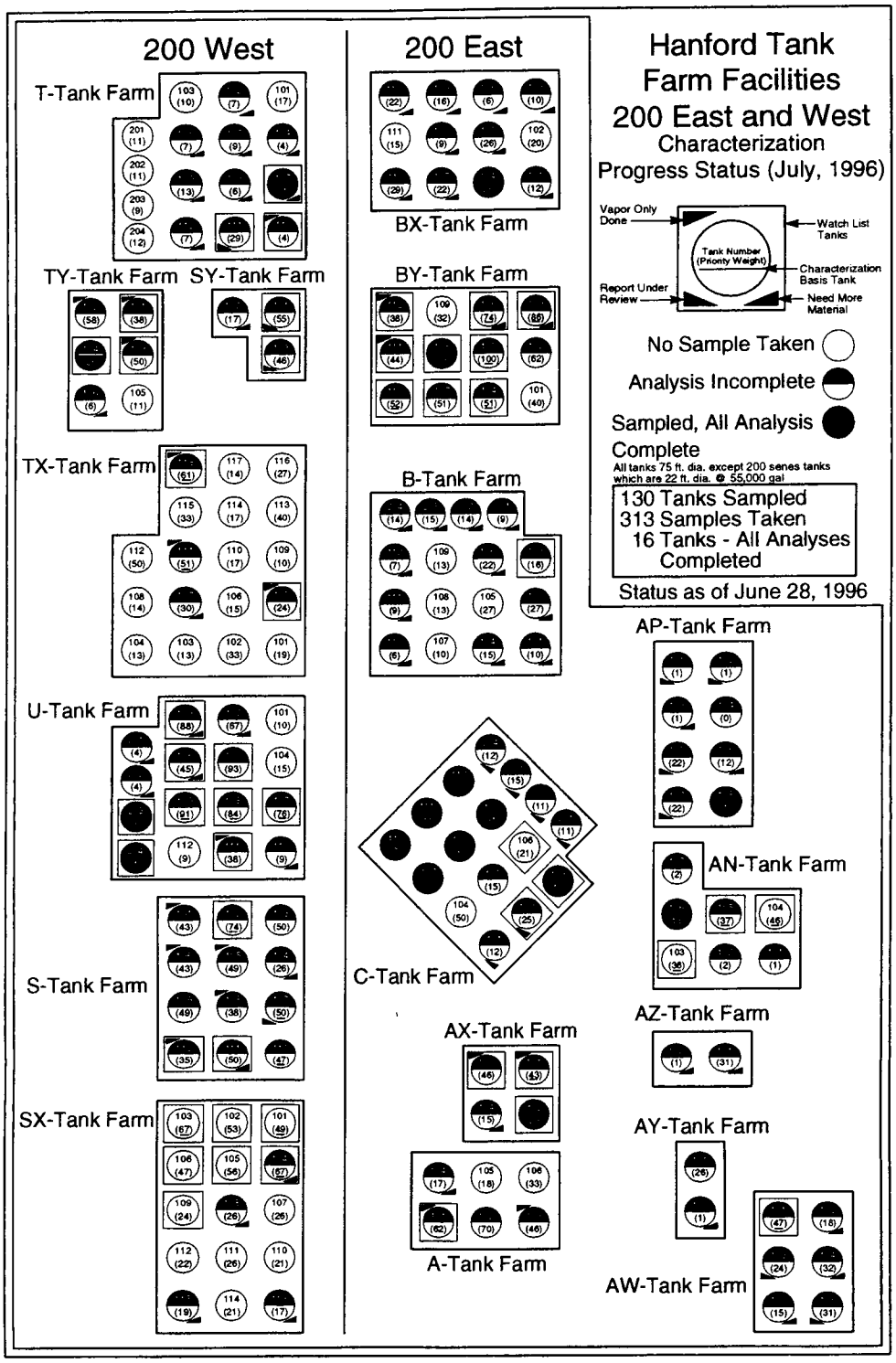


**Figure 2-23. Characterization status of all the underground storage tanks in the 200-East and -West Areas (Hanlon, 1996)**

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**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

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 2.5.2.

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### 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 102-SY, 105-AW, and 102-AZ 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 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 Cs and Sr Capsules

The design of the Cs and Sr capsules and the origin of wastes in these capsules are discussed in Section 2.5.5. 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 2-13. Cesium is primarily present as Cs-137 with a half life of 30.17 yr and decays to Ba-137. Strontium is present mainly as Sr-90 with a half life of 28.6 yr and decays to 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 plans to demonstrate waste retrieval and solidification for long-term disposal. 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.

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# 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 will 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 Hanford (U.S. Department of Energy, 1996b). The other major contributors to radioactivity in Hanford wastes are the cesium and strontium 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, not easily sampled or described, consisting of precipitates, sludges, and supernatants. 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. Characterizing tank contents chemically and radiologically is therefore a challenging task. 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. 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, 1996; 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 gallons 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 the separable liquids have evaporated or been transferred from the SSTs to DSTs, but about six million gallons of water are undrainable 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); strontium is concentrated in the sludge, while cesium is located chiefly in the saltcake and interstitial liquids.

### 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 gallons (Table 2-4). Because they are volumetrically dominated by supernatant liquids transferred from SSTs, the 20 million gallons 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:

- **Double-shell slurry (27 percent of total DST waste volume)**—suspension-rich, high-salt solutions from evaporation of SST and reprocessing plant wastes

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**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**

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- **Dilute noncomplexed waste (26 percent)**—low radioactivity liquid waste from a variety of processing operations
- **Concentrated complexant (20 percent)**—liquid and solid alkaline waste with high organic and transuranic contents
- **Neutralized current acid waste (9 percent)**—80 percent liquid waste generated since 1983 from the PUREX plant
- **Concentrated phosphate waste (5 percent)**—from decontamination of N Reactor
- **Dilute complexed waste (5 percent)**—high-organic liquids from the SSTs
- **Neutralized cladding removal waste (4 percent)**—thick alkaline sludge, chiefly zirconium hydroxide
- **PFP sludge wash and other solids (4 percent)**—sludge from PFP recovery operations

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. Cesium-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 strontium to have settled out in the SST solids before waste transfer to the DSTs.

## 3.2 INVENTORY

As mentioned above, characterization of the 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: estimation based on facility records and direct sample measurement. The former may be unreliable due to incomplete or inaccurate documentation of tank additions, while the latter is limited by the extreme physical and chemical heterogeneity of the tank contents. Furthermore, inventories may change due to additions, transfers, and radioactive decay.

The Westinghouse Hanford Company (WHC) tank waste inventory effort combines both approaches. Golberg and Guberski (1995) compiled the overall chemical and radionuclide inventories for SST and DST tanks for the TWRS Environmental Impact Statement (EIS) (U.S. Department of Energy, 1996b). Their approach was to use historical process records for estimation of SST inventories and measurements augmented by historical data for the DSTs. The resulting total inventories, not broken down by individual tank, are shown in Tables 3-1 and 3-2. (Note that there is a traceable discrepancy in DST soluble chemical components between the versions of Table 3-1 in the Golberg and Guberski report and the EIS itself; the former, primary source is reported here.) In the EIS (U.S. Department of Energy, 1996b), 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 EIS does break down these inventories into aggregated groupings of tanks, consisting of one to three tank farms, for the purposes of groundwater modeling.

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**Table 3-1. 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).**

| 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 |
| $Cr^{+3}$ | 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 3-1. 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). (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 |
| $SO_42^-$ | 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 3-2. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for radionuclides in curies. Data from Golberg and Guberski (1995). The letter "m" denotes the metastable isomer.**

| 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 |

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**Table 3-2. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for radionuclides in curies. Data from Golberg and Guberski (1995). The letter "m" denotes the metastable isomer. (cont'd)**

| Radionuclides | Single-Shell Tank Total | Double-Shell Tanks | | |
|---|---|---|---|---|
| | | Soluble | Insoluble | Total |
| 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 | | | |
| 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 | | | |

**Table 3-2. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for radionuclides in curies. Data from Golberg and Guberski (1995). The letter "m" denotes the metastable isomer. (cont'd)**

| Radionuclides | Single-Shell Tank Total | Double-Shell Tanks | | |
|---|---|---|---|---|
| | | Soluble | Insoluble | Total |
| 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 |
| 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 | | | |

**Table 3-2. Tank Waste Remediation System Environmental Impact Statement estimated total tank waste inventories for radionuclides in curies. Data from Golberg and Guberski (1995). The letter "m" denotes the metastable isomer. (cont'd)**

| Radionuclides | Single-Shell Tank Total | Double-Shell Tanks | | |
|---|---|---|---|---|
| | | Soluble | Insoluble | Total |
| 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 | | | |
| 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 |

WHC efforts at inventory estimation continue under the Historical Tank Content Estimates (HTCE) program. In terms of inventory characterization, the goal of the WHC overall effort is to produce a unified, "best-basis" inventory drawing on all available estimation and analytical results. This work is still in progress, and the most recent results may be viewed at the PNNL 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 analytical data on tank waste samples, and should prove to be a valuable resource for ongoing tank waste familiarization.

A sophisticated and systematic estimation effort is being carried out at Los Alamos National Laboratory (LANL) as part of the overall WHC inventory characterization effort. The most recent report on this modeling effort, termed the Hanford Defined Waste (HDW) model, became available during preparation of this chapter (Revision 4; Agnew, 1997). These newest data will be incorporated at a later stage; all citations of the HDW in this chapter refer to the previous version (Revision 3; Agnew, 1996). The HDW model compiles historical waste transaction records in order to construct spreadsheets delineating time-dependent inventories of solid and liquid chemical inventories for each tank. 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 a variety of chemicals (including organic compounds) and four radionuclides, Sr-90, Cs-137, U-238, and Pu-239. (Note that Revision 4 contains estimates for a number of other radionuclides.) For the purposes of this report, the HDW inventory values are considered the best available for individual tanks, and the total values (i.e., combined TLM and SMM) for each tank are reported in Appendix A. Note that these values, in contrast with the total inventories shown in Tables 3-1 and 3-2, are reported as concentrations: mole/liter for chemical constituents, $\mu$g/g for U-238, and $\mu$Ci/g for Sr-90, Cs-137, and Pu-239. Values for amounts, rather than concentrations, of each constituent, as well as an inventory breakdown between TLM and SMM, are also available in Agnew (1996).

Table 3-3, from the HDW report (Agnew, 1996), shows total site inventories for the studied constituents as an alternative to the values adopted for the EIS (Tables 3-1 and 3-2). This table also shows site-wide representation of some organic compounds not explicitly listed in the EIS. Comparison between the two data sets is briefly discussed later in this chapter.

The EIS argues that, in addition to the four radionuclides covered by the HDW model, the radionuclides most important to risk are C-14, Tc-99, and I-129 (U.S. Department of Energy, 1996b). Because these three are not included in Revision 3 of the HDW, we have extracted from the above referenced web site the individual tank inventories for these three radionuclides under the TWINS heading *Waste Inventory/Inventory Summary*. These are working values pending completion of the "best-basis" inventory, and are reported in Table 3-4. "Best-basis" values for these radionuclides have been determined for only a few tanks; otherwise, the values in Table 3-4 are from the Tank Characterization Report for the individual tank or, if that has not yet been completed, from the HTCE. Note that these values are reported in total curie content of the tanks. It is notable that the Tank Characterization Report values can vary considerably from the HTCE values - by as much as two orders of magnitude.

**Table 3-3. Total tank inventories from the Agnew (1996) Hanford Designed Waste model**

| Species | All Quadrants (kg or Ci) | SSTs (kg or Ci) | DSTs (kg or Ci) | All Quadrants (Mmol) | SSTs (Mmol) | DSTs (Mmol) |
|---|---|---|---|---|---|---|
| $Na^{+}$ | 40,278,796 | 25,846,590 | 14,432,205 | 1,752.01 | 1,124.25 | 627.76 |
| $Al^{3+}$ | 7,718,242 | 5,528,101 | 2,190,140 | 286.07 | 204.90 | 81.18 |
| $Fe^{3+}$ (total) | 1,834,821 | 1,614,566 | 220,255 | 32.85 | 28.91 | 3.94 |
| $Cr^{3+}$ | 784,651 | 651,600 | 133,051 | 15.09 | 12.53 | 2.56 |
| $Bi^{3+}$ | 524,044 | 512,758 | 11,286 | 2.51 | 2.45 | 0.05 |
| $La^{3+}$ | 40,439 | 40,301 | 137 | 0.29 | 0.29 | 9.89E-04 |
| $Hg^{2+}$ | 6,859 | 5,814 | 1,045 | 0.03 | 0.03 | 0.01 |
| $ZrO^{2-}$ (as Zr) | 231,633 | 37,047 | 194,585 | 2.54 | 0.41 | 2.13 |
| $Pb^{2+}$ | 279,158 | 268,445 | 10,712 | 1.35 | 1.30 | 0.05 |
| $Ni^{2+}$ | 182,028 | 143,822 | 38,206 | 3.10 | 2.45 | 0.65 |
| $Sr^{2+}$ | 167,309 | 167,280 | 29 | 1.91 | 1.91 | 3.31E-04 |
| $Mn^{4+}$ | 38,719 | 15,164 | 23,555 | 0.70 | 0.28 | 0.43 |
| $Ca^{2+}$ | 618,706 | 496,631 | 122,075 | 15.44 | 12.39 | 3.05 |
| $K^{+}$ | 481,105 | 181,333 | 299,772 | 12.30 | 4.64 | 7.67 |
| $H_2O$ | 167,209,657 | 92,700,616 | 74,509,041 | | | |
| TOC | 1,804,768 | 908,245 | 896,523 | | | |
| free $OH^{-}$ | 117,845 | 108,634 | 9,212 | | | |
| $OH^{-}$ | 22,987,261 | 16,474,351 | 6,512,909 | 1,352.19 | 969.08 | 383.11 |
| $NO_3^{-}$ | 45,356,204 | 29,146,381 | 16,209,823 | 731.55 | 470.10 | 261.45 |
| $NO_2^{-}$ | 13,558,862 | 8,980,065 | 4,578,797 | 294.76 | 195.22 | 99.54 |
| $CO_3^{2-}$ | 4,828,553 | 2,877,517 | 1,951,035 | 80.46 | 47.95 | 32.51 |



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**Table 3-3. Total tank inventories from the Agnew (1996) Hanford Designed Waste model (cont'd)**

| Species | All Quadrants (kg or Ci) | SSTs (kg or CI) | DSTs (kg or Ci) | All Quadrants (Mmol) | SSTs Mmol | DSTs Mmol |
|---|---|---|---|---|---|---|
| $PO_4^{3-}$ | 4,027,865 | 3,313,321 | 714,543 | 42.41 | 34.89 | 7.52 |
| $SO_4^{2-}$ | 3,216,632 | 1,997,496 | 1,219,136 | 33.49 | 20.79 | 12.69 |
| $SiO_3^{2-}$ (as Si) | 613,786 | 477,306 | 136,479 | 21.85 | 16.99 | 4.86 |
| $F^-$ | 638,880 | 269,420 | 369,461 | 33.63 | 14.18 | 19.45 |
| $Cl^-$ | 956,820 | 575,672 | 381,148 | 27.01 | 16.25 | 10.76 |
| Citrate | 677,916 | 371,956 | 305,960 | 3.59 | 1.97 | 1.62 |
| EDTA | 619,298 | 295,066 | 324,231 | 2.15 | 1.02 | 1.13 |
| HEDTA | 1,033,866 | 478,663 | 555,203 | 3.77 | 1.75 | 2.03 |
| glycolate | 1,100,157 | 406,684 | 693,473 | 14.66 | 5.42 | 9.24 |
| acetate | 99,430 | 56,963 | 42,467 | 1.68 | 0.97 | 0.72 |
| oxalate | 69,140 | 69,065 | 74 | 0.79 | 0.78 | 8.46E-04 |
| DBP | 593,767 | 411,715 | 182,052 | 3.69 | 2.56 | 1.13 |
| butanol | 198,054 | 114,684 | 83,370 | 2.67 | 1.55 | 1.12 |
| $NH_3$ | 412,232 | 90,575 | 321,657 | 24.25 | 5.33 | 18.92 |
| $Fe(CN)_6^{4-}$ | 144,596 | 144,596 | 0 | 0.53 | 0.53 | 0.00 |
| Pu-239 (kg) | 761 | 561 | 200 | 761 (kg) | 561 (kg) | 200 (kg) |
| U-238 (kg) | 2,340,778 | 2,100,669 | 240,110 | 9.83 | 8.83 | 1.01 |
| Cs-137 (Ci) | 45,947,070 | 22,651,678 | 23,295,392 | 45.95 (MCi) | 22.65 (MCi) | 23.30 (MCi) |
| Sr-90 (Ci) | 56,733,866 | 38,208,328 | 18,525,538 | 56.73 (MCi) | 38.21 (MCi) | 18.53 (MCi) |
| BTU | 2,040,032 | 1,241,218 | 798,814 | 2,040,032 | 1,241,218 | 798,814 |
| kgal of waste | 60,892 | 35,198 | 25,694 | 60,892 | 35,198 | 25,694 |

**Table 3-4. Individual tank inventories for C-14, Tc-99, and I-129 from the TWINS online database (http://twins.pnl.gov:8001/TCD/main.html). These are working values from the *Waste Inventory/Inventory Summary*, using "best-basis" values or, if they are not yet determined, Tank Characterization Reports or HTCE inventories (in that order of preference).**

| Tank Name | C-14 (Ci) | Tc-99 (Ci) | I-129 (Ci) |
|---|---|---|---|
| A-101 | 115 | 869. | 1.68 |
| A-102 | 5.13 | 39.1 | 0.0755 |
| A-103 | 47.4 | 362 | 0.699 |
| A-104 | 1.18 | 8.29 | 0.016 |
| A-105 | 1.71 | 12.1 | 0.0235 |
| A-106 | 13.2 | 97.1 | 0.188 |
| AN-101 | 36.3 | 266 | 0.513 |
| AN-102 | 0.634 | 48.6 | 3.17 |
| AN-103 | 105 | 784 | 1.51 |
| AN-104 | 104 | 782 | 1.51 |
| AN-105 | 198 | 1500 | 2.89 |
| AN-106 | 2.08 | 15.4 | 0.0297 |
| AN-107 | 148 | 1160 | 2.25 |
| AP-101 | 4.58 | 33.6 | 0.065 |
| AP-102 | 2.09 | 358 | 1.1 |
| AP-103 | 3.88E-10 | 358 | 0.145 |
| AP-104 | 0.264 | 12.3 | |
| AP-105 | 0.675 | 217 | 0.473 |
| AP-106 | 0.033 | 5.72 | 0.268 |
| AP-107 | 0.0133 | | |
| AP-108 | 8.56 | 42.2 | 0.0836 |
| AW-101 | 1.47 | 598 | 1.19 |
| AW-102 | 1.58E-06 | 1.36 | 0.506 |
| AW-103 | 1.26 | 181 | 0.096 |
| AW-104 | 0.0607 | 0.443 | 0.000857 |
| AW-105 | 3.73 | 80.9 | 5.28 |

**Table 3-4. Individual tank inventories for C-14, Tc-99, and I-129 from the TWINS online database (http://twins.pnl.gov:8001/TCD/main.html). These are working values from the *Waste Inventory/Inventory Summary*, using "best-basis" values or, if they are not yet determined, Tank Characterization Reports or HTCE inventories (in that order of preference). (cont'd)**

| Tank Name | C-14 (Ci) | Tc-99 (Ci) | I-129 (Ci) |
|---|---|---|---|
| AW-106 | 0.2 | 51.6 | 0.561 |
| AX-101 | 98.7 | 753 | 1.45 |
| AX-102 | 5.1 | 37.7 | 0.0728 |
| AX-103 | 12.6 | 95.4 | 0.184 |
| AX-104 | 0.63 | 4.47 | 0.00864 |
| AY-101 | 57.8 | 412 | 0.797 |
| AY-102 | 5 | 1.3 | 0.0532 |
| AZ-101 | 0.353 | 474 | 5.82 |
| AZ-102 | 0.8 | 220.3 | 1.53 |
| B-101 | 0.546 | 3.51 | 0.00675 |
| B-102 | 0.134 | 0.759 | 0.00145 |
| B-103 | 0.141 | 0.79 | 0.00149 |
| B-104 | 0.209 | 1.45 | 0.00273 |
| B-105 | 0.262 | 1.82 | 0.00343 |
| B-106 | 0.248 | 1.72 | 0.00325 |
| B-107 | 0.0548 | 0.379 | 0.000707 |
| B-108 | 0.129 | 0.895 | 0.00168 |
| B-109 | 3.88 | 33.8 | 0.0653 |
| B-110 | 11 | 20.7 | 0.045 |
| B-111 | 1.7 | 121 | 0.0341 |
| B-112 | 2.3 | 13.6 | 0.0263 |
| B-201 | 0.043 | 0.00121 | |
| B-202 | 0.043 | 0.00117 | |
| B-203 | 0.000312 | 0.00216 | |
| B-204 | 0.000305 | 0.00212 | |
| BX-101 | 0.433 | 1.32 | 0.00254 |

**Table 3-4. Individual tank inventories for C-14, Tc-99, and I-129 from the TWINS online database (http://twins.pnl.gov:8001/TCD/main.html). These are working values from the *Waste Inventory/Inventory Summary*, using "best-basis" values or, if they are not yet determined, Tank Characterization Reports or HTCE inventories (in that order of preference). (cont'd)**

| Tank Name | C-14 (Ci) | Tc-99 (Ci) | I-129 (Ci) |
|---|---|---|---|
| BX-102 | 0.239 | 0.214 | 0.000399 |
| BX-103 | 0.88 | 3.05 | 0.00587 |
| BX-104 | 7.05 | 47.5 | 0.0916 |
| BX-105 | 0.3278 | 14.28 | 0.00978 |
| BX-106 | – | – | – |
| BX-107 | 0.491 | 69.3 | 0.00297 |
| BX-108 | 0.0111 | 0.0769 | 0.000145 |
| BX-109 | 0.209 | 1.45 | 0.00273 |
| BX-110 | 5.47 | 30.6 | 0.0592 |
| BX-111 | 23 | 128 | 0.249 |
| BX-112 | 0.231 | 1.74 | 0.00332 |
| BY-101 | 45.4 | 251 | 0.486 |
| BY-102 | 41.2 | 231 | 0.448 |
| BY-103 | 50.3 | 280 | 0.542 |
| BY-104 | 22.8 | 128 | 0.247 |
| BY-105 | 43.7 | 243 | 0.47 |
| BY-106 | 70.1 | 391 | 0.756 |
| BY-107 | 19.3 | 108 | 0.209 |
| BY-108 | 8.35 | 46.9 | 0.0907 |
| BY-109 | 50.1 | 278 | 0.537 |
| BY-110 | 27 | 151 | 0.292 |
| BY-111 | 55.9 | 310 | 0.601 |
| BY-112 | 36.4 | 203 | 0.393 |
| C-101 | 0.0891 | 0.434 | 0.000825 |
| C-102 | 0.211 | 1.23 | 0.00257 |
| C-103 | 5.5 | 41.7 | 0.0808 |

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**Table 3-4. Individual tank inventories for C-14, Tc-99, and I-129 from the TWINS online database (http://twins.pnl.gov:8001/TCD/main.html). These are working values from the *Waste Inventory/Inventory Summary*, using "best-basis" values or, if they are not yet determined, Tank Characterization Reports or HTCE inventories (in that order of preference). (cont'd)**

| Tank Name | C-14 (Ci) | Tc-99 (Ci) | I-129 (Ci) |
|---|---|---|---|
| C-104 | 1.05 | 7.66 | 0.0157 |
| C-105 | 0.591 | 81.2 | 0.076 |
| C-106 | 4.32 | 30.3 | 0.0586 |
| C-107 | 0.595 | 4.04 | 0.0078 |
| C-108 | 0.0678 | 0.47 | 0.000885 |
| C-109 | 0.00569 | 30.6 | 0.00154 |
| C-110 | 0.47627 | 34.129 | 0.00079 |
| C-111 | 0.0315 | 0.219 | 0.000413 |
| C-112 | 0.183 | 1.27 | 0.0024 |
| C-201 | 0.0114 | 0.0168 | |
| C-202 | 0.00113 | 0.00795 | |
| C-203 | 0.0424 | 0.0433 | |
| C-204 | 0.0218 | 0.0256 | |
| S-101 | 31.8 | 229 | 0.44 |
| S-102 | 34.2 | 244 | 0.47 |
| S-103 | 36.5 | 260 | 0.501 |
| S-104 | 1.48 | 39.7 | 0.116 |
| S-105 | 42.4 | 303 | 0.582 |
| S-106 | 58.4 | 418 | 0.805 |
| S-107 | 13.1 | 93 | 0.179 |
| S-108 | 62.9 | 448 | 0.864 |
| S-109 | 63.8 | 454 | 0.875 |
| S-110 | 39.3 | 280 | 0.539 |
| S-111 | 71.5 | 511 | 0.984 |
| S-112 | 66.8 | 476 | 0.917 |
| SX-101 | 17.7 | 131 | 0.25 |

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**Table 3-4. Individual tank inventories for C-14, Tc-99, and I-129 from the TWINS online database (http://twins.pnl.gov:8001/TCD/main.html). These are working values from the *Waste Inventory/Inventory Summary*, using "best-basis" values or, if they are not yet determined, Tank Characterization Reports or HTCE inventories (in that order of preference). (cont'd)**

| Tank Name | C-14 (Ci) | Tc-99 (Ci) | I-129 (Ci) |
|---|---|---|---|
| SX-102 | 88.1 | 629 | 1.21 |
| SX-103 | 90.6 | 648 | 1.25 |
| SX-104 | 76.7 | 548 | 1.06 |
| SX-105 | 109 | 775 | 1.49 |
| SX-106 | 73.7 | 525 | 1.01 |
| SX-107 | 1.85 | 14.2 | 0.027 |
| SX-108 | 1.02 | 7.65 | 0.0146 |
| SX-109 | 8.99 | 69.7 | 0.132 |
| SX-110 | 2.06 | 16.3 | 0.031 |
| SX-111 | 3.16 | 24.7 | 0.0468 |
| SX-112 | 1.97 | 15.3 | 0.029 |
| SX-113 | 0.0171 | 0.12 | 0.00023 |
| SX-114 | 6.74 | 52.6 | 0.0998 |
| SX-115 | 0.311 | 2.38 | 0.00452 |
| SY-101 | 204 | 1460 | 2.79 |
| SY-102 | 1.19 | 28.2 | 0.165 |
| SY-103 | 105 | 766 | 0.258 |
| T-101 | 1.18 | 8.24 | 0.0159 |
| T-102 | 5.91 | 2.31 | 0.000104 |
| T-103 | 0.304 | 2.09 | 0.00404 |
| T-104 | 0.0968 | 1.24 | 99.8 |
| T-105 | 0.81 | 230 | 0.000222 |
| T-106 | 0.00925 | 0.067 | 0.000127 |
| T-107 | | 0.388 | 0.000722 |
| T-108 | 0.0457 | 0.322 | 0.000605 |
| T-109 | 0.0978 | 0.692 | 0.0013 |

**Table 3-4. Individual tank inventories for C-14, Tc-99, and I-129 from the TWINS online database (http://twins.pnl.gov:8001/TCD/main.html). These are working values from the *Waste Inventory/Inventory Summary*, using "best-basis" values or, if they are not yet determined, Tank Characterization Reports or HTCE inventories (in that order of preference). (cont'd)**

| Tank Name | C-14 (Ci) | Tc-99 (Ci) | I-129 (Ci) |
|---|---|---|---|
| T-110 | 0.017 | 14 | 0.00022 |
| T-111 | 0.0198 | 17 | 0.000259 |
| T-112 | 0.00283 | 2 | |
| T-201 | 0.043 | 0.00121 | |
| T-202 | 0.034 | 0.000909 | |
| T-203 | 0.000218 | 0.00151 | |
| T-204 | 0.000237 | 0.00164 | |
| TX-101 | 1.8 | 12.5 | 0.0241 |
| TX-102 | 17.9 | 128 | 0.246 |
| TX-103 | 6.12 | 43.6 | 0.084 |
| TX-104 | 4.01 | 27.4 | 0.0528 |
| TX-105 | 50.5 | 360 | 0.694 |
| TX-106 | 27.7 | 197 | 0.38 |
| TX-107 | 0.516 | 3.16 | 0.00609 |
| TX-108 | 8.21 | 58.5 | 0.113 |
| TX-109 | 0.17 | 1.18 | 0.00222 |
| TX-110 | 30.7 | 219 | 0.422 |
| TX-111 | 25.8 | 184 | 0.354 |
| TX-112 | 52.1 | 372 | 0.717 |
| TX-113 | 34.2 | 243 | 0.469 |
| TX-114 | 38.6 | 275 | 0.53 |
| TX-115 | 47 | 335 | 0.646 |
| TX-116 | 17.5 | 125 | 0.241 |
| TX-117 | 24.4 | 174 | 0.336 |
| TX-118 | 13.8 | 98.5 | 0.19 |
| TY-101 | 0.124 | 0.87 | 0.00164 |

**Table 3-4. Individual tank inventories for C-14, Tc-99, and I-129 from the TWINS online database (http://twins.pnl.gov:8001/TCD/main.html). These are working values from the *Waste Inventory/Inventory Summary*, using "best-basis" values or, if they are not yet determined, Tank Characterization Reports or HTCE inventories (in that order of preference). (cont'd)**

| Tank Name | C-14 (Ci) | Tc-99 (Ci) | I-129 (Ci) |
|---|---|---|---|
| TY-102 | 2.69 | 19.2 | 0.037 |
| TY-103 | 3.51 | 25 | 0.0482 |
| TY-104 | 0.935 | 9.06 | 0.000458 |
| TY-105 | 0.448 | 3.11 | 0.00586 |
| TY-106 | 0.103 | 10.7 | 5.86 |
| U-101 | 0.227 | 0.194 | 0.000362 |
| U-102 | 49.5 | 350 | 0.674 |
| U-103 | 62.7 | 444 | 0.856 |
| U-104 | 4.88 | 32.7 | 0.0629 |
| U-105 | 62.9 | 446 | 0.86 |
| U-106 | 42 | 297 | 0.574 |
| U-107 | 48.3 | 344 | 0.664 |
| U-108 | 76.3 | 542 | 1.05 |
| U-109 | 82.6 | 586 | 1.13 |
| U-110 | 0.35 | 7.3 | 0.00108 |
| U-111 | 32.3 | 230 | 0.444 |
| U-112 | 0.0729 | 0.51 | 0.000976 |
| U-201 | 0.00166 | 0.0119 | |
| U-202 | 0.00165 | 0.0119 | |
| U-203 | 0.0255 | 0.179 | 0.000344 |
| U-204 | 0.000826 | 0.00593 | |

### 3.2.1 Inorganic chemicals

Tables 3-1 and 3-3 show that, by far, the most abundant cation in the tank wastes is sodium; $Na^+$ comprises around 80 percent of the cationic content by both weight and molarity. Figure 3-2 shows the range of variation in $Na^+$ concentrations across all 177 tanks, based on the HDW model. 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.

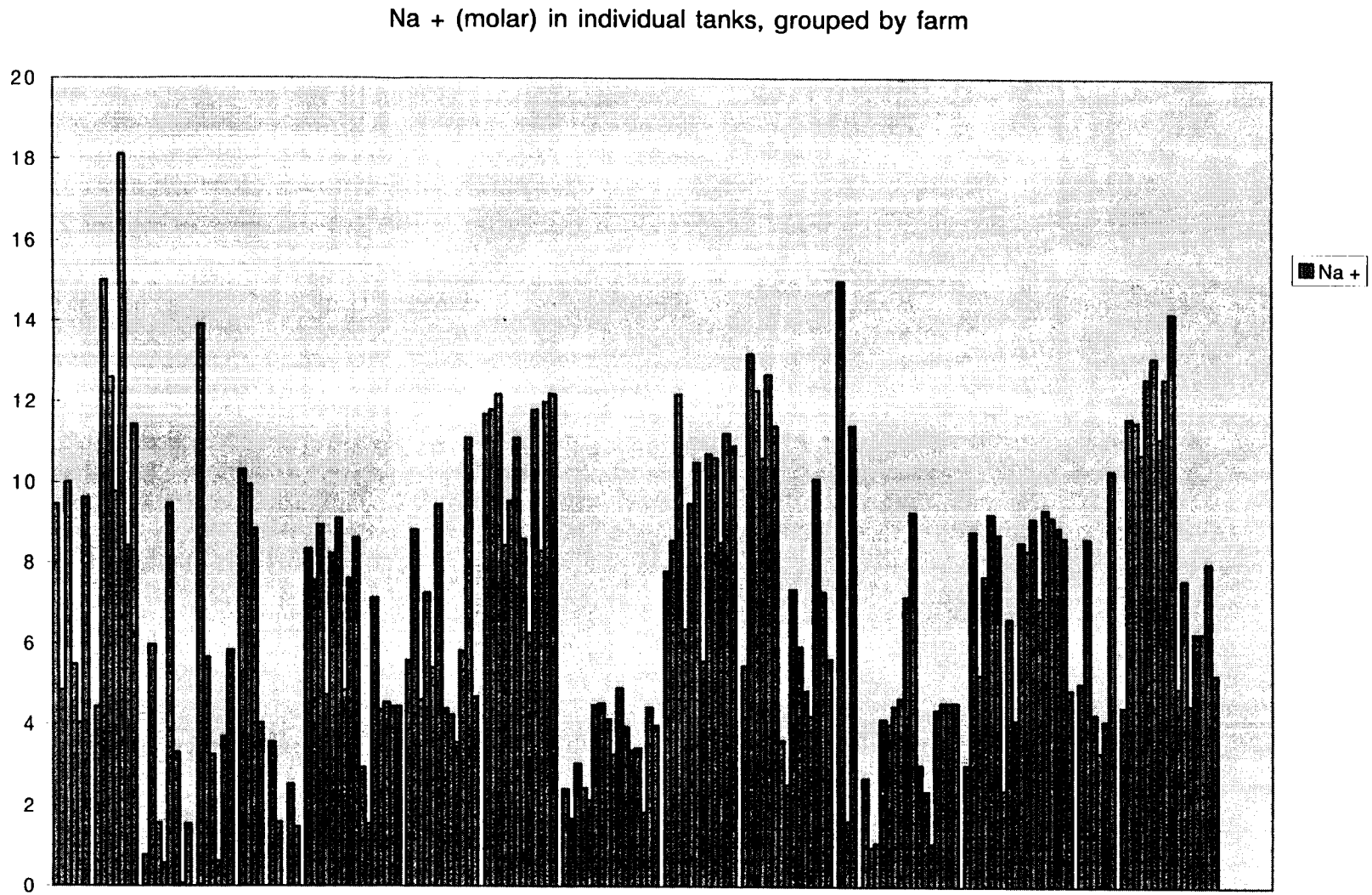


**Figure 3-2. Histogram of molar $Na^+$ in Hanford tanks from the Hanford Defined Waste model (Agnew, 1996). Tank farms are separated by blank spaces along the x axis.**



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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). The range of variation in nitrate concentration among tanks based on the HDW 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 3-1) report organic components only as total organic carbon (TOC). Ongoing individual tank inventory efforts such as HDW provide more detailed breakdown of organic compound contents by tank (Appendix A) and overall for the Hanford site (Table 3-3). The overall site inventories (Table 3-3) show that, on a molar basis, glycolate is the predominant organic complexant. The other listed organic anions—citrate, EDTA, HEDTA, acetate, oxalate, DBP and butane—all have similarly low molar concentrations, ranging from approximately 1/20 to 1/4 of the glycolate value. On a weight basis, glycolate is rivalled in abundance by HEDTA. There are no major differences in organic inventories between SSTs and DSTs.

### 3.2.3 Radionuclides

As mentioned above, the key radionuclides for risk assessment at Hanford are C-14, Sr-90, Tc-99, I-129, Cs-137, and uranium (U.S. Department of Energy, 1996b), Sr-90 and Cs-137 are by far the most abundant radionuclides on an activity basis (Tables 3-2 and 3-3). 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 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 (Appendix A and Table 3-4).

### 3.2.4 Discussion

The nature of the tank waste inventories—chiefly their derivation 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

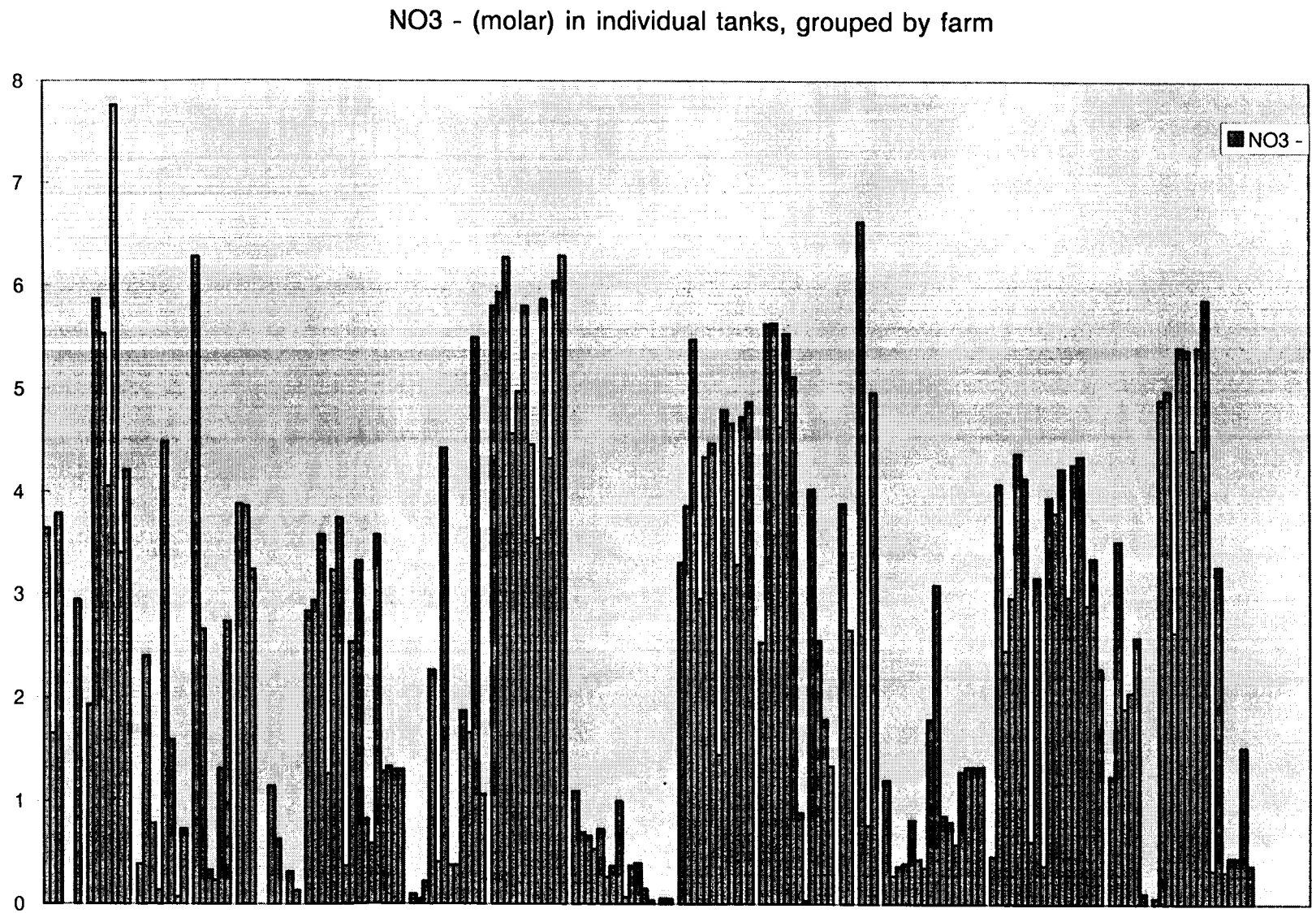


**Figure 3-3. Histogram of molar $NO_3^-$ in Hanford tanks from the Hanford Defined Waste model (Agnew, 1996)**



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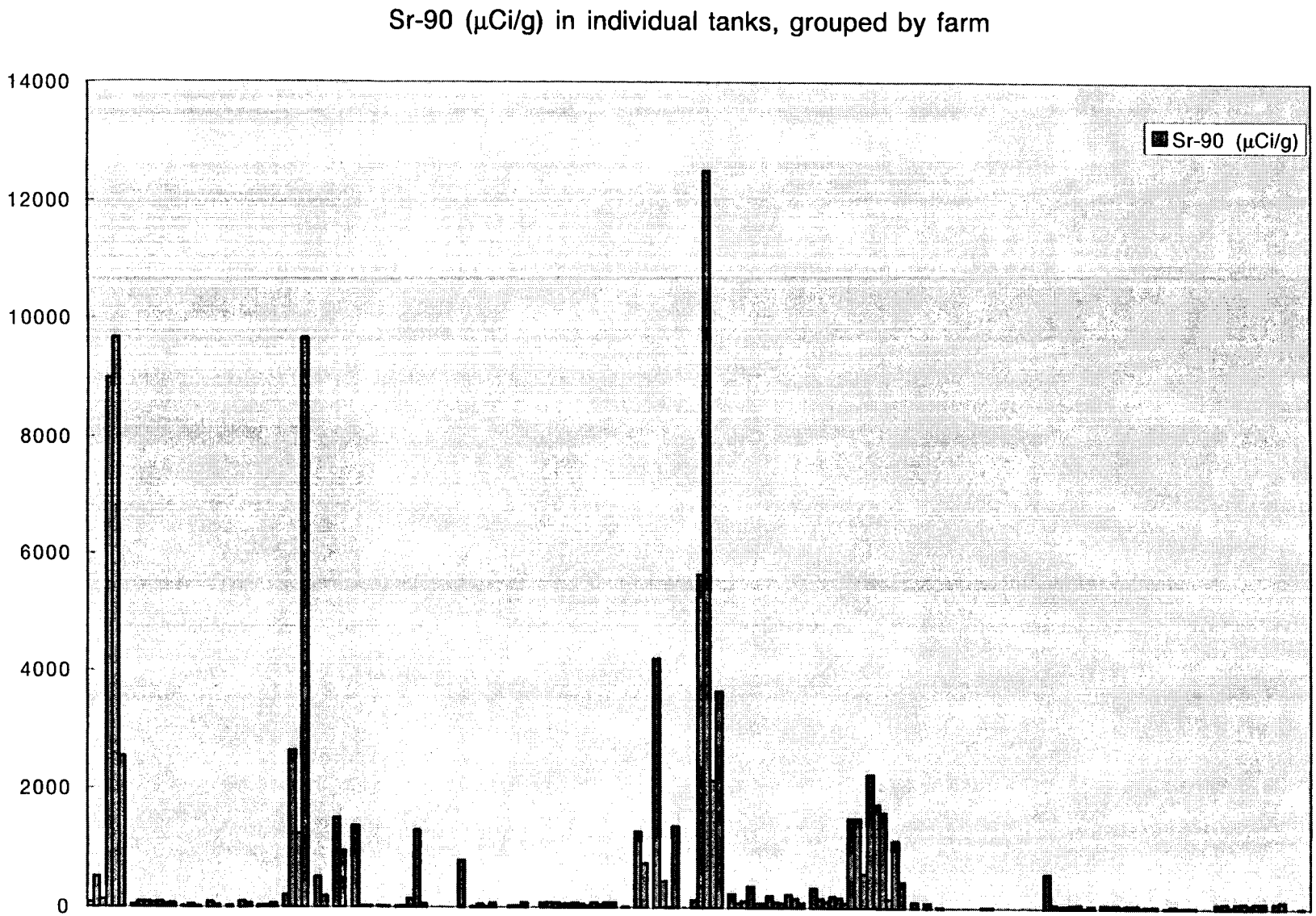


**Figure 3-4. Histogram of $\mu$Ci/g Sr-90 in Hanford tanks from the Hanford Defined Waste model (Agnew, 1996)**



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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. In fact, adequate quantification of these uncertainties remains elusive (Agnew, 1996). A higher degree of confidence in individual tank inventories is the goal of the WHC "best-basis" effort, which as noted is still incomplete. This effort will unify results from the different estimation schemes with analytical data on the wastes themselves. As a "grab bag" example of how divergent analytical data may be from inventory estimation, the TWINS database shows eleven analyses of Tc-99 from tank C-112 which range from 0.08 to 0.23 $\mu$Ci/g, clustering around 0.1 $\mu$Ci/g. In contrast, calculating an average Tc-99 concentration using the total curie content for that tank in Table 3-4 and the tank total waste weight in Agnew (1996) yields 0.002 $\mu$Ci/g. It is recommended that, at the present state of knowledge, individual tank estimates be derived from the HDW tables (Appendix A) and Table 3-4 for those radionuclides not listed in the HDW.

While the overall site tank waste inventories for constituents are subject to lesser uncertainty, significant differences emerge from one estimation scheme to another (compare Tables 3-1 and 3-2 with Table 3-3). 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 3 version cited here. It is noted there that some constituents are listed at contents several times higher in the HDW (Agnew, 1996) than in the Golberg and Guberski WHC (1995) 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 WHC overall inventory as in the HDW, and is potentially significant as a post-remediation pollutant (U.S. Department of Energy, 1996b).

In summary, the best tank waste inventory—the under-development "best-basis" model—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, 1996) is generally preferred for constituents listed therein (Appendix A for individual tanks and Table 3-3 for total inventories). Potentially important radionuclides C-14, Tc-99, and I-129 are not included in the Revision 3 HDW, so the values obtained from the TWINS database and shown in Table 3-4 are preferred. The Revision 4 HDW (Agnew, 1997) does include estimates for these three radionuclides, and these will be incorporated into this chapter at a later date.

## 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 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 U.S. 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.

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 U.S. 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

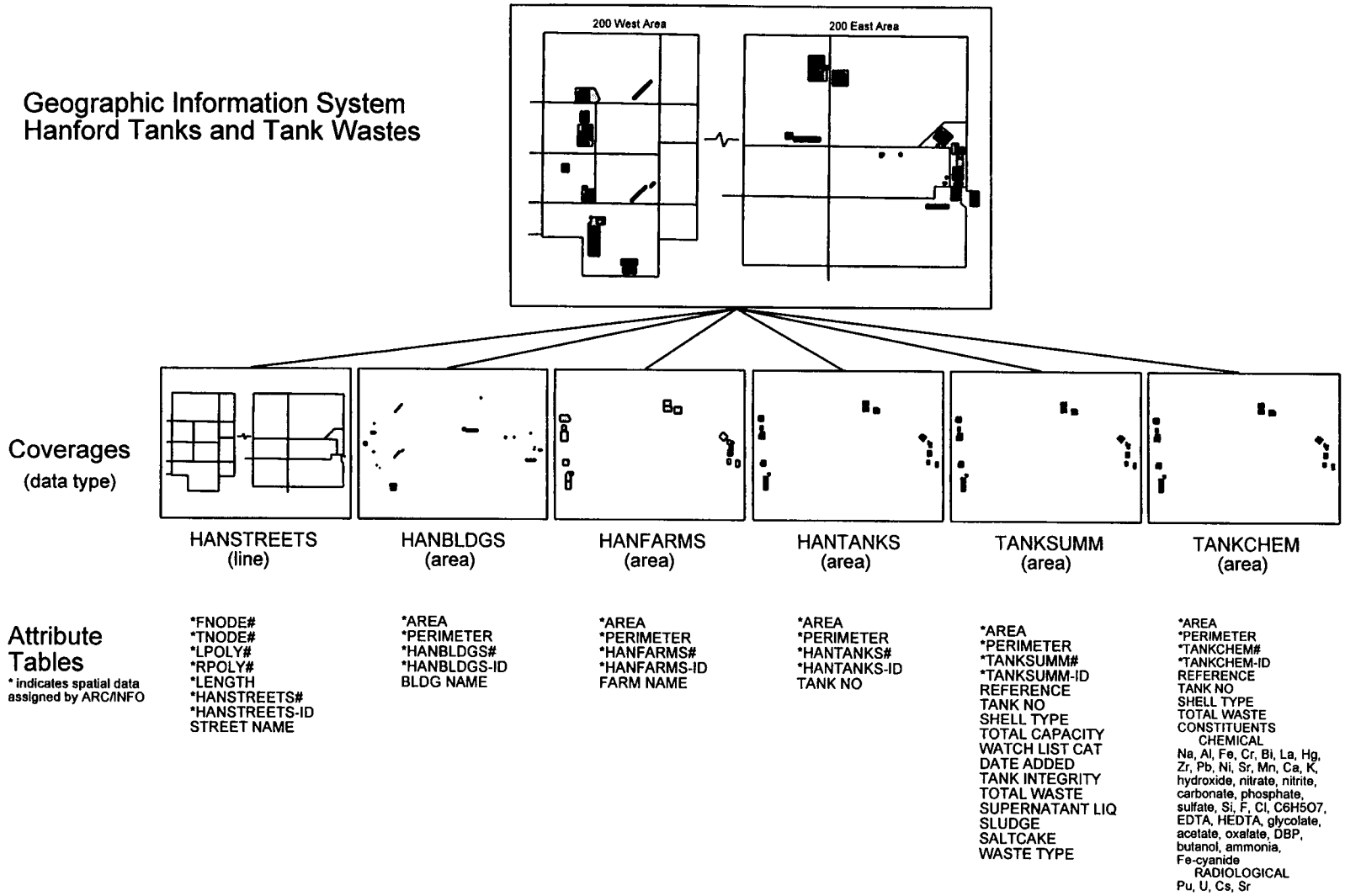


**Figure 3-5. Schematic diagram of the Hanford tanks and tank wastes GIS showing the coverages, their data types, and the data items contained within each coverage**



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site. In addition, unlike the UNIX-based ARC/INFO, ArcView can be installed and executed on either Windows or UNIX platforms.

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 $\mu$Ci/g. The information resulting from this query operation are presented graphically in Figure 3-7. In this figure, the tanks with a Pu-239 concentration greater than 1.0 $\mu$Ci/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.

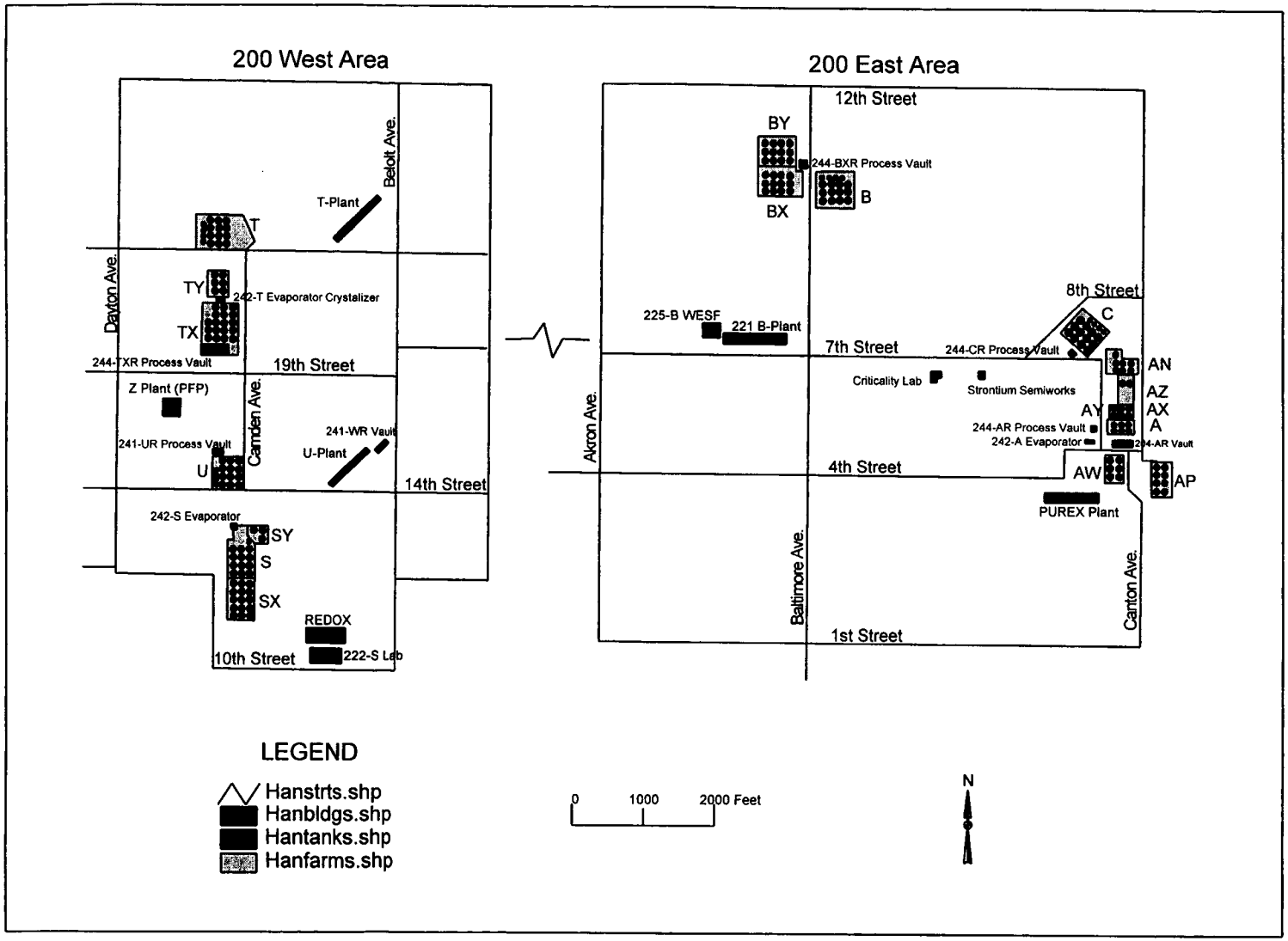


**Figure 3-6. Map of the 200 Areas at the Hanford site constructed with Arc View using the Hanford tanks ARC/INFO coverages**



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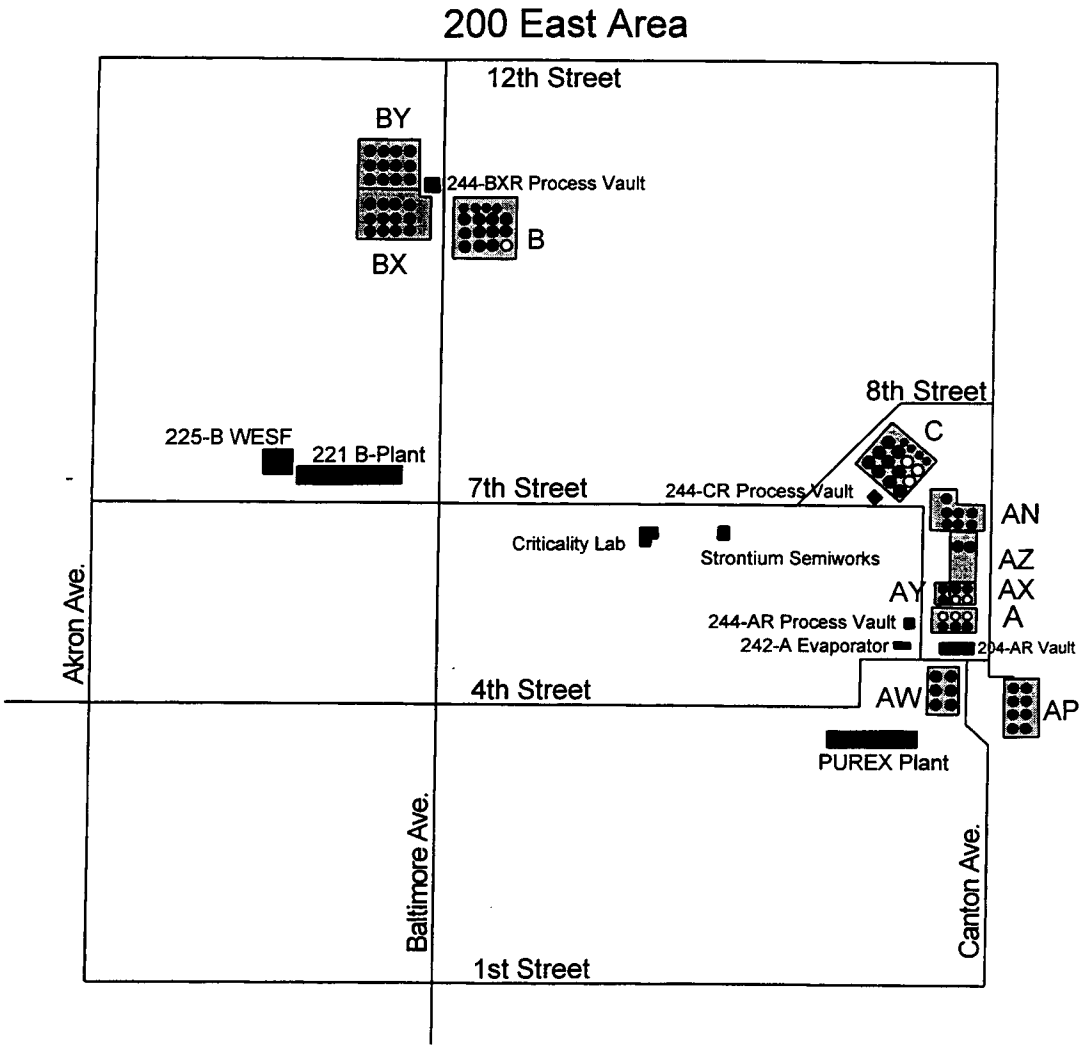


| | | | | | | |
|---|---|---|---|---|---|---|
| Polygon | 0.007 | 0.300 | 39 | 325 | B-101 | 1.140000 |
| Polygon | 0.008 | 0.318 | 80 | 334 | C-106 | 3.670000 |
| Polygon | 0.008 | 0.318 | 88 | 337 | C-103 | 1.150000 |
| Polygon | 0.008 | 0.318 | 94 | 336 | C-102 | 1.020000 |
| Polygon | 0.004 | 0.239 | 110 | 356 | AX-102 | 1.870000 |
| Polygon | 0.004 | 0.239 | 112 | 355 | AX-104 | 1.040000 |
| Polygon | 0.004 | 0.239 | 113 | 359 | A-106 | 1.620000 |
| Polygon | 0.004 | 0.239 | 114 | 358 | A-105 | 1.040000 |
| Polygon | 0.004 | 0.239 | 115 | 357 | A-104 | 7.030000 |

**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 $\mu$Ci/g. The tank numbers and estimated Pu-239 concentrations of the highlighted tanks are listed in the last two columns of the table at the bottom right. The table also contains spatial information about each tank which is assigned by ARC/INFO.**

# 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 high-level radioactive waste to the environment. The DOE developed a set of criteria to identify tanks with potential safety concerns as Watch-list tanks. 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 Hanford 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 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) 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 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[1]) and any tanks containing materials related to contents of tank SY-101 or tanks that exhibited slurry growth, episodic level drops, or pressure bumps. 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.

[1] The lower flammability limit in air for hydrogen gas, ammonia, and methane are 4, 16, and 5 volume%, 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 December, 1996 (D. Wodrich, personal communications, January 14, 1997).

(*) 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).



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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 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 (Wodrich, 1997).[2] 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.

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

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 plutonium and uranium, 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 ethylenediaminetetraacetate (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, the 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 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 square 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[3] (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

[3] The Data Quality Objectives (DQO) Process, defined by the U.S. Environmental Protection Agency (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, 1994) provides excellent guidance on the steps of the DQO process for developing data quality criteria and performance specifications for data operations.

**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 recovery) | Glycolic acid | 694 kg (1,530 lb) |
| B Plant (strontium recovery) | Citric acid | 633 kg (1,396 lb) |
| B Plant (strontium recovery) | HEDTA | 745 kg (1,642 lb) |
| B Plant (strontium 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 (1992).
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 = Ethylenediaminetetraacetic acid
HEDTA = Hydroxyethylene(ethylenediamine)triacetic acid
NPH = Normal paraffin hydrocarbons
PUREX = Plutonium-Uranium Extraction
TBP = Tributyl phosphate

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 cesium 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 co-precipitate cesium 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 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 uranium 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 bismuth phosphate 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 uranium, 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). 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, ferrocyanide decomposition may have occurred in the tanks. As a result, the concentration of ferrocyanide may be much less than that predicted by tank inventory records. Tank waste samples that have been analyzed to date support the conclusion 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 (Wodrich, 1997).[4] All tanks have been removed from

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

the Ferrocyanide Watch-list and that the Ferrocyanide Safety Issue was officially closed as of December, 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), ten SSTs have high-lead loads (>42,000 kJ/h [>40,000 Btu/hr]) 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]. 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 ground if a tank leak develops. Because of high-heat concerns, tank C-106 was placed on the High-Heat Watch List and deemed as a Priority 1 safety issue. Although the method of active ventilation 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 HEPA-Filter Blow-Out Issue Associated with Flammable Gas Tanks

Another scenario associated with the presence of flammable gas mixtures in the 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 high-efficiency particulate air (HEPA) filters on the tanks have an operating limit of +2.5 kPa (+10 inches 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 Resource Conservation and Recovery Act (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

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**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 |

**Table 4-3. TWRS 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-110 | 1984 | 2,000 | --- | 5/95 |
| C-111 | 1968 | 5,500[6] | --- | 3/84 |
| 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 |
| 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 |

## Table 4-3. TWRS 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] |
|---|---|---|---|---|
| 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.

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 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 241-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 $S_N$[5] code ONEDANT to calculate the $k_\infty$[6] corresponding to the plutonium concentrations in sedimentary layers of this tank. They found that these layers have a $k_\infty$ 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 critical masses of Pu-239 are 9,800 and 900 g for plutonium metal and ideally light-water-moderated bare spherical reactors, respectively, and 320 g for an ideally 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 and U-235 in tank SY-101 to be about 3,580 g and 89,500 g, respectively. These values suggest that the major criticality concern with the tank wastes in SY-101 is probably not the Pu-239 concentration but rather the U-235 concentration of the sedimentary layers. Although Perry et al. (1994) did not account for fissile nuclides other than Pu-239, their conclusion that the tank is extremely subcritical is *probably* still true even if a non-conservative fissile inventory (i.e., solely Pu-239) is assumed because a factor of 16,000 increase in Pu-239 concentration is necessary to approach criticality in the tank. As a result of

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

[6] $k_\infty$ is the neutron multiplication factor for a material with infinite extent, that is, neutron leakage out of the system is zero.

these findings, the tanks in the Hanford TWRS were ranked based on their total inventory of fissile nuclides (the sum of U-233, U-235, Pu-239, and Pu-241 inventories, in grams) using data from Agnew (1996). The results of this ranking are shown in Table 4-4, along with the total fissile nuclide content of each tank. It should be noted that tank SY-102 is not particularly high on this list.

It is recommended that future NRC and CNWRA detailed investigations into criticality safety of the TWRS focus on retrieval and subsequent processing of wastes from tanks with high total fissile nuclide concentrations and not just tanks with high plutonium concentrations, as wastes with high total fissile concentrations would likely be the most susceptible to nuclear criticalities. Criticality safety evaluation should also focus on processes that could concentrate the fissiles during waste processing such as chemical separation, evaporation, and settling.

#### 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 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 plutonium 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 plutonium was found to be 27 kg for the four drum (of DOT-17C specifications) arrangement. This was the most reactive arrangement of weapons grade plutonium 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 vitrification 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 uranium and plutonium with respect to iron and manganese neutron absorbers, (ii) fissile material adsorbed onto monosodium titanate, (iii) fissile material entrained in the sludge solids, (iv) plutonium 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 which 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.

**Table 4-4. A ranking of the tanks based on their fissile nuclide content**

| Tank | Fissile Content (g) | Tank | Fissile Content (g) | Tank | Fissile Content (g) |
|---|---|---|---|---|---|
| BX-103 | 5.98E+05 | TX-116 | 1.54E+05 | TX-114 | 5.50E+04 |
| T-104 | 5.28E+05 | AW-103 | 1.42E+05 | AN-107 | 5.38E+04 |
| BX-105 | 5.04E+05 | AW-105 | 1.34E+05 | SX-105 | 5.31E+04 |
| U-102 | 4.96E+05 | C-105 | 1.23E+05 | SX-103 | 5.16E+04 |
| C-102 | 4.95E+05 | TX-105 | 1.21E+05 | B-109 | 5.10E+04 |
| BY-101 | 4.70E+05 | U-107 | 1.15E+05 | S-111 | 4.99E+04 |
| U-110 | 4.67E+05 | AN-105 | 1.08E+05 | S-110 | 4.95E+04 |
| BY-109 | 4.66E+05 | TX-117 | 1.06E+05 | S-104 | 4.85E+04 |
| TX-109 | 4.58E+05 | BY-106 | 1.03E+05 | SY-103 | 4.84E+04 |
| BX-104 | 4.50E+05 | TY-104 | 1.01E+05 | U-112 | 4.79E+04 |
| U-104 | 4.42E+05 | SY-101 | 9.61E+04 | S-109 | 4.77E+04 |
| BX-107 | 4.19E+05 | AZ-101 | 9.52E+04 | B-106 | 4.70E+04 |
| U-103 | 3.80E+05 | AN-103 | 9.34E+04 | C-106 | 4.68E+04 |
| U-105 | 3.80E+05 | AP-105 | 9.18E+04 | AY-101 | 4.63E+04 |
| C-104 | 3.68E+05 | C-101 | 9.04E+04 | SY-102 | 4.50E+04 |
| BY-111 | 3.65E+05 | TX-107 | 8.77E+04 | TX-112 | 4.49E+04 |
| C-107 | 3.37E+05 | AW-104 | 8.77E+04 | A-101 | 4.49E+04 |
| U-109 | 3.27E+05 | AN-102 | 8.52E+04 | SX-104 | 4.42E+04 |
| BX-101 | 3.20E+05 | BY-103 | 8.44E+04 | C-203 | 4.39E+04 |
| U-106 | 3.02E+05 | BY-110 | 8.22E+04 | B-102 | 4.37E+04 |
| S-107 | 3.02E+05 | B-101 | 7.96E+04 | SX-102 | 4.26E+04 |
| TY-101 | 2.62E+05 | TX-118 | 7.73E+04 | T-102 | 4.25E+04 |
| BX-102 | 2.57E+05 | BY-112 | 7.52E+04 | AX-101 | 4.13E+04 |
| BY-102 | 2.55E+05 | AW-106 | 7.46E+04 | BX-109 | 3.95E+04 |
| U-101 | 2.40E+05 | AZ-102 | 7.05E+04 | S-112 | 3.83E+04 |
| BY-105 | 2.39E+05 | BX-111 | 7.04E+04 | BX-106 | 3.83E+04 |
| C-110 | 2.37E+05 | AN-104 | 6.94E+04 | TX-101 | 3.77E+04 |
| TX-113 | 2.31E+05 | AW-102 | 6.85E+04 | C-108 | 3.70E+04 |
| T-107 | 2.17E+05 | B-108 | 6.74E+04 | T-108 | 3.67E+04 |
| TX-104 | 1.99E+05 | B-105 | 6.72E+04 | SX-106 | 3.58E+04 |
| AW-101 | 1.97E+05 | S-106 | 6.61E+04 | C-103 | 3.53E+04 |
| BX-110 | 1.93E+05 | TX-111 | 6.56E+04 | C-112 | 3.53E+04 |
| U-108 | 1.72E+05 | TX-110 | 6.30E+04 | BY-104 | 3.39E+04 |
| B-104 | 1.70E+05 | C-111 | 6.03E+04 | AP-106 | 3.36E+04 |
| T-101 | 1.64E+05 | S-101 | 6.00E+04 | TX-102 | 3.32E+04 |
| BX-112 | 1.64E+05 | BY-107 | 5.58E+04 | AP-102 | 3.31E+04 |
| TY-103 | 1.60E+05 | B-103 | 5.52E+04 | S-108 | 3.29E+04 |

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**Table 4-4. A ranking of the tanks based on their fissile nuclide content (cont'd)**

| Tank | Fissile Content (g) | Tank | Fissile Content (g) |
|---|---|---|---|
| SX-101 | 2.54E+04 | T-112 | 1.05E+03 |
| S-105 | 2.39E+04 | AN-106 | 8.93E+02 |
| C-204 | 2.21E+04 | SX-115 | 8.00E+02 |
| SX-109 | 2.14E+04 | A-104 | 5.79E+02 |
| AN-101 | 2.03E+04 | B-107 | 4.11E+02 |
| S-103 | 1.80E+04 | C-202 | 2.32E+02 |
| A-103 | 1.80E+04 | AX-103 | 1.49E+02 |
| SX-114 | 1.68E+04 | B-203 | 1.00E+02 |
| S-102 | 1.65E+04 | B-204 | 9.83E+01 |
| C-109 | 1.47E+04 | SX-113 | 7.63E+01 |
| TY-102 | 1.45E+04 | T-204 | 7.61E+01 |
| BY-108 | 1.28E+04 | T-203 | 7.04E+01 |
| T-110 | 1.13E+04 | B-201 | 5.62E+01 |
| C-201 | 1.11E+04 | T-201 | 5.62E+01 |
| AY-102 | 1.06E+04 | B-202 | 5.44E+01 |
| T-111 | 1.05E+04 | T-202 | 4.22E+01 |
| SX-111 | 9.68E+03 | TY-106 | 4.45E+00 |
| AX-102 | 8.70E+03 | AP-104 | 0.00E+00 |
| AP-101 | 8.22E+03 | AP-107 | 0.00E+00 |
| B-110 | 7.87E+03 | | |
| B-111 | 7.82E+03 | | |
| SX-107 | 6.42E+03 | | |
| SX-112 | 6.36E+03 | | |
| SX-110 | 6.04E+03 | | |
| TX-103 | 5.05E+03 | | |
| U-202 | 4.84E+03 | | |
| U-201 | 4.84E+03 | | |
| SX-108 | 4.41E+03 | | |
| A-102 | 4.25E+03 | | |
| AP-108 | 3.97E+03 | | |
| B-112 | 3.32E+03 | | |
| AP-103 | 3.21E+03 | | |
| A-105 | 3.02E+03 | | |
| U-203 | 2.47E+03 | | |
| U-204 | 2.42E+03 | | |
| TY-105 | 1.67E+03 | | |
| AX-104 | 1.11E+03 | | |

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## 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[7]
- 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 fissionable material concentration (Pu equivalent[8]), 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 $\mu$Ci/L or $\mu$g/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.

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[7] 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).

[8] 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 fissionable 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).

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 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, 1994b). Source wastes will be categorized according to U.S. EPA compatibility matrix (U.S. Environmental Protection Agency, 1994) 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 ($10 \times 10^6$ 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, as noted in Section 2.6.4.

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 8 in Section 4.3.1.

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# APPENDIX A

# HANFORD DEFINED WASTE MODEL TANK INVENTORIES

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g.**

| Tank | Type | Total waste (kgal) | $Na^{+}$ | $Al^{3+}$ | $Fe^{3+}$ | $Cr^{3+}$ | $Bi^{3+}$ | $La^{3+}$ | $Hg^{2+}$ | $ZrO(OH)_2$ | $Pb^{2+}$ | $Ni^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-101 | SS | 953 | 9.44 | 1.34 | 1.33E-02 | 4.00E-02 | 9.84E-04 | 1.90E-05 | 7.85E-06 | 5.36E-04 | 1.06E-03 | 4.49E-03 |
| A-102 | SS | 41 | 4.82 | 0.622 | 0.112 | 1.81E-02 | 4.53E-04 | 8.14E-06 | 3.68E-06 | 2.38E-04 | 5.06E-04 | 1.85E-03 |
| A-103 | SS | 371 | 10 | 1.42 | 1.57E-02 | 4.14E-02 | 1.03E-03 | 1.86E-05 | 8.41E-06 | 5.44E-04 | 1.16E-03 | 5.37E-03 |
| A-104 | SS | 28 | 5.47 | 6.86E-02 | 1.35 | 1.39E-02 | 9.30E-06 | 0 | 2.92E-07 | 3.31E-07 | 4.77E-05 | 0.138 |
| A-105 | SS | 19 | 4.03 | 0 | 2.96 | 6.51E-03 | 0 | 0 | 0 | 0 | 0 | 5.82E-02 |
| A-106 | SS | 125 | 9.62 | 1.02 | 0.571 | 3.55E-02 | 7.67E-04 | 1.83E-05 | 5.78E-06 | 4.64E-04 | 7.25E-04 | 2.69E-02 |
| AN-101 | DS | 740 | 4.4 | 0.64 | 2.74E-03 | 2.45E-02 | 5.71E-04 | 2.99E-06 | 3.63E-06 | 4.43E-04 | 3.67E-04 | 2.34E-03 |
| AN-102 | DS | 1090 | 15 | 2.07 | 8.45E-03 | 6.61E-02 | 1.46E-03 | 2.44E-05 | 1.14E-05 | 8.01E-04 | 1.53E-03 | 7.09E-03 |
| AN-103 | DS | 953 | 12.6 | 1.66 | 1.50E-02 | 5.15E-02 | 1.16E-03 | 1.34E-05 | 1.38E-05 | 2.22E-03 | 1.15E-03 | 1.06E-02 |
| AN-104 | DS | 1060 | 9.76 | 1.31 | 7.07E-03 | 4.05E-02 | 9.56E-04 | 1.29E-05 | 9.15E-06 | 1.16E-03 | 9.44E-04 | 5.69E-03 |
| AN-105 | DS | 1130 | 18.1 | 2.45 | 1.23E-02 | 7.22E-02 | 1.91E-03 | 2.08E-05 | 1.39E-05 | 1.23E-03 | 1.73E-03 | 1.06E-02 |
| AN-106 | DS | 21 | 8.41 | 1.1 | 6.33E-03 | 4.18E-02 | 8.41E-04 | 1.86E-05 | 6.28E-06 | 5.23E-04 | 7.78E-04 | 5.43E-03 |
| AN-107 | DS | 1060 | 11.4 | 1.68 | 5.71E-03 | 4.30E-02 | 1.22E-03 | 1.22E-05 | 1.02E-05 | 5.85E-04 | 1.47E-03 | 4.69E-03 |
| AP-101 | DS | 1060 | 0.755 | 8.14E-02 | 2.64E-03 | 2.67E-03 | 3.86E-05 | 1.11E-06 | 9.62E-07 | 2.22E-04 | 4.32E-05 | 5.52E-04 |
| AP-102 | DS | 1100 | 5.96 | 0.776 | 4.57E-03 | 2.99E-02 | 5.93E-04 | 1.31E-05 | 4.43E-06 | 3.69E-04 | 5.49E-04 | 3.92E-03 |
| AP-103 | DS | 1130 | 1.55 | 0.204 | 1.41E-03 | 2.68E-03 | 8.85E-06 | 1.95E-07 | 2.04E-07 | 4.61E-05 | 9.89E-06 | 1.13E-03 |
| AP-104 | DS | 18 | 0.55 | 0 | 1.73E-03 | 6.93E-03 | 0 | 0 | 0 | 0 | 0 | 1.56E-03 |
| AP-105 | DS | 820 | 9.47 | 1.08 | 1.23E-02 | 3.71E-02 | 5.07E-04 | 1.36E-05 | 1.36E-05 | 3.21E-03 | 5.78E-04 | 7.73E-03 |
| AP-106 | DS | 1130 | 3.31 | 0.4 | 3.90E-03 | 1.05E-02 | 1.33E-04 | 3.41E-06 | 3.53E-06 | 8.31E-04 | 1.52E-04 | 2.57E-03 |
| AP-107 | DS | 1110 | 6.03E-02 | 0 | 2.01E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AP-108 | DS | 1130 | 1.53 | 0.219 | 1.39E-03 | 1.45E-03 | 1.57E-06 | 3.36E-08 | 2.81E-08 | 5.72E-06 | 5.25E-06 | 1.04E-03 |
| AW-101 | DS | 1140 | 13.9 | 1.67 | 0.115 | 5.95E-02 | 1.09E-03 | 1.55E-05 | 1.85E-05 | 3.62E-03 | 1.20E-03 | 1.61E-02 |
| AW-102 | DS | 979 | 5.65 | 0.638 | 7.30E-03 | 2.34E-02 | 3.49E-04 | 8.46E-06 | 7.99E-06 | 1.88E-03 | 3.47E-04 | 4.69E-03 |
| AW-103 | DS | 646 | 3.27 | 6.66E-04 | 0.205 | 1.44E-04 | 4.35E-07 | 3.69E-09 | 1.18E-03 | 0.522 | 1.20E-06 | 3.13E-05 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | Type | Total waste (kgal) | $Na^{+}$ | $Al^{3+}$ | $Fe^{3+}$ | $Cr^{3+}$ | $Bi^{3+}$ | $La^{3+}$ | $Hg^{2+}$ | $ZrO(OH)_2$ | $Pb^{2+}$ | $Ni^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AW-104 | DS | 1120 | 0.613 | 6.90E-04 | 0.169 | 7.31E-03 | 4.75E-07 | 6.93E-09 | 9.34E-06 | 4.13E-03 | 4.01E-05 | 1.13E-02 |
| AW-105 | DS | 1040 | 3.7 | 0.271 | 0.124 | 1.03E-02 | 1.37E-04 | 2.54E-06 | 4.40E-04 | 0.193 | 1.61E-04 | 4.73E-03 |
| AW-106 | DS | 1110 | 5.83 | 0.683 | 9.34E-03 | 2.30E-02 | 3.10E-04 | 8.04E-06 | 7.74E-06 | 1.80E-03 | 3.45E-04 | 5.78E-03 |
| AX-101 | SS | 748 | 10.3 | 1.46 | 5.09E-02 | 4.26E-02 | 1.06E-03 | 1.93E-05 | 8.63E-06 | 5.61E-04 | 1.18E-03 | 5.15E-03 |
| AX-102 | SS | 39 | 9.94 | 1.49 | 0.208 | 4.31E-02 | 1.00E-03 | 2.25E-05 | 7.66E-06 | 5.89E-04 | 9.84E-04 | 1.26E-02 |
| AX-103 | SS | 112 | 8.86 | 1.2 | 0.374 | 3.53E-02 | 8.61E-04 | 1.66E-05 | 6.87E-06 | 4.67E-04 | 9.28E-04 | 1.09E-02 |
| AX-104 | SS | 6.99 | 4.03 | 0 | 2.96 | 6.51E-03 | 0 | 0 | 0 | 0 | 0 | 5.82E-02 |
| AY-101 | DS | 881 | 3.57 | 0.396 | 4.55E-02 | 1.56E-02 | 1.81E-04 | 3.56E-06 | 1.52E-06 | 1.03E-04 | 2.02E-04 | 1.12E-02 |
| AY-102 | DS | 711 | 1.58 | 0.433 | 9.84E-02 | 1.01E-03 | 7.18E-07 | 1.54E-08 | 1.29E-08 | 2.62E-06 | 9.98E-07 | 4.89E-02 |
| AZ-101 | DS | 960 | 2.53 | 0.317 | 8.92E-02 | 1.97E-03 | 4.60E-05 | 9.37E-07 | 3.55E-07 | 2.63E-05 | 4.69E-05 | 1.61E-03 |
| AZ-102 | DS | 963 | 1.45 | 0.165 | 8.90E-02 | 2.40E-04 | 2.05E-06 | 2.38E-08 | 1.69E-08 | 1.13E-06 | 2.98E-06 | 5.35E-04 |
| B-101 | SS | 113 | 8.35 | 1.3 | 0.592 | 4.56E-03 | 3.46E-02 | 0 | 3.84E-05 | 2.95E-03 | 3.74E-08 | 0.222 |
| B-102 | SS | 32 | 7.58 | 0.377 | 0.179 | 5.22E-03 | 3.46E-02 | 7.26E-08 | 2.23E-04 | 2.98E-03 | 1.02E-02 | 6.26E-03 |
| B-103 | SS | 59 | 8.96 | 0.211 | 0.201 | 5.68E-03 | 4.37E-02 | 0 | 4.84E-05 | 3.72E-03 | 0 | 7.70E-03 |
| B-104 | SS | 371 | 4.72 | 0.322 | 0.377 | 4.18E-03 | 6.62E-02 | 0 | 2.74E-05 | 2.97E-03 | 0 | 2.42E-03 |
| B-105 | SS | 158 | 8.24 | 0.249 | 0.239 | 5.53E-03 | 5.06E-02 | 0 | 4.64E-05 | 3.76E-03 | 0 | 6.88E-03 |
| B-106 | SS | 117 | 9.11 | 0.224 | 0.203 | 5.93E-03 | 4.57E-02 | 5.33E-06 | 5.06E-05 | 3.89E-03 | 4.08E-06 | 8.03E-03 |
| B-107 | SS | 165 | 4.85 | 0.473 | 0.321 | 3.75E-03 | 7.65E-02 | 0 | 1.05E-04 | 1.02E-02 | 1.94E-06 | 1.16E-03 |
| B-108 | SS | 94 | 7.62 | 0.314 | 0.248 | 5.14E-03 | 5.72E-02 | 0 | 7.08E-05 | 6.23E-03 | 0 | 5.58E-03 |
| B-109 | SS | 127 | 8.64 | 1.19 | 0.183 | 1.25E-02 | 3.08E-02 | 1.15E-06 | 6.42E-04 | 2.70E-03 | 3.38E-02 | 5.96E-03 |
| B-110 | SS | 246 | 2.96 | 0 | 0.681 | 4.07E-03 | 7.03E-02 | 0 | 0 | 0 | 0 | 2.05E-03 |
| B-111 | SS | 237 | 1.54 | 6.84E-03 | 1.03 | 8.75E-03 | 3.62E-02 | 1.77E-08 | 4.28E-08 | 1.63E-06 | 6.85E-06 | 9.41E-03 |
| B-112 | SS | 33 | 7.14 | 1.15 | 0.341 | 2.88E-02 | 1.79E-02 | 1.85E-06 | 1.83E-05 | 1.70E-04 | 2.86E-03 | 7.31E-03 |
| B-201 | SS | 29 | 4.36 | 0 | 0.349 | 3.32E-03 | 5.83E-02 | 0.229 | 0 | 0 | 0 | 1.30E-03 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | Type | Total waste (kgal) | $Na^{+}$ | $Al^{3+}$ | $Fe^{3+}$ | $Cr^{3+}$ | $Bi^{3+}$ | $La^{3+}$ | $Hg^{2+}$ | $ZrO(OH)_2$ | $Pb^{2+}$ | $Ni^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B-202 | SS | 27 | 4.52 | 0 | 0.361 | 3.44E-03 | 6.04E-02 | 0.237 | 0 | 0 | 0 | 1.34E-03 |
| B-203 | SS | 51 | 4.43 | 0 | 0.354 | 3.37E-03 | 5.92E-02 | 0.232 | 0 | 0 | 0 | 1.32E-03 |
| B-204 | SS | 50 | 4.43 | 0 | 0.354 | 3.51E-03 | 5.92E-02 | 0.232 | 0 | 0 | 0 | 1.35E-03 |
| BX-101 | SS | 43 | 5.58 | 1.86 | 0.747 | 1.36E-03 | 2.02E-05 | 7.24E-08 | 1.75E-07 | 6.65E-06 | 2.80E-05 | 0.365 |
| BX-102 | SS | 96 | 8.83 | 0.362 | 0.116 | 4.19E-04 | 0 | 0 | 3.08E-04 | 0 | 1.70E-02 | 2.09E-04 |
| BX-103 | SS | 66 | 4.59 | 0.76 | 0.153 | 2.59E-03 | 3.17E-05 | 1.10E-07 | 7.17E-04 | 1.10E-05 | 3.95E-02 | 7.44E-04 |
| BX-104 | SS | 99 | 7.26 | 0.671 | 5.26E-02 | 2.57E-02 | 5.46E-04 | 1.68E-05 | 3.74E-06 | 3.76E-04 | 4.13E-04 | 3.11E-03 |
| BX-105 | SS | 51 | 5.4 | 0.116 | 0.108 | 5.08E-03 | 9.03E-05 | 2.31E-06 | 6.64E-07 | 5.66E-05 | 8.09E-05 | 9.90E-04 |
| BX-106 | SS | 46 | 9.47 | 1.58 | 1.80E-02 | 3.65E-02 | 7.37E-04 | 2.66E-06 | 2.39E-05 | 2.44E-04 | 3.74E-03 | 8.70E-03 |
| BX-107 | SS | 345 | 4.37 | 0.621 | 0.267 | 4.04E-03 | 6.43E-02 | 4.75E-12 | 8.72E-05 | 9.02E-03 | 3.60E-07 | 1.23E-03 |
| BX-108 | SS | 26 | 4.22 | 0.668 | 0.251 | 4.05E-03 | 6.06E-02 | 0 | 8.18E-05 | 8.66E-03 | 0 | 1.25E-03 |
| BX-109 | SS | 193 | 3.57 | 0.152 | 1.33 | 3.18E-03 | 7.78E-03 | 0 | 1.02E-05 | 1.24E-03 | 0 | 1.44E-03 |
| BX-110 | SS | 198 | 5.82 | 1.02 | 0.187 | 1.40E-02 | 4.46E-02 | 6.85E-07 | 6.73E-05 | 6.55E-03 | 1.20E-03 | 3.86E-03 |
| BX-111 | SS | 211 | 11.1 | 1.95 | 4.07E-02 | 4.36E-02 | 7.46E-03 | 2.74E-06 | 3.95E-05 | 1.32E-03 | 4.81E-03 | 1.17E-02 |
| BX-112 | SS | 165 | 4.67 | 0.74 | 0.183 | 4.78E-03 | 4.43E-02 | 2.38E-08 | 5.63E-05 | 6.37E-03 | 7.82E-06 | 2.65E-03 |
| BY-101 | SS | 387 | 11.7 | 1.94 | 2.59E-02 | 4.59E-02 | 8.13E-04 | 2.92E-06 | 3.28E-05 | 2.68E-04 | 5.13E-03 | 1.23E-02 |
| BY-102 | SS | 341 | 11.8 | 2 | 2.10E-02 | 4.72E-02 | 8.47E-04 | 3.05E-06 | 3.34E-05 | 2.80E-04 | 5.22E-03 | 1.24E-02 |
| BY-103 | SS | 400 | 12.2 | 2.23 | 2.60E-02 | 4.96E-02 | 8.79E-04 | 3.15E-06 | 1.68E-04 | 2.90E-04 | 1.29E-02 | 1.32E-02 |
| BY-104 | SS | 326 | 8.45 | 1.16 | 0.448 | 2.87E-02 | 0.132 | 1.74E-06 | 1.96E-05 | 1.60E-04 | 3.06E-03 | 6.70E-02 |
| BY-105 | SS | 503 | 9.55 | 1.47 | 0.293 | 3.48E-02 | 8.11E-02 | 2.16E-06 | 2.43E-05 | 1.99E-04 | 3.80E-03 | 4.57E-02 |
| BY-106 | SS | 642 | 11.1 | 1.82 | 0.154 | 4.34E-02 | 4.11E-02 | 2.73E-06 | 3.07E-05 | 2.51E-04 | 4.80E-03 | 3.18E-02 |
| BY-107 | SS | 266 | 8.61 | 1.28 | 0.396 | 2.98E-02 | 7.66E-02 | 1.81E-06 | 2.55E-05 | 7.99E-04 | 3.18E-03 | 4.45E-02 |
| BY-108 | SS | 228 | 6.28 | 0.593 | 0.66 | 1.62E-02 | 0.185 | 8.92E-07 | 1.00E-05 | 8.20E-05 | 1.57E-03 | 0.102 |
| BY-109 | SS | 423 | 11.8 | 1.96 | 2.48E-02 | 4.65E-02 | 8.23E-04 | 2.95E-06 | 3.32E-05 | 2.71E-04 | 5.19E-03 | 1.24E-02 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in μg/g, and Sr-90, Cs-137, and Pu-239 in μCi/g (cont'd).**

| Tank | Type | Total waste (kgal) | $Na^{+}$ | $Al^{3+}$ | $Fe^{3+}$ | $Cr^{3+}$ | $Bi^{3+}$ | $La^{3+}$ | $Hg^{2+}$ | $ZrO(OH)_2$ | $Pb^{2+}$ | $Ni^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BY-110 | SS | 398 | 8.32 | 1.2 | 0.375 | 2.80E-02 | 0.104 | 1.69E-06 | 2.43E-05 | 8.07E-04 | 2.96E-03 | 5.90E-02 |
| BY-111 | SS | 459 | 12 | 2.02 | 2.19E-02 | 4.79E-02 | 8.49E-04 | 3.04E-06 | 3.42E-05 | 2.80E-04 | 5.35E-03 | 1.28E-02 |
| BY-112 | SS | 291 | 12.2 | 2.09 | 3.61E-02 | 4.94E-02 | 6.76E-03 | 3.14E-06 | 3.52E-05 | 2.89E-04 | 5.51E-03 | 1.58E-02 |
| C-101 | SS | 88 | 2.41 | 3.42 | 0.727 | 2.58E-03 | 0 | 0 | 2.54E-03 | 0 | 0.133 | 1.29E-03 |
| C-102 | SS | 423 | 1.68 | 5.02 | 0.501 | 2.69E-03 | 0 | 0 | 4.87E-03 | 2.85E-02 | 0.263 | 3.56E-03 |
| C-103 | SS | 195 | 3.04 | 1.2 | 0.199 | 7.31E-03 | 1.26E-04 | 4.99E-07 | 4.81E-04 | 4.43E-05 | 2.26E-02 | 1.85E-02 |
| C-104 | SS | 295 | 2.43 | 3.45 | 1.13 | 3.68E-03 | 1.15E-05 | 2.52E-07 | 2.97E-03 | 8.48E-02 | 0.132 | 4.67E-02 |
| C-105 | SS | 150 | 2.14 | 4.64 | 0.306 | 2.61E-03 | 0 | 0 | 2.27E-03 | 0 | 0.106 | 1.30E-03 |
| C-106 | SS | 229 | 4.47 | 2.18 | 1.17 | 6.52E-03 | 4.04E-06 | 9.73E-19 | 3.75E-04 | 1.44E-07 | 1.75E-02 | 0.333 |
| C-107 | SS | 275 | 4.5 | 1.17 | 0.427 | 3.30E-03 | 6.10E-02 | 0.00E+0 | 8.79E-04 | 8.16E-03 | 4.38E-02 | 1.08E-03 |
| C-108 | SS | 66 | 4.12 | 0.239 | 0.803 | 2.77E-03 | 3.38E-02 | 0 | 4.64E-05 | 4.53E-03 | 0 | 0.12 |
| C-109 | SS | 66 | 3.28 | 0.184 | 0.894 | 1.27E-03 | 1.17E-02 | 0 | 1.60E-05 | 1.56E-03 | 1.61E-02 | 0.464 |
| C-110 | SS | 187 | 4.88 | 0.475 | 0.323 | 3.77E-03 | 7.70E-02 | 0 | 1.06E-04 | 1.03E-02 | 0 | 1.16E-03 |
| C-111 | SS | 57 | 3.94 | 1.76 | 0.282 | 3.10E-03 | 4.86E-02 | 0 | 7.76E-04 | 6.51E-03 | 3.30E-02 | 5.82E-02 |
| C-112 | SS | 104 | 3.38 | 0.996 | 0.382 | 9.96E-04 | 1.11E-02 | 0 | 5.02E-04 | 1.49E-03 | 2.56E-02 | 0.453 |
| C-201 | SS | 2 | 3.43 | 0 | 2.89 | 3.92E-03 | 0 | 0 | 0 | 0 | 7.58E-02 | 9.29E-02 |
| C-202 | SS | 1 | 1.83 | 0 | 5.67 | 6.59E-03 | 0 | 0 | 0 | 0 | 0.152 | 0.185 |
| C-203 | SS | 5 | 4.4 | 0 | 1.23 | 2.31E-03 | 0 | 0 | 0 | 0 | 3.03E-02 | 3.75E-02 |
| C-204 | SS | 3 | 3.97 | 0 | 1.97 | 3.02E-03 | 0 | 0 | 0 | 0 | 5.05E-02 | 6.21E-02 |
| S-101 | SS | 427 | 7.81 | 2.61 | 0.236 | 0.262 | 5.12E-04 | 1.40E-05 | 2.81E-04 | 3.53E-04 | 8.44E-03 | 1.69E-02 |
| S-102 | SS | 549 | 8.58 | 1.19 | 1.29E-02 | 4.98E-02 | 9.63E-04 | 2.98E-05 | 6.50E-06 | 6.67E-04 | 7.07E-04 | 5.12E-03 |
| S-103 | SS | 248 | 12.2 | 1.78 | 4.47E-02 | 9.24E-02 | 1.44E-03 | 4.73E-05 | 9.50E-06 | 9.96E-04 | 1.02E-03 | 8.62E-03 |
| S-104 | SS | 294 | 6.37 | 3.19 | 0.395 | 0.446 | 4.15E-06 | 1.61E-11 | 3.34E-04 | 2.01E-06 | 9.71E-03 | 2.70E-02 |
| S-105 | SS | 407 | 9.49 | 1.5 | 1.11E-02 | 6.82E-02 | 6.98E-04 | 1.42E-09 | 5.65E-06 | | | |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | Type | Total waste (kgal) | $Na^{+}$ | $Al^{3+}$ | $Fe^{3+}$ | $Cr^{3+}$ | $Bi^{3+}$ | $La^{3+}$ | $Hg^{2+}$ | $ZrO(OH)_2$ | $Pb^{2+}$ | $Ni^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S-106 | SS | 479 | 10.5 | 2.33 | 1.71E-02 | 6.32E-02 | 5.79E-04 | 2.62E-08 | 2.78E-04 | 3.98E-04 | 8.47E-03 | 7.86E-03 |
| S-107 | SS | 376 | 5.56 | 4.67 | 0.346 | 0.234 | 2.54E-04 | 8.03E-06 | 2.29E-03 | 4.45E-02 | 6.44E-02 | 1.47E-02 |
| S-108 | SS | 502 | 10.7 | 1.68 | 1.69E-02 | 7.94E-02 | 7.51E-04 | 1.77E-09 | 6.14E-06 | 5.23E-04 | 7.19E-04 | 6.54E-03 |
| S-109 | SS | 507 | 10.6 | 1.87 | 1.09E-02 | 6.82E-02 | 7.18E-04 | 1.50E-08 | 1.11E-04 | 4.98E-04 | 3.72E-03 | 5.92E-03 |
| S-110 | SS | 390 | 8.52 | 2.74 | 0.246 | 0.242 | 5.59E-04 | 5.80E-06 | 2.56E-04 | 3.76E-04 | 7.82E-03 | 1.57E-02 |
| S-111 | SS | 538 | 11.2 | 2.39 | 0.135 | 0.171 | 7.44E-04 | 1.21E-05 | 9.71E-05 | 5.06E-04 | 3.35E-03 | 1.20E-02 |
| S-112 | SS | 523 | 10.9 | 1.75 | 1.37E-02 | 7.68E-02 | 7.63E-04 | 1.86E-07 | 2.96E-05 | 5.31E-04 | 1.41E-03 | 6.43E-03 |
| SX-101 | SS | 456 | 5.46 | 2.09 | 0.349 | 0.381 | 1.80E-04 | 5.12E-06 | 1.62E-06 | 1.24E-04 | 1.97E-04 | 2.32E-02 |
| SX-102 | SS | 543 | 13.2 | 2.17 | 0.118 | 0.159 | 1.47E-03 | 5.30E-05 | 1.01E-05 | 1.00E-03 | 1.12E-03 | 1.26E-02 |
| SX-103 | SS | 652 | 12.3 | 1.69 | 2.54E-02 | 0.101 | 1.37E-03 | 6.62E-05 | 8.93E-06 | 9.43E-04 | 9.58E-04 | 9.24E-03 |
| SX-104 | SS | 614 | 10.6 | 2.08 | 0.171 | 0.214 | 9.79E-04 | 2.85E-05 | 7.05E-06 | 6.74E-04 | 7.96E-04 | 1.50E-02 |
| SX-105 | SS | 683 | 12.7 | 1.87 | 6.63E-02 | 0.149 | 1.25E-03 | 4.59E-05 | 9.04E-06 | 8.55E-04 | 1.03E-03 | 1.01E-02 |
| SX-106 | SS | 538 | 11.4 | 1.52 | 7.42E-03 | 5.70E-02 | 1.36E-03 | 4.47E-05 | 8.90E-06 | 9.37E-04 | 9.56E-04 | 6.37E-03 |
| SX-107 | SS | 104 | 3.62 | 3.83 | 1.24 | 1.58 | 1.23E-06 | 4.78E-12 | 1.94E-07 | 5.99E-07 | 3.07E-05 | 6.03E-02 |
| SX-108 | SS | 87 | 2.54 | 4.27 | 1.36 | 1.6 | 0 | 0 | 0 | 0 | 0 | 6.45E-02 |
| SX-109 | SS | 250 | 7.35 | 2.07 | 0.363 | 0.608 | 5.74E-06 | 2.22E-11 | 9.01E-07 | 2.78E-06 | 1.43E-04 | 2.79E-02 |
| SX-110 | SS | 62 | 5.93 | 3.12 | 1.39 | 2.38 | 3.65E-06 | 1.41E-11 | 5.74E-07 | 1.77E-06 | 9.10E-05 | 6.80E-02 |
| SX-111 | SS | 125 | 4.82 | 3.42 | 1.23 | 1.81 | 2.54E-06 | 9.82E-12 | 3.98E-07 | 1.23E-06 | 6.32E-05 | 6.07E-02 |
| SX-112 | SS | 92 | 4.21 | 3.62 | 1.22 | 1.67 | 1.89E-06 | 7.31E-12 | 2.96E-07 | 9.16E-07 | 4.70E-05 | 6.00E-02 |
| SX-113 | SS | 31 | 10.1 | 0.342 | 0.149 | 5.63E-02 | 0 | 0 | 0 | 0 | 0 | 3.26E-03 |
| SX-114 | SS | 181 | 7.3 | 2.23 | 0.623 | 1.12 | 5.55E-06 | 2.15E-11 | 8.71E-07 | 2.69E-06 | 1.38E-04 | 3.82E-02 |
| SX-115 | SS | 12 | 5.61 | 2.75 | 0.515 | 0.551 | 3.77E-06 | 1.46E-11 | 5.93E-07 | 1.83E-06 | 9.40E-05 | 3.29E-02 |
| SY-101 | DS | 1100 | 15 | 1.97 | 9.80E-03 | 7.30E-02 | 1.74E-03 | 6.09E-05 | 1.17E-05 | 1.20E-03 | 1.27E-03 | 8.33E-03 |
| SY-102 | DS | 747 | 1.62 | 0.54 | 8.40E-02 | 1.32E-02 | 3.14E-04 | 1.42E-06 | 1.32E-06 | 2.13E-04 | 1.19E-04 | 7.11E-03 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | Type | Total waste (kgal) | $Na^{+}$ | $Al^{3+}$ | $Fe^{3+}$ | $Cr^{3+}$ | $Bi^{3+}$ | $La^{3+}$ | $Hg^{2+}$ | $ZrO(OH)_2$ | $Pb^{2+}$ | $Ni^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SY-103 | DS | 744 | 11.4 | 1.55 | 7.19E-03 | 5.52E-02 | 1.30E-03 | 3.84E-05 | 8.98E-06 | 8.63E-04 | 1.02E-03 | 6.11E-03 |
| T-101 | SS | 102 | 2.69 | 2.25 | 0.161 | 9.72E-03 | 4.86E-04 | 1.80E-04 | 3.78E-03 | 2.47E-04 | 0.112 | 1.61E-03 |
| T-102 | SS | 32 | 0.964 | 3.11 | 0.25 | 1.32E-03 | 0 | 0 | 3.14E-03 | 0 | 0.173 | 6.59E-04 |
| T-103 | SS | 27 | 1.08 | 3.71 | 0.292 | 2.17E-03 | 2.45E-06 | 4.52E-11 | 3.72E-03 | 1.41E-06 | 0.205 | 8.14E-04 |
| T-104 | SS | 445 | 4.12 | 0.699 | 0.238 | 4.24E-03 | 5.76E-02 | 2.81E-08 | 7.75E-05 | 8.35E-03 | 2.50E-06 | 1.27E-03 |
| T-105 | SS | 98 | 4.01 | 0.229 | 0.459 | 3.57E-03 | 7.95E-02 | 0 | 1.54E-05 | 1.86E-03 | 0 | 1.27E-03 |
| T-106 | SS | 21 | 4.44 | 4.7 | 0.184 | 2.97E-03 | 2.10E-02 | 0 | 2.44E-03 | 3.34E-03 | 7.02E-02 | 1.09E-03 |
| T-107 | SS | 180 | 4.63 | 0.452 | 0.307 | 3.58E-03 | 7.31E-02 | 0 | 1.00E-04 | 9.78E-03 | 0 | 1.10E-03 |
| T-108 | SS | 44 | 7.18 | 0.316 | 0.27 | 4.55E-03 | 6.05E-02 | 0 | 7.08E-05 | 6.66E-03 | 0 | 6.52E-03 |
| T-109 | SS | 58 | 9.29 | 0.17 | 0.222 | 5.26E-03 | 4.55E-02 | 0 | 3.90E-05 | 3.34E-03 | 0 | 1.14E-02 |
| T-110 | SS | 379 | 3.02 | 0 | 0.636 | 3.98E-03 | 7.12E-02 | 6.24E-03 | 0 | 0 | 0 | 1.35E-02 |
| T-111 | SS | 458 | 2.36 | 0 | 0.68 | 4.41E-03 | 5.79E-02 | 1.86E-02 | 0 | 0 | 0 | 1.42E-03 |
| T-112 | SS | 67 | 1.07 | 0 | 0.703 | 4.58E-03 | 3.68E-02 | 0 | 0 | 0 | 0 | 1.35E-03 |
| T-201 | SS | 29 | 4.36 | 0 | 0.349 | 3.32E-03 | 5.83E-02 | 0.229 | 0 | 0 | 0 | 1.30E-03 |
| T-202 | SS | 21 | 4.52 | 0 | 0.361 | 3.44E-03 | 6.04E-02 | 0.237 | 0 | 0 | 0 | 1.34E-03 |
| T-203 | SS | 35 | 4.52 | 0 | 0.361 | 3.44E-03 | 6.04E-02 | 0.237 | 0 | 0 | 0 | 1.34E-03 |
| T-204 | SS | 38 | 4.52 | 0 | 0.361 | 3.44E-03 | 6.04E-02 | 0.237 | 0 | 0 | 0 | 1.34E-03 |
| TX-101 | SS | 87 | 3.02 | 3.83 | 0.878 | 0.708 | 9.11E-05 | 2.30E-06 | 6.30E-07 | 6.33E-05 | 6.92E-05 | 4.46E-02 |
| TX-102 | SS | 217 | 8.79 | 1.01 | 7.23E-03 | 3.46E-02 | 1.73E-03 | 1.33E-09 | 9.48E-06 | 1.28E-03 | 8.52E-04 | 5.12E-03 |
| TX-103 | SS | 157 | 5.24 | 0.612 | 7.79E-03 | 2.11E-02 | 1.92E-03 | 6.09E-05 | 6.14E-06 | 7.88E-04 | 4.88E-04 | 3.26E-03 |
| TX-104 | SS | 65 | 7.7 | 0.731 | 3.72E-02 | 2.47E-02 | 1.16E-03 | 8.91E-10 | 6.39E-06 | 8.63E-04 | 5.76E-04 | 3.82E-03 |
| TX-105 | SS | 609 | 9.24 | 1.14 | 8.06E-03 | 3.88E-02 | 1.96E-03 | 1.54E-09 | 1.08E-05 | 1.45E-03 | 9.80E-04 | 5.67E-03 |
| TX-106 | SS | 341 | 8.73 | 1.09 | 1.83E-02 | 4.52E-02 | 1.72E-03 | 1.31E-09 | 9.42E-06 | 1.27E-03 | 8.49E-04 | 5.79E-03 |
| TX-107 | SS | 36 | 2.4 | 0.149 | 2.73E-02 | 5.25E-03 | 2.37E-04 | 1.81E-10 | 1.30E-06 | 1.76E-04 | 1.18E-04 | 8.83E-04 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | Type | Total waste (kgal) | $Na^{+}$ | $Al^{3+}$ | $Fe^{3+}$ | $Cr^{3+}$ | $Bi^{3+}$ | $La^{3+}$ | $Hg^{2+}$ | $ZrO(OH)_2$ | $Pb^{2+}$ | $Ni^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TX-108 | SS | 134 | 6.63 | 0.791 | 5.33E-02 | 2.69E-02 | 1.35E-03 | 1.03E-09 | 7.38E-06 | 1.00E-03 | 6.62E-04 | 4.00E-03 |
| TX-109 | SS | 384 | 4.11 | 0.7 | 0.239 | 4.10E-03 | 5.79E-02 | 0 | 7.80E-05 | 8.39E-03 | 0 | 7.86E-03 |
| TX-110 | SS | 462 | 8.54 | 1.05 | 2.29E-02 | 3.35E-02 | 5.82E-03 | 1.26E-09 | 1.46E-05 | 1.84E-03 | 8.13E-04 | 5.03E-03 |
| TX-111 | SS | 370 | 8.33 | 1.04 | 2.63E-02 | 3.21E-02 | 6.69E-03 | 1.19E-09 | 1.53E-05 | 1.97E-03 | 7.69E-04 | 4.86E-03 |
| TX-112 | SS | 649 | 9.12 | 1.12 | 1.46E-02 | 3.79E-02 | 3.67E-03 | 1.51E-09 | 1.27E-05 | 1.59E-03 | 1.05E-03 | 5.98E-03 |
| TX-113 | SS | 607 | 7.16 | 1.07 | 5.87E-02 | 2.74E-02 | 1.47E-02 | 9.88E-10 | 2.63E-05 | 3.18E-03 | 8.54E-04 | 4.56E-03 |
| TX-114 | SS | 535 | 9.34 | 1.09 | 3.16E-02 | 3.59E-02 | 7.21E-03 | 1.35E-09 | 1.59E-05 | 1.87E-03 | 1.05E-03 | 6.66E-03 |
| TX-115 | SS | 568 | 9.16 | 1.17 | 2.90E-02 | 3.85E-02 | 2.04E-03 | 1.48E-09 | 1.20E-05 | 1.53E-03 | 1.13E-03 | 5.95E-03 |
| TX-116 | SS | 563 | 8.91 | 0.416 | 0.14 | 1.21E-02 | 2.69E-02 | 6.05E-10 | 2.66E-05 | 2.51E-03 | 3.71E-04 | 8.31E-03 |
| TX-117 | SS | 532 | 8.65 | 0.717 | 9.15E-02 | 2.10E-02 | 1.82E-02 | 1.08E-09 | 2.30E-05 | 2.29E-03 | 8.25E-04 | 7.95E-03 |
| TX-118 | SS | 285 | 4.84 | 2.07 | 0.238 | 2.08E-02 | 1.67E-03 | 1.43E-05 | 4.87E-06 | 5.68E-04 | 3.92E-04 | 1.61E-02 |
| TY-101 | SS | 118 | 5.01 | 0.33 | 0.151 | 3.18E-03 | 0.147 | 0 | 1.52E-05 | 1.58E-02 | 0 | 0.121 |
| TY-102 | SS | 64 | 8.62 | 0.618 | 0.104 | 2.06E-02 | 2.15E-02 | 6.91E-10 | 2.26E-05 | 2.19E-03 | 4.46E-04 | 7.86E-03 |
| TY-103 | SS | 162 | 4.24 | 0.404 | 0.625 | 1.12E-02 | 6.21E-02 | 3.85E-10 | 2.78E-06 | 7.30E-03 | 2.46E-04 | 5.74E-02 |
| TY-104 | SS | 46 | 3.34 | 0 | 1.47 | 2.74E-03 | 0 | 0 | 0 | 0 | 0 | 1.37E-03 |
| TY-105 | SS | 231 | 4.09 | 0 | 1.08 | 3.36E-03 | 0 | 0 | 0 | 0 | 0 | 1.68E-03 |
| TY-106 | SS | 21 | 10.3 | 7.62E-02 | 0.16 | 1.39E-04 | 0 | 0 | 0 | 0 | 0 | 6.94E-05 |
| U-101 | SS | 25 | 4.43 | 0 | 0.104 | 1.09E-03 | 0 | 0 | 0 | 0 | 0 | 5.46E-04 |
| U-102 | SS | 374 | 11.6 | 1.44 | 2.10E-02 | 5.22E-02 | 1.44E-03 | 5.07E-05 | 9.33E-06 | 1.01E-03 | 9.87E-04 | 6.31E-03 |
| U-103 | SS | 468 | 11.5 | 1.47 | 1.55E-02 | 5.32E-02 | 1.43E-03 | 4.04E-05 | 9.31E-06 | 1.00E-03 | 9.86E-04 | 6.32E-03 |
| U-104 | SS | 122 | 10.7 | 0.921 | 7.33E-02 | 2.34E-02 | 1.52E-03 | 8.17E-10 | 1.22E-05 | 1.19E-03 | 1.34E-03 | 5.05E-03 |
| U-105 | SS | 418 | 12.6 | 1.6 | 1.71E-02 | 5.81E-02 | 1.54E-03 | 4.86E-05 | 1.00E-05 | 1.08E-03 | 1.07E-03 | 6.89E-03 |
| U-106 | SS | 226 | 13.1 | 1.68 | 2.16E-02 | 6.15E-02 | 1.23E-03 | 5.24E-05 | 8.98E-06 | 8.22E-04 | 1.04E-03 | 6.86E-03 |
| U-107 | SS | 406 | 11.1 | 3.38 | 3.71E-02 | 4.82E-02 | 1.15E-03 | 3.79E-05 | 7.71E-04 | 7.92E-04 | 2.28E-02 | 5.56E-03 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | Type | Total waste (kgal) | $Na^{+}$ | $Al^{3+}$ | $Fe^{3+}$ | $Cr^{3+}$ | $Bi^{3+}$ | $La^{3+}$ | $Hg^{2+}$ | $ZrO(OH)_2$ | $Pb^{2+}$ | $Ni^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U-108 | SS | 468 | 12.6 | 2.02 | 3.43E-02 | 6.50E-02 | 1.18E-03 | 4.22E-05 | 6.21E-04 | 7.96E-04 | 1.91E-02 | 7.06E-03 |
| U-109 | SS | 463 | 14.2 | 2.42 | 2.34E-02 | 6.90E-02 | 1.28E-03 | 3.77E-05 | 2.21E-04 | 8.76E-04 | 7.20E-03 | 7.54E-03 |
| U-110 | SS | 186 | 4.9 | 0.414 | 0.297 | 3.44E-03 | 6.71E-02 | 0 | 9.20E-05 | 8.97E-03 | 0 | 1.09E-03 |
| U-111 | SS | 329 | 7.6 | 1.17 | 5.75E-02 | 7.16E-02 | 3.88E-03 | 2.65E-05 | 9.78E-06 | 9.87E-04 | 6.07E-04 | 6.12E-03 |
| U-112 | SS | 49 | 4.48 | 2.27 | 0.376 | 0.128 | 5.03E-02 | 0 | 5.69E-04 | 6.73E-03 | 1.44E-02 | 8.12E-03 |
| U-201 | SS | 5 | 6.27 | 8.96 | 0.132 | 1.63E-03 | 3.94E-08 | 0 | 3.26E-03 | 2.95E-08 | 9.41E-02 | 8.15E-04 |
| U-202 | SS | 5 | 6.27 | 8.97 | 0.132 | 1.63E-03 | 0 | 0 | 3.26E-03 | 0 | 9.41E-02 | 8.14E-04 |
| U-203 | SS | 3 | 8.02 | 8.12 | 0.112 | 1.76E-02 | 1.37E-04 | 0 | 2.72E-03 | 1.03E-04 | 7.89E-02 | 2.19E-03 |
| U-204 | SS | 3 | 5.23 | 7.47 | 0.11 | 1.36E-03 | 0 | 0 | 2.72E-03 | 0 | 7.84E-02 | 6.79E-04 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Cl^-$ | citrate | EDTA | HEDTA | glycolate | acetate | oxalate | DBP | butanol | $NH_3$ | $Fe(CN)_6^{4-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A-101 | 0.168 | 2.70E-02 | 2.91E-02 | 5.24E-02 | 0.108 | 1.84E-02 | 1.63E-05 | 2.14E-02 | 2.14E-02 | 3.37E-02 | 0 |
| A-102 | 8.15E-02 | 1.26E-02 | 2.35E-02 | 4.41E-02 | 6.91E-02 | 9.27E-03 | 6.96E-06 | 1.02E-02 | 1.02E-02 | 2.31E-02 | 0 |
| A-103 | 0.178 | 2.89E-02 | 3.20E-02 | 5.74E-02 | 0.115 | 2.11E-02 | 1.59E-05 | 2.33E-02 | 2.33E-02 | 3.52E-02 | 0 |
| A-104 | 1.47E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.191 | 0 |
| A-105 | 2.11E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.242 | 0 |
| A-106 | 0.142 | 1.93E-02 | 4.60E-02 | 8.90E-02 | 0.129 | 9.95E-03 | 1.57E-05 | 1.47E-02 | 1.47E-02 | 8.87E-02 | 0 |
| AN-101 | 7.65E-02 | 9.86E-03 | 3.33E-03 | 5.45E-03 | 2.18E-02 | 3.87E-03 | 2.56E-06 | 7.26E-03 | 7.26E-03 | 4.24E-02 | 0 |
| AN-102 | 0.267 | 4.73E-02 | 3.81E-02 | 6.83E-02 | 0.174 | 2.52E-02 | 2.09E-05 | 3.51E-02 | 3.51E-02 | 5.79E-02 | 0 |
| AN-103 | 0.219 | 3.21E-02 | 1.85E-02 | 3.21E-02 | 0.196 | 1.56E-02 | 1.15E-05 | 2.26E-02 | 2.26E-02 | 0.445 | 0 |
| AN-104 | 0.172 | 2.63E-02 | 2.15E-02 | 3.84E-02 | 0.143 | 1.47E-02 | 1.10E-05 | 1.98E-02 | 1.98E-02 | 0.191 | 0 |
| AN-105 | 0.33 | 4.74E-02 | 3.13E-02 | 5.45E-02 | 0.26 | 2.59E-02 | 1.78E-05 | 3.38E-02 | 3.38E-02 | 8.63E-02 | 0 |
| AN-106 | 0.144 | 2.12E-02 | 1.73E-02 | 3.13E-02 | 8.42E-02 | 1.09E-02 | 1.59E-05 | 1.58E-02 | 1.58E-02 | 3.48E-02 | 0 |
| AN-107 | 0.207 | 3.43E-02 | 3.67E-02 | 6.38E-02 | 0.142 | 3.04E-02 | 1.04E-05 | 2.91E-02 | 2.91E-02 | 3.20E-02 | 0 |
| AP-101 | 1.27E-02 | 1.82E-03 | 7.28E-04 | 1.29E-03 | 1.58E-02 | 5.44E-04 | 9.50E-07 | 1.10E-03 | 1.10E-03 | 0.1 | 0 |
| AP-102 | 0.102 | 1.50E-02 | 1.22E-02 | 2.21E-02 | 5.94E-02 | 7.67E-03 | 1.12E-05 | 1.11E-02 | 1.11E-02 | 2.48E-02 | 0 |
| AP-103 | 3.06E-02 | 5.12E-03 | 1.77E-04 | 3.15E-04 | 6.63E-02 | 1.27E-04 | 1.66E-07 | 2.55E-04 | 2.55E-04 | 1.32E-02 | 0 |
| AP-104 | 2.75E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AP-105 | 0.159 | 2.39E-02 | 9.60E-03 | 1.69E-02 | 0.208 | 7.17E-03 | 1.17E-05 | 1.52E-02 | 1.52E-02 | 0.816 | 0 |
| AP-106 | 5.75E-02 | 9.51E-03 | 2.53E-03 | 4.46E-03 | 9.78E-02 | 1.88E-03 | 2.92E-06 | 4.01E-03 | 4.01E-03 | 0.213 | 0 |
| AP-107 | 9.25E-04 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5.03E-02 | 0 |
| AP-108 | 2.75E-02 | 6.12E-03 | 3.51E-05 | 6.28E-05 | 8.12E-02 | 2.36E-05 | 2.87E-08 | 3.19E-04 | 3.19E-04 | 6.60E-03 | 0 |
| AW-101 | 0.238 | 3.31E-02 | 1.97E-02 | 3.42E-02 | 0.211 | 1.66E-02 | 1.33E-05 | 2.61E-02 | 2.61E-02 | 0.815 | 0 |
| AW-102 | 9.37E-02 | 1.40E-02 | 5.76E-03 | 1.03E-02 | 0.117 | 4.02E-03 | 7.24E-06 | 9.34E-03 | 9.34E-03 | 0.466 | 0 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Cl^-$ | citrate | EDTA | HEDTA | glycolate | acetate | oxalate | DBP | butanol | $NH_3$ | $Fe(CN)_6^{4-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AW-103 | 3.97E-03 | 1.31E-05 | 5.28E-06 | 8.48E-06 | 8.41E-05 | 6.61E-06 | 3.16E-09 | 6.19E-05 | 6.19E-05 | 0.635 | 0 |
| AW-104 | 3.67E-03 | 1.40E-05 | 1.10E-05 | 1.96E-05 | 8.03E-05 | 7.63E-06 | 5.93E-09 | 3.12E-03 | 3.12E-03 | 3.12E-03 | 0 |
| AW-105 | 4.27E-02 | 5.84E-03 | 2.66E-03 | 4.66E-03 | 4.83E-02 | 2.09E-03 | 2.17E-06 | 4.30E-03 | 4.30E-03 | 0.53 | 0 |
| AW-106 | 9.76E-02 | 1.48E-02 | 5.46E-03 | 9.64E-03 | 0.129 | 4.10E-03 | 6.88E-06 | 9.13E-03 | 9.13E-03 | 0.456 | 0 |
| AX-101 | 0.183 | 2.96E-02 | 3.29E-02 | 5.91E-02 | 0.118 | 2.15E-02 | 1.65E-05 | 2.38E-02 | 2.38E-02 | 3.83E-02 | 0 |
| AX-102 | 0.171 | 2.74E-02 | 2.32E-02 | 4.18E-02 | 9.50E-02 | 1.49E-02 | 1.92E-05 | 2.01E-02 | 2.01E-02 | 5.58E-02 | 0 |
| AX-103 | 0.152 | 2.44E-02 | 2.37E-02 | 4.22E-02 | 0.101 | 1.64E-02 | 1.42E-05 | 1.88E-02 | 1.88E-02 | 5.90E-02 | 0 |
| AX-104 | 2.11E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.242 | 0 |
| AY-101 | 6.13E-02 | 1.42E-02 | 2.81E-02 | 5.54E-02 | 6.89E-02 | 2.32E-03 | 3.05E-06 | 9.29E-03 | 9.20E-03 | 1.78E-02 | 0 |
| AY-102 | 2.54E-02 | 5.87E-03 | 1.61E-05 | 2.87E-05 | 7.81E-02 | 1.08E-05 | 1.31E-08 | 3.59E-05 | 3.59E-05 | 4.30E-03 | 0 |
| AZ-101 | 4.49E-02 | 1.38E-03 | 1.24E-03 | 2.25E-03 | 7.11E-03 | 7.46E-04 | 8.02E-07 | 9.72E-04 | 9.72E-04 | 1.92E-02 | 0 |
| AZ-102 | 2.44E-02 | 4.41E-04 | 3.50E-03 | 6.99E-03 | 1.23E-02 | 4.24E-05 | 2.04E-08 | 9.68E-05 | 9.68E-05 | 1.26E-02 | 0 |
| B-101 | 7.32E-02 | 1.90E-03 | 0 | 0 | 2.04E-02 | 0 | 0 | 1.61E-05 | 1.61E-05 | 2.26E-02 | 0 |
| B-102 | 6.99E-02 | 4.02E-04 | 7.45E-05 | 1.19E-05 | 4.18E-04 | 4.38E-04 | 6.21E-08 | 3.96E-04 | 3.96E-04 | 1.05E-03 | 0 |
| B-103 | 8.38E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 2.04E-05 | 2.04E-05 | 8.59E-04 | 0 |
| B-104 | 3.18E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 3.93E-06 | 3.93E-06 | 3.46E-04 | 0 |
| B-105 | 7.59E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 1.77E-05 | 1.77E-05 | 7.86E-04 | 0 |
| B-106 | 8.79E-02 | 3.85E-05 | 6.87E-06 | 1.13E-06 | 4.25E-05 | 4.03E-05 | 4.56E-06 | 5.66E-05 | 5.66E-05 | 9.37E-04 | 0 |
| B-107 | 1.48E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 1.21E-06 | 1.21E-06 | 1.79E-04 | 0 |
| B-108 | 6.17E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 1.37E-05 | 1.37E-05 | 6.42E-04 | 0 |
| B-109 | 0.104 | 8.54E-03 | 1.92E-03 | 2.59E-04 | 6.02E-03 | 1.14E-02 | 9.83E-07 | 9.09E-03 | 9.09E-03 | 4.27E-03 | 0 |
| B-110 | 2.05E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.95E-03 | 0 |
| B-111 | 1.72E-02 | 1.32E-04 | 2.95E-05 | 3.99E-06 | 9.27E-05 | 1.76E-04 | 1.51E-08 | 1.40E-04 | 1.40E-04 | 2.66E-02 | 0 |



162/184

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Cl^-$ | citrate | EDTA | HEDTA | glycolate | acetate | oxalate | DBP | butanol | $NH_3$ | $Fe(CN)_6^{4-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B-112 | 7.98E-02 | 1.38E-02 | 3.09E-03 | 4.17E-04 | 9.70E-03 | 1.84E-02 | 1.58E-06 | 1.46E-02 | 1.46E-02 | 5.91E-03 | 0 |
| B-201 | 2.41E-02 | 0 | 0 | 0 | 0 | 0 | 0.621 | 0 | 0 | 0 | 0 |
| B-202 | 2.49E-02 | 0 | 0 | 0 | 0 | 0 | 0.643 | 0 | 0 | 0 | 0 |
| B-203 | 2.44E-02 | 0 | 0 | 0 | 0 | 0 | 0.63 | 0 | 0 | 0 | 0 |
| B-204 | 2.45E-02 | 0 | 0 | 0 | 0 | 0 | 0.63 | 0 | 0 | 0 | 0 |
| BX-101 | 1.45E-02 | 3.15E-03 | 1.21E-04 | 1.63E-05 | 3.52E-02 | 7.19E-04 | 6.19E-08 | 5.71E-04 | 5.71E-04 | 2.69E-02 | 0 |
| BX-102 | 7.42E-04 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.57E-06 | 0 |
| BX-103 | 7.74E-03 | 1.26E-03 | 4.48E-04 | 5.57E-04 | 1.69E-03 | 1.08E-03 | 9.38E-08 | 1.13E-03 | 1.13E-03 | 8.20E-04 | 0 |
| BX-104 | 9.20E-02 | 1.29E-02 | 1.34E-02 | 2.59E-02 | 5.85E-02 | 3.00E-03 | 1.43E-05 | 8.31E-03 | 8.31E-03 | 2.45E-02 | 0 |
| BX-105 | 1.63E-02 | 2.27E-03 | 2.28E-03 | 4.25E-03 | 9.34E-03 | 1.01E-03 | 1.97E-06 | 1.63E-03 | 1.63E-03 | 3.63E-03 | 0 |
| BX-106 | 0.106 | 1.99E-02 | 5.70E-03 | 3.15E-03 | 1.88E-02 | 2.63E-02 | 2.28E-06 | 2.10E-02 | 2.10E-02 | 9.07E-03 | 0 |
| BX-107 | 1.43E-02 | 5.84E-05 | 1.05E-06 | 2.12E-06 | 1.34E-05 | 8.84E-09 | 4.07E-12 | 3.71E-05 | 3.71E-05 | 3.74E-04 | 0 |
| BX-108 | 1.39E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.66E-04 | 0 |
| BX-109 | 7.96E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 2.29E-05 | 2.29E-05 | 8.12E-04 | 0 |
| BX-110 | 3.77E-02 | 5.09E-03 | 1.14E-03 | 1.54E-04 | 3.58E-03 | 6.80E-03 | 5.86E-07 | 5.40E-03 | 5.40E-03 | 2.51E-03 | 0 |
| BX-111 | 0.11 | 2.04E-02 | 4.57E-03 | 6.17E-04 | 1.43E-02 | 2.72E-02 | 2.34E-06 | 2.16E-02 | 2.16E-02 | 8.81E-03 | 0 |
| BX-112 | 2.83E-02 | 1.55E-04 | 1.35E-04 | 2.13E-04 | 3.84E-04 | 1.79E-04 | 2.04E-08 | 1.57E-04 | 1.57E-04 | 7.08E-04 | 0 |
| BY-101 | 0.115 | 2.17E-02 | 4.87E-03 | 6.57E-04 | 1.53E-02 | 2.90E-02 | 2.50E-06 | 2.30E-02 | 2.30E-02 | 9.31E-03 | 0 |
| BY-102 | 0.12 | 2.27E-02 | 5.57E-03 | 1.68E-03 | 1.73E-02 | 3.02E-02 | 2.61E-06 | 2.40E-02 | 2.40E-02 | 9.80E-03 | 0 |
| BY-103 | 0.124 | 2.34E-02 | 5.26E-03 | 7.11E-04 | 1.65E-02 | 3.13E-02 | 2.70E-06 | 2.49E-02 | 2.49E-02 | 1.01E-02 | 0 |
| BY-104 | 0.104 | 1.30E-02 | 2.91E-03 | 3.92E-04 | 9.12E-03 | 1.73E-02 | 1.49E-06 | 1.38E-02 | 1.38E-02 | 5.73E-03 | 3.59E-02 |
| BY-105 | 0.107 | 1.61E-02 | 3.61E-03 | 4.87E-04 | 1.13E-02 | 2.15E-02 | 1.85E-06 | 1.71E-02 | 1.71E-02 | 7.00E-03 | 2.21E-02 |
| BY-106 | 0.12 | 2.03E-02 | 4.56E-03 | 6.16E-04 | 1.43E-02 | 2.71E-02 | 2.34E-06 | 2.16E-02 | 2.16E-02 | 8.77E-03 | 1.67E-02 |



1/63/84

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Cl^-$ | citrate | EDTA | HEDTA | glycolate | acetate | oxalate | DBP | butanol | $NH_3$ | $Fe(CN)_6^{4-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BY-107 | 0.101 | 1.34E-02 | 3.02E-03 | 4.07E-04 | 9.47E-03 | 1.79E-02 | 1.55E-06 | 1.43E-02 | 1.43E-02 | 5.97E-03 | 3.07E-02 |
| BY-108 | 9.13E-02 | 6.63E-03 | 1.49E-03 | 2.01E-04 | 4.67E-03 | 8.85E-03 | 7.63E-07 | 7.04E-03 | 7.04E-03 | 3.07E-03 | 8.98E-02 |
| BY-109 | 0.116 | 2.19E-02 | 4.93E-03 | 6.65E-04 | 1.55E-02 | 2.93E-02 | 2.53E-06 | 2.33E-02 | 2.33E-02 | 9.41E-03 | 0 |
| BY-110 | 9.74E-02 | 1.25E-02 | 2.81E-03 | 3.80E-04 | 8.83E-03 | 1.67E-02 | 1.44E-06 | 1.33E-02 | 1.33E-02 | 5.55E-03 | 4.59E-02 |
| BY-111 | 0.12 | 2.26E-02 | 5.08E-03 | 6.86E-04 | 1.59E-02 | 3.02E-02 | 2.60E-06 | 2.40E-02 | 2.40E-02 | 9.71E-03 | 0 |
| BY-112 | 0.125 | 2.33E-02 | 5.24E-03 | 7.07E-04 | 1.64E-02 | 3.12E-02 | 2.69E-06 | 2.48E-02 | 2.48E-02 | 1.00E-02 | 1.61E-03 |
| C-101 | 3.63E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 9.48E-06 | 9.48E-06 | 3.57E-04 | 0 |
| C-102 | 1.44E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 1.09E-04 | 1.09E-04 | 2.04E-02 | 0 |
| C-103 | 3.74E-02 | 5.02E-03 | 3.01E-02 | 5.72E-02 | 6.41E-02 | 9.57E-03 | 4.27E-07 | 4.28E-03 | 4.28E-03 | 2.79E-02 | 0 |
| C-104 | 1.72E-02 | 3.06E-04 | 5.20E-03 | 1.03E-02 | 1.10E-02 | 2.10E-04 | 2.16E-07 | 2.09E-03 | 2.09E-03 | 0.125 | 0 |
| C-105 | 1.43E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 2.78E-06 | 2.78E-06 | 2.24E-04 | 0 |
| C-106 | 2.27E-02 | 2.29E-03 | 5.12E-13 | 4.33E-13 | 3.06E-02 | 1.90E-12 | 8.32E-19 | 1.82E-06 | 1.82E-06 | 0.101 | 0 |
| C-107 | 1.68E-02 | 0 | 9.31E-03 | 1.86E-02 | 1.86E-02 | 0 | 0 | 1.89E-06 | 1.89E-06 | 8.49E-03 | 0 |
| C-108 | 5.08E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 1.05E-05 | 1.05E-05 | 4.52E-02 | 6.49E-02 |
| C-109 | 3.95E-02 | 3.50E-03 | 6.99E-03 | 0 | 0 | 4.46E-02 | 0 | 0 | 0 | 0.215 | 0.243 |
| C-110 | 1.48E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.79E-04 | 0 |
| C-111 | 1.51E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.17E-02 | 3.13E-02 |
| C-112 | 3.69E-02 | 3.17E-04 | 6.34E-04 | 0 | 0 | 4.04E-03 | 0 | 0 | 0 | 0.175 | 0.247 |
| C-201 | 2.09E-02 | 1.65E-02 | 3.30E-02 | 0 | 0 | 0.21 | 0 | 0 | 0 | 0.223 | 0 |
| C-202 | 4.05E-02 | 3.30E-02 | 6.59E-02 | 0 | 0 | 0.42 | 0 | 0 | 0 | 0.445 | 0 |
| C-203 | 9.10E-03 | 6.58E-03 | 1.32E-02 | 0 | 0 | 8.39E-02 | 0 | 0 | 0 | 8.90E-02 | 0 |
| C-204 | 1.43E-02 | 1.10E-02 | 2.20E-02 | 0 | 0 | 0.14 | 0 | 0 | 0 | 0.148 | 0 |
| S-101 | 0.12 | 1.29E-02 | 6.51E-03 | 1.20E-02 | 3.91E-02 | 3.13E-03 | 1.20E-05 | 8.44E-03 | 8.44E-03 | 5.90E-02 | 0 |



164/84

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Cl^-$ | citrate | EDTA | HEDTA | glycolate | acetate | oxalate | DBP | butanol | $NH_3$ | $Fe(CN)_6^{4-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S-102 | 0.151 | 2.10E-02 | 1.18E-02 | 2.21E-02 | 6.78E-02 | 4.55E-03 | 2.55E-05 | 1.39E-02 | 1.39E-02 | 4.35E-02 | 0 |
| S-103 | 0.217 | 2.99E-02 | 1.67E-02 | 3.13E-02 | 9.71E-02 | 6.62E-03 | 4.04E-05 | 1.99E-02 | 1.99E-02 | 6.52E-02 | 0 |
| S-104 | 7.90E-02 | 2.21E-04 | 8.62E-06 | 7.16E-06 | 3.13E-04 | 3.24E-05 | 1.38E-11 | 1.96E-04 | 1.96E-04 | 6.54E-02 | 0 |
| S-105 | 0.158 | 1.72E-02 | 1.91E-03 | 3.06E-03 | 2.64E-02 | 2.46E-03 | 1.22E-09 | 1.16E-02 | 1.16E-02 | 5.14E-02 | 0 |
| S-106 | 0.172 | 2.19E-02 | 1.96E-03 | 3.22E-03 | 4.18E-02 | 2.26E-03 | 2.24E-08 | 1.38E-02 | 1.38E-02 | 5.20E-02 | 0 |
| S-107 | 5.93E-02 | 6.02E-03 | 6.77E-03 | 1.31E-02 | 2.88E-02 | 1.41E-03 | 6.87E-06 | 3.86E-03 | 3.86E-03 | 7.62E-02 | 0 |
| S-108 | 0.179 | 2.18E-02 | 2.35E-03 | 3.86E-03 | 3.41E-02 | 2.70E-03 | 1.52E-09 | 1.44E-02 | 1.44E-02 | 5.81E-02 | 0 |
| S-109 | 0.174 | 2.28E-02 | 2.26E-03 | 3.70E-03 | 3.74E-02 | 2.63E-03 | 1.28E-08 | 1.48E-02 | 1.48E-02 | 5.50E-02 | 0 |
| S-110 | 0.139 | 2.01E-02 | 5.78E-03 | 1.05E-02 | 5.03E-02 | 3.52E-03 | 4.97E-06 | 1.28E-02 | 1.28E-02 | 6.68E-02 | 0 |
| S-111 | 0.19 | 2.56E-02 | 6.00E-03 | 1.07E-02 | 5.88E-02 | 4.12E-03 | 1.03E-05 | 1.63E-02 | 1.63E-02 | 7.06E-02 | 0 |
| S-112 | 0.181 | 2.23E-02 | 2.46E-03 | 4.05E-03 | 3.50E-02 | 2.84E-03 | 1.59E-07 | 1.47E-02 | 1.47E-02 | 5.84E-02 | 0 |
| SX-101 | 8.18E-02 | 4.14E-03 | 2.15E-03 | 4.03E-03 | 1.29E-02 | 8.76E-04 | 4.38E-06 | 2.76E-03 | 2.76E-03 | 6.32E-02 | 0 |
| SX-102 | 0.233 | 3.49E-02 | 1.95E-02 | 3.61E-02 | 0.111 | 9.07E-03 | 4.53E-05 | 2.30E-02 | 2.30E-02 | 7.66E-02 | 0 |
| SX-103 | 0.213 | 2.75E-02 | 1.83E-02 | 3.47E-02 | 9.98E-02 | 6.43E-03 | 5.66E-05 | 1.82E-02 | 1.82E-02 | 6.03E-02 | 0 |
| SX-104 | 0.182 | 2.44E-02 | 1.34E-02 | 2.49E-02 | 7.88E-02 | 6.06E-03 | 2.44E-05 | 1.59E-02 | 1.59E-02 | 6.96E-02 | 0 |
| SX-105 | 0.222 | 3.33E-02 | 1.78E-02 | 3.30E-02 | 0.106 | 8.45E-03 | 3.92E-05 | 2.14E-02 | 2.14E-02 | 6.75E-02 | 0 |
| SX-106 | 0.201 | 2.79E-02 | 1.57E-02 | 2.94E-02 | 9.08E-02 | 6.17E-03 | 3.83E-05 | 1.86E-02 | 1.86E-02 | 5.65E-02 | 0 |
| SX-107 | 5.47E-02 | 6.58E-05 | 2.56E-06 | 2.13E-06 | 9.29E-05 | 9.64E-06 | 4.09E-12 | 5.83E-05 | 5.83E-05 | 0.161 | 0 |
| SX-108 | 4.17E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.172 | 0 |
| SX-109 | 9.88E-02 | 3.06E-04 | 1.19E-05 | 9.89E-06 | 4.32E-04 | 4.48E-05 | 1.90E-11 | 2.71E-04 | 2.71E-04 | 6.78E-02 | 0 |
| SX-110 | 8.31E-02 | 1.95E-04 | 7.58E-06 | 6.30E-06 | 2.75E-04 | 2.85E-05 | 1.21E-11 | 1.73E-04 | 1.73E-04 | 0.185 | 0 |
| SX-111 | 6.93E-02 | 1.35E-04 | 5.27E-06 | 4.37E-06 | 1.91E-04 | 1.98E-05 | 8.40E-12 | 1.20E-04 | 1.20E-04 | 0.162 | 0 |
| SX-112 | 6.19E-02 | 1.01E-04 | 3.92E-06 | 3.25E-06 | 1.42E-04 | 1.47E-05 | 6.25E-12 | 8.92E-05 | 8.92E-05 | 0.16 | 0 |



165/189

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Cl^-$ | citrate | EDTA | HEDTA | glycolate | acetate | oxalate | DBP | butanol | $NH_3$ | $Fe(CN)_6^{4-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SX-113 | 2.52E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.48E-03 | 0 |
| SX-114 | 9.86E-02 | 2.96E-04 | 1.15E-05 | 9.57E-06 | 4.18E-04 | 4.33E-05 | 1.84E-11 | 2.62E-04 | 2.62E-04 | 9.80E-02 | 0 |
| SX-115 | 7.79E-02 | 2.01E-04 | 7.84E-06 | 6.51E-06 | 2.84E-04 | 2.95E-05 | 1.25E-11 | 1.78E-04 | 1.78E-04 | 8.13E-02 | 0 |
| SY-101 | 0.266 | 3.83E-02 | 2.69E-02 | 5.09E-02 | 0.139 | 9.26E-03 | 5.21E-05 | 2.52E-02 | 2.52E-02 | 7.27E-02 | 0 |
| SY-102 | 2.47E-02 | 2.95E-03 | 1.80E-03 | 3.36E-03 | 9.67E-03 | 7.28E-04 | 1.21E-06 | 2.15E-03 | 2.15E-03 | 1.41E-03 | 0 |
| SY-103 | 0.203 | 2.93E-02 | 2.14E-02 | 3.98E-02 | 0.104 | 9.71E-03 | 3.28E-05 | 2.03E-02 | 2.03E-02 | 5.31E-02 | 0 |
| T-101 | 4.31E-02 | 5.65E-02 | 3.17E-03 | 6.21E-03 | 2.10E-02 | 4.35E-04 | 1.54E-04 | 3.68E-03 | 3.68E-03 | 1.06E-02 | 0 |
| T-102 | 4.57E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.79E-05 | 0 |
| T-103 | 7.51E-03 | 6.41E-04 | 1.12E-05 | 2.01E-05 | 1.25E-03 | 8.02E-06 | 3.87E-11 | 3.56E-04 | 3.56E-04 | 6.12E-04 | 0 |
| T-104 | 1.42E-02 | 8.84E-05 | 6.86E-05 | 1.30E-04 | 3.70E-04 | 2.21E-05 | 2.40E-08 | 5.37E-05 | 5.37E-05 | 5.42E-04 | 0 |
| T-105 | 2.07E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.47E-04 | 0 |
| T-106 | 9.52E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.42E-04 | 0 |
| T-107 | 1.41E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.70E-04 | 0 |
| T-108 | 4.97E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 1.08E-05 | 1.08E-05 | 5.55E-04 | 0 |
| T-109 | 8.16E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 2.06E-05 | 2.06E-05 | 8.99E-04 | 0 |
| T-110 | 2.06E-02 | 0 | 0 | 0 | 0 | 0 | 1.69E-02 | 0 | 0 | 4.87E-08 | 0 |
| T-111 | 1.90E-02 | 0 | 0 | 0 | 0 | 0 | 5.05E-02 | 0 | 0 | 4.89E-08 | 0 |
| T-112 | 1.44E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5.09E-08 | 0 |
| T-201 | 2.41E-02 | 0 | 0 | 0 | 0 | 0 | 0.621 | 0 | 0 | 0 | 0 |
| T-202 | 2.49E-02 | 0 | 0 | 0 | 0 | 0 | 0.643 | 0 | 0 | 0 | 0 |
| T-203 | 2.49E-02 | 0 | 0 | 0 | 0 | 0 | 0.643 | 0 | 0 | 0 | 0 |
| T-204 | 2.49E-02 | 0 | 0 | 0 | 0 | 0 | 0.643 | 0 | 0 | 0 | 0 |
| TX-101 | 4.90E-02 | 2.09E-03 | 1.06E-03 | 1.99E-03 | 6.40E-03 | 4.12E-04 | 1.97E-06 | 1.38E-03 | 1.38E-03 | 0.11 | 0 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Cl^-$ | citrate | EDTA | HEDTA | glycolate | acetate | oxalate | DBP | butanol | $NH_3$ | $Fe(CN)_6^{4-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TX-102 | 0.164 | 1.51E-02 | 2.10E-02 | 4.12E-02 | 7.85E-02 | 2.51E-03 | 1.14E-09 | 1.23E-02 | 1.23E-02 | 4.78E-02 | 0 |
| TX-103 | 9.59E-02 | 9.89E-03 | 5.16E-03 | 9.86E-03 | 3.58E-02 | 1.46E-03 | 5.21E-05 | 7.58E-03 | 7.58E-03 | 2.77E-02 | 0 |
| TX-104 | 0.119 | 1.09E-02 | 1.63E-02 | 3.21E-02 | 6.79E-02 | 1.72E-03 | 7.62E-10 | 8.30E-03 | 8.30E-03 | 3.27E-02 | 0 |
| TX-105 | 0.17 | 1.71E-02 | 2.08E-03 | 3.25E-03 | 4.02E-02 | 2.91E-03 | 1.32E-09 | 1.42E-02 | 1.42E-02 | 5.44E-02 | 0 |
| TX-106 | 0.163 | 1.53E-02 | 1.15E-02 | 2.23E-02 | 6.56E-02 | 2.52E-03 | 1.12E-09 | 1.22E-02 | 1.22E-02 | 4.92E-02 | 0 |
| TX-107 | 2.45E-02 | 2.21E-03 | 3.26E-03 | 6.41E-03 | 1.36E-02 | 3.50E-04 | 1.55E-10 | 1.69E-03 | 1.69E-03 | 6.67E-03 | 0 |
| TX-108 | 0.123 | 1.16E-02 | 2.91E-03 | 5.20E-03 | 3.43E-02 | 1.96E-03 | 8.80E-10 | 9.52E-03 | 9.52E-03 | 3.72E-02 | 0 |
| TX-109 | 1.37E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.96E-04 | 0 |
| TX-110 | 0.155 | 1.46E-02 | 1.03E-02 | 1.98E-02 | 6.00E-02 | 2.41E-03 | 1.08E-09 | 1.17E-02 | 1.17E-02 | 4.56E-02 | 0 |
| TX-111 | 0.15 | 1.40E-02 | 1.22E-02 | 2.36E-02 | 6.38E-02 | 2.28E-03 | 1.02E-09 | 1.11E-02 | 1.11E-02 | 4.33E-02 | 0 |
| TX-112 | 0.16 | 1.61E-02 | 1.24E-03 | 1.48E-03 | 3.26E-02 | 3.21E-03 | 1.29E-09 | 1.41E-02 | 1.41E-02 | 5.44E-02 | 0 |
| TX-113 | 0.11 | 8.56E-03 | 4.46E-04 | 2.58E-04 | 1.75E-02 | 2.03E-03 | 8.45E-10 | 9.48E-03 | 9.48E-03 | 4.24E-02 | 0 |
| TX-114 | 0.157 | 1.31E-02 | 6.53E-04 | 3.99E-04 | 2.58E-02 | 2.91E-03 | 1.16E-09 | 1.28E-02 | 1.28E-02 | 5.31E-02 | 0 |
| TX-115 | 0.165 | 1.45E-02 | 2.54E-03 | 4.19E-03 | 3.57E-02 | 2.88E-03 | 1.27E-09 | 1.40E-02 | 1.40E-02 | 5.90E-02 | 0 |
| TX-116 | 8.59E-02 | 2.71E-05 | 3.39E-05 | 2.97E-07 | 9.80E-06 | 2.15E-04 | 5.18E-10 | 2.57E-03 | 2.57E-03 | 2.09E-02 | 0 |
| TX-117 | 0.106 | 7.37E-04 | 8.53E-05 | 1.85E-05 | 2.43E-03 | 4.86E-04 | 9.28E-10 | 6.71E-03 | 6.71E-03 | 4.52E-02 | 0 |
| TX-118 | 8.97E-02 | 9.12E-03 | 5.70E-03 | 1.09E-02 | 3.24E-02 | 1.61E-03 | 1.22E-05 | 6.60E-03 | 6.60E-03 | 2.30E-02 | 0 |
| TY-101 | 4.27E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 8.02E-06 | 8.02E-06 | 1.95E-02 | 6.36E-02 |
| TY-102 | 0.119 | 7.93E-03 | 2.19E-03 | 3.96E-03 | 2.49E-02 | 1.33E-03 | 5.91E-10 | 6.41E-03 | 6.41E-03 | 2.54E-02 | 0 |
| TY-103 | 8.11E-02 | 4.11E-03 | 1.71E-04 | 1.25E-04 | 8.35E-03 | 6.95E-04 | 3.30E-10 | 3.54E-03 | 3.54E-03 | 2.33E-02 | 3.02E-02 |
| TY-104 | 8.77E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 2.60E-05 | 2.60E-05 | 8.11E-04 | 0 |
| TY-105 | 0.107 | 0 | 0 | 0 | 0 | 0 | 0 | 3.18E-05 | 3.18E-05 | 9.35E-04 | 0 |
| TY-106 | 4.44E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 1.32E-06 | 1.32E-06 | 4.11E-05 | 0 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Cl^-$ | citrate | EDTA | HEDTA | glycolate | acetate | oxalate | DBP | butanol | $NH_3$ | $Fe(CN)_6^{4-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| U-101 | 1.11E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.09E-06 | 0 |
| U-102 | 0.196 | 2.67E-02 | 1.80E-02 | 3.41E-02 | 9.72E-02 | 6.34E-03 | 4.34E-05 | 1.81E-02 | 1.81E-02 | 5.53E-02 | 0 |
| U-103 | 0.199 | 2.71E-02 | 1.80E-02 | 3.39E-02 | 9.73E-02 | 6.47E-03 | 3.46E-05 | 1.82E-02 | 1.82E-02 | 5.51E-02 | 0 |
| U-104 | 8.54E-02 | 1.01E-04 | 1.55E-04 | 6.53E-07 | 1.78E-05 | 9.85E-04 | 6.99E-10 | 8.49E-03 | 8.49E-03 | 5.61E-02 | 0 |
| U-105 | 0.218 | 3.01E-02 | 2.03E-02 | 3.83E-02 | 0.11 | 7.27E-03 | 4.16E-05 | 2.01E-02 | 2.01E-02 | 5.98E-02 | 0 |
| U-106 | 0.221 | 3.56E-02 | 2.19E-02 | 4.08E-02 | 0.13 | 9.67E-03 | 4.48E-05 | 2.23E-02 | 2.23E-02 | 5.71E-02 | 0 |
| U-107 | 0.171 | 2.37E-02 | 1.34E-02 | 2.52E-02 | 7.75E-02 | 5.29E-03 | 3.24E-05 | 1.58E-02 | 1.58E-02 | 4.78E-02 | 0 |
| U-108 | 0.219 | 3.54E-02 | 1.86E-02 | 3.41E-02 | 0.11 | 9.55E-03 | 3.61E-05 | 2.25E-02 | 2.25E-02 | 5.96E-02 | 0 |
| U-109 | 0.239 | 3.82E-02 | 2.26E-02 | 4.21E-02 | 0.131 | 1.01E-02 | 3.22E-05 | 2.39E-02 | 2.39E-02 | 6.52E-02 | 0 |
| U-110 | 1.31E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.57E-04 | 0 |
| U-111 | 0.131 | 1.79E-02 | 1.03E-02 | 1.95E-02 | 5.89E-02 | 3.89E-03 | 2.27E-05 | 1.19E-02 | 1.19E-02 | 4.16E-02 | 0 |
| U-112 | 1.61E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.89E-02 | 0 |
| U-201 | 5.41E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.78E-04 | 0 |
| U-202 | 5.41E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.76E-04 | 0 |
| U-203 | 3.33E-02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.82E-03 | 0 |
| U-204 | 4.50E-03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.47E-04 | 0 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Sr^{2+}$ | $Mn^{4+}$ | $Ca^{2+}$ | $K^{+}$ | $OH^{-}$ | $NO_3^{-}$ | $NO_2^{-}$ | $CO_3^{2-}$ | $PO_4^{3-}$ | $SO_4^{2-}$ | $SiO_3^{2-}$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-101 | 6.35E-06 | 3.69E-03 | 2.43E-02 | 4.66E-02 | 5.85 | 3.64 | 1.95 | 0.417 | 7.49E-02 | 0.227 | 6.36E-02 | 5.94E-02 |
| A-102 | 2.71E-06 | 1.73E-03 | 2.02E-02 | 2.24E-02 | 3.49 | 1.65 | 0.943 | 0.219 | 3.48E-02 | 0.113 | 0.16 | 2.75E-02 |
| A-103 | 6.21E-06 | 3.97E-03 | 2.44E-02 | 4.94E-02 | 6.24 | 3.78 | 2.07 | 0.445 | 7.96E-02 | 0.244 | 8.25E-02 | 6.30E-02 |
| A-104 | 0 | 2.14E-03 | 0.121 | 6.04E-03 | 4.6 | 4.17E-09 | 0.631 | 0.23 | 1.88E-02 | 6.68E-02 | 2.21 | 3.16E-04 |
| A-105 | 0 | 0 | 0.243 | 4.59E-03 | 10.2 | 1.52E-14 | 0.587 | 0.243 | 0 | 0.129 | 1.52 | 0 |
| A-106 | 6.12E-06 | 3.04E-03 | 6.92E-02 | 3.86E-02 | 7.59 | 2.94 | 1.72 | 0.413 | 5.90E-02 | 0.195 | 0.847 | 4.50E-02 |
| AN-101 | 9.98E-07 | 1.68E-03 | 1.24E-02 | 2.67E-02 | 2.74 | 1.93 | 0.986 | 0.147 | 3.90E-02 | 8.87E-02 | 2.79E-02 | 3.82E-02 |
| AN-102 | 8.15E-06 | 7.07E-03 | 3.84E-02 | 7.51E-02 | 9.11 | 5.86 | 3.03 | 0.695 | 0.124 | 0.358 | 0.1 | 8.76E-02 |
| AN-103 | 4.48E-06 | 9.23E-03 | 4.72E-02 | 0.179 | 7.34 | 5.53 | 1.95 | 0.673 | 0.163 | 0.241 | 8.20E-02 | 0.192 |
| AN-104 | 4.30E-06 | 6.72E-03 | 3.20E-02 | 9.52E-02 | 5.75 | 4.05 | 1.68 | 0.506 | 0.116 | 0.208 | 6.10E-02 | 0.106 |
| AN-105 | 6.93E-06 | 9.30E-03 | 5.57E-02 | 9.82E-02 | 10.8 | 7.76 | 3.02 | 0.904 | 0.185 | 0.379 | 0.112 | 0.122 |
| AN-106 | 6.20E-06 | 2.86E-03 | 2.87E-02 | 3.99E-02 | 4.84 | 3.4 | 1.59 | 0.337 | 0.18 | 0.181 | 5.26E-02 | 5.04E-02 |
| AN-107 | 4.06E-06 | 4.94E-03 | 2.58E-02 | 5.82E-02 | 7.31 | 4.21 | 2.32 | 0.542 | 9.81E-02 | 0.287 | 6.91E-02 | 7.66E-02 |
| AP-101 | 3.70E-07 | 8.49E-04 | 1.19E-02 | 1.86E-02 | 0.382 | 0.39 | 7.43E-02 | 4.75E-02 | 1.20E-02 | 1.10E-02 | 4.21E-03 | 1.82E-02 |
| AP-102 | 4.37E-06 | 2.02E-03 | 2.07E-02 | 2.82E-02 | 3.42 | 2.4 | 1.12 | 0.238 | 0.134 | 0.128 | 3.71E-02 | 3.56E-02 |
| AP-103 | 6.49E-08 | 1.97E-04 | 6.34E-03 | 9.53E-03 | 0.945 | 0.782 | 6.24E-02 | 0.107 | 5.93E-03 | 2.06E-02 | 1.24E-02 | 4.47E-03 |
| AP-104 | 0 | 0 | 7.78E-03 | 5.98E-04 | 4.47E-02 | 0.136 | 1.21E-02 | 1.70E-03 | 0.13 | 3.47E-03 | 0 | 0 |
| AP-105 | 4.54E-06 | 1.26E-02 | 5.53E-02 | 0.266 | 4.88 | 4.48 | 0.984 | 0.649 | 0.175 | 0.146 | 5.56E-02 | 0.263 |
| AP-106 | 1.14E-06 | 3.34E-03 | 1.76E-02 | 7.23E-02 | 1.81 | 1.59 | 0.282 | 0.233 | 4.84E-02 | 4.86E-02 | 2.20E-02 | 6.81E-02 |
| AP-107 | 0 | 0 | 9.05E-03 | 2.01E-04 | 1.61E-02 | 6.66E-02 | 0 | 4.92E-04 | 0 | 0 | 0 | 0 |
| AP-108 | 1.12E-08 | 5.15E-04 | 6.25E-03 | 6.82E-03 | 0.983 | 0.729 | 5.03E-02 | 0.121 | 1.01E-02 | 2.06E-02 | 1.43E-02 | 8.64E-04 |
| AW-103 | 1.23E-09 | 9.74E-05 | 5.65E-02 | 0.184 | 2.78 | 0.328 | 7.75E-03 | 5.84E-02 | 1.15E-03 | 1.55E-04 | 3.07E-05 | 3.05 |
| AW-101 | 5.18E-06 | 1.54E-02 | 8.60E-02 | 0.295 | 7.8 | 6.28 | 1.92 | 0.854 | 0.231 | 0.248 | 7.75E-02 | 0.304 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Sr^{2+}$ | $Mn^{4+}$ | $Ca^{2+}$ | $K^{+}$ | $OH^{-}$ | $NO_3^{-}$ | $NO_2^{-}$ | $CO_3^{2-}$ | $PO_4^{3-}$ | $SO_4^{2-}$ | $SiO_3^{2-}$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AW-102 | 2.82E-06 | 7.90E-03 | 3.29E-02 | 0.153 | 2.89 | 2.66 | 0.617 | 0.385 | 0.11 | 8.82E-02 | 3.33E-02 | 0.153 |
| AW-106 | 2.68E-06 | 7.59E-03 | 3.33E-02 | 0.15 | 3.08 | 2.74 | 0.629 | 0.394 | 0.106 | 8.98E-02 | 3.70E-02 | 0.147 |
| AW-105 | 8.47E-07 | 3.68E-03 | 4.63E-02 | 0.163 | 2.41 | 1.31 | 0.266 | 0.203 | 5.04E-02 | 3.81E-02 | 1.35E-02 | 1.22 |
| AW-104 | 2.31E-09 | 5.47E-03 | 4.80E-02 | 7.17E-03 | 0.556 | 0.231 | 1.66E-02 | 0.141 | 6.34E-02 | 3.79E-03 | 3.25E-05 | 2.36E-02 |
| AX-101 | 6.44E-06 | 4.06E-03 | 2.79E-02 | 5.07E-02 | 6.54 | 3.88 | 2.13 | 0.458 | 8.16E-02 | 0.251 | 9.34E-02 | 6.47E-02 |
| AX-102 | 7.50E-06 | 3.57E-03 | 6.42E-02 | 4.70E-02 | 7.3 | 3.86 | 2.01 | 0.437 | 7.60E-02 | 0.222 | 0.221 | 5.94E-02 |
| AX-103 | 5.53E-06 | 3.22E-03 | 5.05E-02 | 4.18E-02 | 6.48 | 3.24 | 1.77 | 0.404 | 6.53E-02 | 0.215 | 0.245 | 5.20E-02 |
| AX-104 | 0 | 0 | 0.243 | 4.59E-03 | 10.2 | 1.52E-14 | 0.587 | 0.243 | 0 | 0.129 | 1.52 | 0 |
| AY-101 | 1.19E-06 | 2.01E-03 | 2.59E-02 | 1.67E-02 | 2.08 | 1.14 | 0.665 | 0.203 | 1.69E-02 | 9.44E-02 | 9.97E-02 | 1.05E-02 |
| AY-102 | 5.12E-09 | 4.20E-05 | 1.50E-02 | 5.70E-03 | 2.12 | 0.631 | 8.06E-02 | 0.117 | 4.42E-03 | 1.86E-02 | 0.106 | 3.95E-04 |
| AZ-101 | 3.12E-07 | 2.37E-04 | 1.51E-02 | 1.03E-02 | 2.71 | 0.311 | 0.414 | 3.70E-02 | 4.39E-03 | 0.108 | 7.21E-02 | 2.43E-02 |
| AZ-102 | 7.95E-09 | 9.94E-05 | 1.28E-02 | 5.39E-03 | 1.73 | 0.129 | 0.205 | 2.79E-02 | 1.50E-03 | 5.89E-02 | 8.36E-02 | 1.23E-02 |
| B-101 | 0 | 0 | 0.116 | 1.33E-02 | 7.41 | 2.84 | 0.411 | 0.287 | 1.07 | 0.117 | 0.5 | 0.119 |
| B-102 | 2.42E-08 | 5.16E-05 | 8.64E-02 | 1.26E-02 | 3.1 | 2.94 | 0.263 | 0.359 | 1.09 | 0.123 | 2.50E-02 | 0.122 |
| B-103 | 0 | 0 | 9.03E-02 | 1.49E-02 | 2.1 | 3.58 | 0.284 | 0.304 | 1.35 | 0.143 | 3.00E-02 | 0.15 |
| B-104 | 0 | 0 | 0.105 | 6.27E-03 | 2.18 | 1.26 | 0.136 | 0.129 | 0.997 | 6.24E-02 | 5.89E-02 | 0.175 |
| B-105 | 0 | 0 | 9.25E-02 | 1.36E-02 | 1.7 | 3.23 | 0.265 | 0.198 | 1.32 | 0.128 | 3.77E-02 | 0.162 |
| B-106 | 1.78E-06 | 8.99E-06 | 8.99E-02 | 1.58E-02 | 1.56 | 3.75 | 0.3 | 0.218 | 1.39 | 0.145 | 3.14E-02 | 0.158 |
| B-107 | 0 | 0 | 7.50E-02 | 3.21E-03 | 2.61 | 0.373 | 0.178 | 7.50E-02 | 1.32 | 4.44E-02 | 6.28E-02 | 0.164 |
| B-108 | 0 | 0 | 8.51E-02 | 1.12E-02 | 1.94 | 2.54 | 0.256 | 0.167 | 1.38 | 0.109 | 4.30E-02 | 0.161 |
| B-109 | 3.83E-07 | 1.16E-03 | 9.53E-02 | 2.40E-02 | 5.1 | 3.32 | 0.841 | 0.281 | 0.952 | 0.166 | 3.03E-02 | 0.126 |
| B-110 | 0 | 0 | 0.199 | 4.45E-03 | 2.09 | 0.829 | 8.91E-03 | 0.199 | 0.647 | 3.45E-02 | 7.14E-02 | 0.145 |
| B-111 | 5.90E-09 | 1.78E-05 | 0.274 | 3.79E-03 | 3.34 | 0.589 | 7.54E-02 | 0.276 | 0.124 | 3.94E-02 | 0.184 | 9.68E-02 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Sr^{2+}$ | $Mn^{4+}$ | $Ca^{2+}$ | $K^{+}$ | $OH^{-}$ | $NO_3^{-}$ | $NO_2^{-}$ | $CO_3^{2-}$ | $PO_4^{3-}$ | $SO_4^{2-}$ | $SiO_3^{2-}$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B-112 | 1.84E-06 | 1.87E-03 | 0.153 | 2.31E-02 | 5.96 | 3.58 | 1 | 0.386 | 9.89E-02 | 0.121 | 4.81E-02 | 8.06E-02 |
| B-201 | 1.51 | 3.73E-03 | 0.235 | 0.22 | 4.75 | 1.28 | 0 | 0.235 | 9.32E-02 | 1.30E-03 | 0 | 1.96 |
| B-202 | 1.57 | 3.86E-03 | 0.244 | 0.228 | 4.92 | 1.33 | 0 | 0.244 | 9.65E-02 | 1.34E-03 | 0 | 2.03 |
| B-203 | 1.54 | 3.79E-03 | 0.239 | 0.223 | 4.82 | 1.3 | 7.71E-07 | 0.239 | 9.46E-02 | 1.32E-03 | 0 | 1.99 |
| B-204 | 1.53 | 3.79E-03 | 0.239 | 0.223 | 4.82 | 1.3 | 4.10E-04 | 0.239 | 9.46E-02 | 1.39E-03 | 0 | 1.99 |
| BX-101 | 2.41E-08 | 7.29E-05 | 0.118 | 3.38E-03 | 17.8 | 9.13E-02 | 0.345 | 1.39 | 0.273 | 6.73E-02 | 0.723 | 1.34E-03 |
| BX-102 | 0 | 0 | 9.35E-02 | 1.61E-04 | 4.05 | 4.18E-02 | 1.39E-02 | 0.469 | 9.58E-02 | 2.02E-02 | 4.02 | 0 |
| BX-103 | 3.66E-08 | 1.77E-04 | 0.108 | 2.11E-03 | 12.9 | 0.218 | 0.11 | 1.6 | 0.33 | 7.72E-02 | 3.00E-03 | 2.07E-03 |
| BX-104 | 5.59E-06 | 1.75E-03 | 5.03E-02 | 2.46E-02 | 8.03 | 2.26 | 1.01 | 0.992 | 0.205 | 0.145 | 3.77E-02 | 3.08E-02 |
| BX-105 | 7.69E-07 | 3.08E-04 | 7.82E-02 | 4.38E-03 | 11.6 | 0.41 | 0.181 | 1.74 | 0.367 | 9.33E-02 | 7.25E-03 | 5.25E-03 |
| BX-106 | 2.42E-06 | 2.74E-03 | 5.25E-02 | 3.14E-02 | 7.58 | 4.43 | 1.44 | 0.5 | 8.28E-02 | 0.166 | 5.52E-02 | 4.88E-02 |
| BX-107 | 1.58E-12 | 8.00E-06 | 6.39E-02 | 3.11E-03 | 2.83 | 0.383 | 0.206 | 6.44E-02 | 1.16 | 4.74E-02 | 5.81E-02 | 0.175 |
| BX-108 | 0 | 0 | 6.05E-02 | 3.01E-03 | 2.9 | 0.381 | 0.213 | 6.05E-02 | 1.11 | 4.80E-02 | 5.66E-02 | 0.179 |
| BX-109 | 0 | 0 | 0.292 | 1.35E-02 | 5.14 | 1.87 | 0.348 | 0.429 | 0.253 | 0.116 | 8.82E-03 | 3.38E-02 |
| BX-110 | 7.62E-07 | 6.90E-04 | 6.02E-02 | 1.03E-02 | 4.29 | 1.66 | 0.544 | 0.151 | 0.84 | 7.91E-02 | 5.99E-02 | 0.156 |
| BX-111 | 3.05E-06 | 2.76E-03 | 6.91E-02 | 3.24E-02 | 8.29 | 5.5 | 1.52 | 0.432 | 0.192 | 0.17 | 7.40E-02 | 7.96E-02 |
| BX-112 | 7.94E-09 | 2.24E-05 | 5.40E-02 | 5.52E-03 | 2.88 | 1.06 | 0.266 | 8.11E-02 | 0.976 | 7.07E-02 | 4.64E-02 | 0.184 |
| BY-101 | 3.25E-06 | 2.94E-03 | 7.44E-02 | 3.41E-02 | 9.5 | 5.81 | 1.58 | 0.634 | 0.1 | 0.181 | 7.09E-02 | 5.39E-02 |
| BY-102 | 3.32E-06 | 3.08E-03 | 7.19E-02 | 3.56E-02 | 9.22 | 5.94 | 1.64 | 0.568 | 8.58E-02 | 0.185 | 7.28E-02 | 5.61E-02 |
| BY-103 | 3.51E-06 | 3.18E-03 | 7.90E-02 | 3.69E-02 | 9.47 | 6.28 | 1.71 | 0.497 | 6.70E-02 | 0.187 | 7.65E-02 | 5.82E-02 |
| BY-104 | 1.94E-06 | 1.76E-03 | 0.179 | 2.80E-02 | 6.56 | 4.57 | 1.02 | 0.41 | 0.224 | 0.181 | 7.24E-02 | 0.122 |
| BY-105 | 2.41E-06 | 2.18E-03 | 0.47 | 3.00E-02 | 8.08 | 4.98 | 1.21 | 0.482 | 0.173 | 0.19 | 0.172 | 9.48E-02 |
| BY-106 | 3.04E-06 | 2.76E-03 | 0.105 | 3.45E-02 | 8.28 | 5.81 | 1.5 | 0.468 | 0.117 | 0.188 | 7.60E-02 | 8.03E-02 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Sr^{2+}$ | $Mn^{4+}$ | $Ca^{2+}$ | $K^{+}$ | $OH^{-}$ | $NO_3^{-}$ | $NO_2^{-}$ | $CO_3^{2-}$ | $PO_4^{3-}$ | $SO_4^{2-}$ | $SiO_3^{2-}$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BY-107 | 2.01E-06 | 1.82E-03 | 0.148 | 2.72E-02 | 6.72 | 4.46 | 1.07 | 0.4 | 0.232 | 0.168 | 6.56E-02 | 0.104 |
| BY-108 | 9.92E-07 | 8.99E-04 | 0.217 | 2.26E-02 | 4.73 | 3.55 | 0.594 | 0.335 | 0.291 | 0.177 | 6.65E-02 | 0.158 |
| BY-109 | 3.29E-06 | 2.98E-03 | 7.43E-02 | 3.45E-02 | 9.46 | 5.87 | 1.59 | 0.619 | 9.67E-02 | 0.182 | 7.18E-02 | 5.45E-02 |
| BY-110 | 1.88E-06 | 1.70E-03 | 0.148 | 2.64E-02 | 6.28 | 4.33 | 0.994 | 0.372 | 0.263 | 0.17 | 6.95E-02 | 0.124 |
| BY-111 | 3.39E-06 | 3.07E-03 | 7.40E-02 | 3.56E-02 | 9.38 | 6.05 | 1.64 | 0.58 | 8.73E-02 | 0.185 | 7.39E-02 | 5.62E-02 |
| BY-112 | 3.49E-06 | 3.16E-03 | 7.82E-02 | 3.70E-02 | 9.1 | 6.29 | 1.7 | 0.507 | 7.78E-02 | 0.19 | 7.75E-02 | 6.19E-02 |
| C-101 | 0 | 0 | 0.253 | 6.32E-03 | 14.3 | 1.09 | 0.42 | 0.371 | 5.42E-02 | 5.34E-02 | 5.82E-03 | 0 |
| C-102 | 0 | 0 | 0.287 | 9.65E-03 | 18.8 | 0.697 | 0.243 | 0.315 | 1.44E-02 | 1.74E-02 | 1.34E-03 | 0.169 |
| C-103 | 1.66E-07 | 9.35E-04 | 4.11E-02 | 1.10E-02 | 4.85 | 0.66 | 0.53 | 0.159 | 1.37E-02 | 6.45E-02 | 0.307 | 8.17E-03 |
| C-104 | 8.41E-08 | 1.00E-04 | 0.337 | 2.25E-02 | 15.9 | 0.54 | 0.564 | 0.386 | 1.46E-02 | 2.00E-02 | 8.39E-02 | 0.494 |
| C-105 | 0 | 0 | 0.143 | 2.64E-03 | 16.3 | 0.726 | 0.643 | 0.16 | 1.19E-02 | 2.25E-02 | 1.52E-02 | 0 |
| C-106 | 3.24E-19 | 9.28E-04 | 0.133 | 5.85E-03 | 11.9 | 0.263 | 0.62 | 0.231 | 1.75E-02 | 4.53E-02 | 1.5 | 1.37E-04 |
| C-107 | 0.00E+00 | 0 | 0.113 | 3.65E-03 | 5.72 | 0.366 | 2.12E-01 | 0.128 | 1.06 | 4.30E-02 | 1.81E-01 | 1.31E-01 |
| C-108 | 0 | 0 | 0.308 | 9.32E-03 | 3.76 | 0.996 | 0.628 | 0.371 | 0.652 | 7.14E-02 | 2.78E-02 | 7.26E-02 |
| C-109 | 0 | 0 | 0.553 | 1.54E-02 | 4.18 | 6.31E-02 | 1.66 | 0.554 | 0.281 | 2.24E-02 | 9.57E-03 | 2.50E-02 |
| C-110 | 0 | 0 | 7.55E-02 | 3.23E-03 | 2.62 | 0.374 | 0.179 | 7.55E-02 | 1.33 | 4.47E-02 | 6.32E-02 | 0.165 |
| C-111 | 0 | 0 | 0.151 | 3.29E-03 | 6.81 | 0.395 | 0.499 | 0.151 | 0.852 | 3.24E-02 | 4.47E-02 | 0.104 |
| C-112 | 0 | 0 | 0.585 | 8.63E-03 | 5.27 | 0.146 | 1.68 | 0.586 | 0.273 | 1.85E-02 | 1.12E-02 | 2.38E-02 |
| C-201 | 0 | 0 | 4.41E-02 | 3.67E-02 | 15 | 3.12E-02 | 0.453 | 0.945 | 0.2 | 6.88E-02 | 7.75E-04 | 0 |
| C-202 | 0 | 0 | 4.04E-03 | 7.31E-02 | 17.8 | 1.49E-17 | 0.897 | 4.04E-03 | 0 | 5.56E-02 | 0 | 0 |
| C-203 | 0 | 0 | 6.81E-02 | 1.48E-02 | 13.4 | 5.00E-02 | 0.186 | 1.51 | 0.32 | 7.67E-02 | 1.24E-03 | 0 |
| C-204 | 0 | 0 | 5.74E-02 | 2.45E-02 | 14.1 | 4.16E-02 | 0.305 | 1.26 | 0.267 | 7.32E-02 | 1.03E-03 | 0 |
| S-101 | 4.67E-06 | 1.68E-03 | 8.50E-02 | 3.04E-02 | 11.1 | 3.31 | 1.89 | 0.256 | 3.74E-02 | 0.115 | 6.46E-02 | 2.89E-02 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Sr^{2+}$ | $Mn^{4+}$ | $Ca^{2+}$ | $K^{+}$ | $OH^{-}$ | $NO_3^{-}$ | $NO_2^{-}$ | $CO_3^{2-}$ | $PO_4^{3-}$ | $SO_4^{2-}$ | $SiO_3^{2-}$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S-102 | 9.93E-06 | 2.92E-03 | 2.67E-02 | 4.07E-02 | 5.13 | 3.86 | 1.75 | 0.321 | 6.62E-02 | 0.177 | 5.83E-02 | 5.42E-02 |
| S-103 | 1.58E-05 | 4.10E-03 | 4.37E-02 | 5.86E-02 | 7.73 | 5.48 | 2.5 | 0.469 | 9.69E-02 | 0.255 | 8.30E-02 | 8.13E-02 |
| S-104 | 4.88E-11 | 3.02E-05 | 0.131 | 1.72E-02 | 13.7 | 2.96 | 1.82 | 0.134 | 2.68E-04 | 3.06E-02 | 7.65E-02 | 2.38E-04 |
| S-105 | 4.75E-10 | 2.34E-03 | 2.88E-02 | 4.01E-02 | 6.33 | 4.34 | 2.4 | 0.227 | 5.16E-02 | 0.153 | 6.05E-02 | 3.88E-02 |
| S-106 | 8.74E-09 | 2.80E-03 | 3.57E-02 | 4.32E-02 | 9.5 | 4.47 | 2.57 | 0.273 | 5.23E-02 | 0.167 | 6.70E-02 | 3.20E-02 |
| S-107 | 2.68E-06 | 8.17E-04 | 0.131 | 2.42E-02 | 18.8 | 1.45 | 1.26 | 0.224 | 1.86E-02 | 6.07E-02 | 2.95E-02 | 0.267 |
| S-108 | 5.91E-10 | 2.93E-03 | 3.32E-02 | 4.56E-02 | 7.16 | 4.8 | 2.69 | 0.275 | 6.15E-02 | 0.179 | 6.94E-02 | 4.16E-02 |
| S-109 | 5.00E-09 | 3.01E-03 | 3.34E-02 | 4.46E-02 | 7.84 | 4.67 | 2.6 | 0.283 | 6.21E-02 | 0.179 | 6.87E-02 | 3.98E-02 |
| S-110 | 1.93E-06 | 2.52E-03 | 7.74E-02 | 3.56E-02 | 11.6 | 3.29 | 2.2 | 0.313 | 4.46E-02 | 0.149 | 5.52E-02 | 3.13E-02 |
| S-111 | 4.02E-06 | 3.27E-03 | 5.91E-02 | 4.87E-02 | 10.2 | 4.73 | 2.81 | 0.353 | 6.35E-02 | 0.195 | 7.36E-02 | 4.14E-02 |
| S-112 | 6.21E-08 | 2.99E-03 | 3.35E-02 | 4.63E-02 | 7.43 | 4.88 | 2.72 | 0.281 | 6.27E-02 | 0.183 | 7.06E-02 | 4.23E-02 |
| SX-101 | 1.71E-06 | 5.49E-04 | 0.104 | 1.93E-02 | 9.42 | 2.54 | 1.63 | 0.161 | 1.25E-02 | 5.37E-02 | 5.91E-02 | 1.01E-02 |
| SX-102 | 1.77E-05 | 4.50E-03 | 6.12E-02 | 6.32E-02 | 9.6 | 5.63 | 2.78 | 0.538 | 0.104 | 0.281 | 9.02E-02 | 8.32E-02 |
| SX-103 | 2.21E-05 | 3.60E-03 | 4.78E-02 | 5.78E-02 | 7.51 | 5.64 | 2.4 | 0.453 | 9.11E-02 | 0.243 | 9.51E-02 | 7.75E-02 |
| SX-104 | 9.49E-06 | 3.13E-03 | 7.04E-02 | 4.79E-02 | 9.2 | 4.64 | 2.4 | 0.4 | 7.17E-02 | 0.201 | 8.01E-02 | 5.52E-02 |
| SX-105 | 1.53E-05 | 4.24E-03 | 5.07E-02 | 5.95E-02 | 8.45 | 5.54 | 2.63 | 0.489 | 9.42E-02 | 0.26 | 9.68E-02 | 7.06E-02 |
| SX-106 | 1.49E-05 | 3.84E-03 | 3.37E-02 | 5.45E-02 | 6.59 | 5.13 | 2.27 | 0.432 | 9.08E-02 | 0.238 | 7.73E-02 | 7.64E-02 |
| SX-107 | 1.46E-11 | 8.98E-06 | 0.259 | 1.19E-02 | 21.1 | 0.886 | 1.86 | 0.26 | 7.96E-05 | 2.05E-02 | 0.138 | 7.06E-05 |
| SX-108 | 0 | 0 | 0.275 | 9.07E-03 | 22.6 | 2.79E-02 | 1.88 | 0.275 | 0 | 1.57E-02 | 0.108 | 0 |
| SX-109 | 6.77E-11 | 4.17E-05 | 0.129 | 2.15E-02 | 10.5 | 4.03 | 1.86 | 0.133 | 3.70E-04 | 3.74E-02 | 0.13 | 3.28E-04 |
| SX-110 | 4.31E-11 | 2.66E-05 | 0.299 | 1.81E-02 | 22.7 | 2.56 | 1.73 | 0.301 | 2.36E-04 | 3.03E-02 | 0.309 | 2.09E-04 |
| SX-111 | 2.99E-11 | 1.85E-05 | 0.264 | 1.51E-02 | 20.8 | 1.79 | 1.81 | 0.266 | 1.64E-04 | 2.57E-02 | 0.204 | 1.45E-04 |
| SX-112 | 2.23E-11 | 1.37E-05 | 0.26 | 1.35E-02 | 20.8 | 1.34 | 1.83 | 0.261 | 1.22E-04 | 2.31E-02 | 0.168 | 1.08E-04 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Sr^{2+}$ | $Mn^{4+}$ | $Ca^{2+}$ | $K^{+}$ | $OH^{-}$ | $NO_3^{-}$ | $NO_2^{-}$ | $CO_3^{2-}$ | $PO_4^{3-}$ | $SO_4^{2-}$ | $SiO_3^{2-}$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SX-113 | 0 | 0 | 8.87E-02 | 5.48E-04 | 1.2 | 2.27E-03 | 0.126 | 1.38E-02 | 0 | 9.87E-04 | 5.31 | 0 |
| SX-114 | 6.54E-11 | 4.04E-05 | 0.173 | 2.15E-02 | 13.5 | 3.89 | 1.81 | 0.177 | 3.58E-04 | 3.70E-02 | 0.193 | 3.17E-04 |
| SX-115 | 4.45E-11 | 2.75E-05 | 0.146 | 1.70E-02 | 12.5 | 2.66 | 1.9 | 0.148 | 2.44E-04 | 2.98E-02 | 7.03E-02 | 2.16E-04 |
| SY-101 | 2.03E-05 | 5.14E-03 | 4.45E-02 | 7.21E-02 | 8.61 | 6.63 | 2.93 | 0.597 | 0.121 | 0.322 | 0.104 | 9.85E-02 |
| SY-102 | 9.52E-07 | 1.32E-04 | 2.61E-02 | 8.70E-03 | 2.18 | 0.767 | 0.276 | 8.78E-02 | 1.84E-02 | 3.72E-02 | 4.07E-03 | 7.94E-03 |
| SY-103 | 1.28E-05 | 3.99E-03 | 3.27E-02 | 5.51E-02 | 6.73 | 4.97 | 2.29 | 0.454 | 9.09E-02 | 0.248 | 7.77E-02 | 7.43E-02 |
| T-101 | 5.99E-05 | 8.62E-04 | 0.119 | 1.91E-02 | 9.22 | 1.2 | 0.43 | 0.241 | 2.87E-02 | 5.40E-02 | 1.48E-02 | 2.71E-02 |
| T-102 | 0 | 0 | 0.176 | 9.94E-04 | 12.1 | 0.278 | 0.12 | 0.288 | 2.50E-02 | 1.02E-02 | 9.69E-05 | 0 |
| T-103 | 1.51E-11 | 7.63E-05 | 0.206 | 1.74E-03 | 14 | 0.374 | 0.169 | 0.278 | 1.51E-02 | 1.20E-02 | 1.05E-03 | 1.24E-04 |
| T-104 | 9.36E-09 | 1.07E-05 | 5.78E-02 | 3.11E-03 | 2.94 | 0.395 | 0.223 | 5.90E-02 | 1.06 | 4.90E-02 | 5.55E-02 | 0.18 |
| T-105 | 0 | 0 | 0.118 | 4.50E-03 | 2.1 | 0.815 | 6.69E-02 | 0.118 | 0.979 | 4.22E-02 | 7.06E-02 | 0.177 |
| T-106 | 0 | 0 | 9.25E-02 | 2.07E-03 | 17.6 | 0.438 | 0.46 | 9.25E-02 | 0.419 | 2.82E-02 | 3.05E-02 | 9.13E-02 |
| T-107 | 0 | 0 | 7.17E-02 | 3.07E-03 | 2.49 | 0.355 | 0.17 | 7.17E-02 | 1.27 | 4.24E-02 | 6.00E-02 | 0.157 |
| T-108 | 0 | 0 | 9.53E-02 | 9.04E-03 | 2.01 | 1.79 | 0.237 | 0.166 | 1.52 | 9.37E-02 | 4.24E-02 | 0.155 |
| T-109 | 0 | 0 | 0.113 | 1.43E-02 | 1.45 | 3.09 | 0.29 | 0.248 | 1.69 | 0.138 | 2.34E-02 | 0.146 |
| T-110 | 4.13E-02 | 1.02E-04 | 0.196 | 1.03E-02 | 2.04 | 0.854 | 1.73E-03 | 0.196 | 0.651 | 3.25E-02 | 5.27E-02 | 0.197 |
| T-111 | 0.123 | 3.03E-04 | 0.232 | 2.16E-02 | 2.38 | 0.8 | 1.52E-03 | 0.232 | 0.402 | 2.75E-02 | 3.50E-02 | 0.279 |
| T-112 | 0 | 0 | 0.247 | 3.12E-03 | 2.16 | 0.585 | 1.35E-03 | 0.247 | 0.126 | 2.27E-02 | 1.65E-02 | 9.79E-02 |
| T-201 | 1.51 | 3.73E-03 | 0.235 | 0.22 | 4.75 | 1.28 | 0 | 0.235 | 9.32E-02 | 1.30E-03 | 0 | 1.96 |
| T-202 | 1.57 | 3.86E-03 | 0.244 | 0.228 | 4.92 | 1.33 | 0 | 0.244 | 9.65E-02 | 1.34E-03 | 0 | 2.03 |
| T-203 | 1.57 | 3.86E-03 | 0.244 | 0.228 | 4.92 | 1.33 | 0 | 0.244 | 9.65E-02 | 1.34E-03 | 0 | 2.03 |
| T-204 | 1.57 | 3.86E-03 | 0.244 | 0.228 | 4.92 | 1.33 | 0 | 0.244 | 9.65E-02 | 1.34E-03 | 0 | 2.03 |
| TX-101 | 7.67E-07 | 2.76E-04 | 0.192 | 1.13E-02 | 17.3 | 0.469 | 1.76 | 0.287 | 2.02E-02 | 3.28E-02 | 1.55E-02 | 5.12E-03 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Sr^{2+}$ | $Mn^{4+}$ | $Ca^{2+}$ | $K^{+}$ | $OH^{-}$ | $NO_3^{-}$ | $NO_2^{-}$ | $CO_3^{2-}$ | $PO_4^{3-}$ | $SO_4^{2-}$ | $SiO_3^{2-}$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TX-102 | 4.42E-10 | 2.25E-03 | 2.86E-02 | 4.31E-02 | 4.59 | 4.08 | 1.41 | 0.386 | 9.69E-02 | 0.206 | 5.73E-02 | 9.86E-02 |
| TX-103 | 2.03E-05 | 1.44E-03 | 1.83E-02 | 2.78E-02 | 2.71 | 2.46 | 0.843 | 0.215 | 8.64E-02 | 0.118 | 3.35E-02 | 6.20E-02 |
| TX-104 | 2.97E-10 | 1.52E-03 | 4.32E-02 | 3.08E-02 | 6.63 | 2.97 | 0.983 | 0.793 | 0.174 | 0.166 | 4.19E-02 | 6.62E-02 |
| TX-105 | 5.14E-10 | 2.55E-03 | 3.06E-02 | 4.58E-02 | 5.14 | 4.38 | 1.58 | 0.391 | 0.109 | 0.216 | 5.87E-02 | 0.112 |
| TX-106 | 4.37E-10 | 2.20E-03 | 3.04E-02 | 4.29E-02 | 4.83 | 4.14 | 1.43 | 0.368 | 9.37E-02 | 0.199 | 5.60E-02 | 9.76E-02 |
| TX-107 | 6.05E-11 | 3.09E-04 | 2.27E-02 | 6.32E-03 | 3.39 | 0.618 | 0.202 | 0.474 | 0.102 | 4.73E-02 | 8.76E-03 | 1.35E-02 |
| TX-108 | 3.43E-10 | 1.70E-03 | 3.22E-02 | 3.25E-02 | 3.82 | 3.16 | 1.1 | 0.303 | 8.14E-02 | 0.154 | 4.12E-02 | 7.68E-02 |
| TX-109 | 0 | 0 | 5.80E-02 | 2.98E-03 | 2.94 | 0.383 | 0.218 | 5.80E-02 | 1.07 | 4.86E-02 | 5.56E-02 | 0.181 |
| TX-110 | 4.20E-10 | 2.11E-03 | 3.04E-02 | 4.08E-02 | 4.58 | 3.95 | 1.36 | 0.344 | 0.168 | 0.193 | 5.72E-02 | 0.108 |
| TX-111 | 3.98E-10 | 2.00E-03 | 3.04E-02 | 3.93E-02 | 4.52 | 3.8 | 1.31 | 0.336 | 0.186 | 0.187 | 5.70E-02 | 0.111 |
| TX-112 | 5.04E-10 | 2.50E-03 | 3.32E-02 | 4.44E-02 | 4.92 | 4.23 | 1.58 | 0.35 | 0.166 | 0.217 | 5.82E-02 | 0.118 |
| TX-113 | 3.29E-10 | 1.61E-03 | 3.54E-02 | 3.20E-02 | 4.46 | 2.98 | 1.18 | 0.242 | 0.34 | 0.159 | 5.46E-02 | 0.14 |
| TX-114 | 4.50E-10 | 2.22E-03 | 4.09E-02 | 4.33E-02 | 4.81 | 4.27 | 1.52 | 0.344 | 0.292 | 0.214 | 5.62E-02 | 0.129 |
| TX-115 | 4.94E-10 | 2.44E-03 | 3.59E-02 | 4.63E-02 | 5.17 | 4.35 | 1.61 | 0.361 | 0.109 | 0.217 | 5.89E-02 | 0.117 |
| TX-116 | 2.02E-10 | 3.84E-04 | 8.39E-02 | 2.09E-02 | 2.13 | 2.9 | 0.568 | 0.218 | 1 | 0.136 | 0.713 | 0.128 |
| TX-117 | 3.62E-10 | 1.05E-03 | 6.58E-02 | 3.17E-02 | 3.29 | 3.35 | 0.951 | 0.257 | 0.689 | 0.163 | 0.349 | 0.134 |
| TX-118 | 4.76E-06 | 1.27E-03 | 7.32E-02 | 2.30E-02 | 7.74 | 2.28 | 0.806 | 0.247 | 7.61E-02 | 9.79E-02 | 2.94E-02 | 4.29E-02 |
| TY-101 | 0 | 0 | 0.19 | 7.97E-03 | 1.69 | 1.24 | 0.484 | 0.236 | 0.926 | 6.53E-02 | 8.07E-02 | 0.186 |
| TY-102 | 2.30E-10 | 1.15E-03 | 6.55E-02 | 2.83E-02 | 3.03 | 3.52 | 0.867 | 0.291 | 0.814 | 0.164 | 3.87E-02 | 0.118 |
| TY-103 | 1.28E-10 | 6.34E-04 | 0.206 | 1.83E-02 | 3.84 | 1.9 | 0.709 | 0.346 | 0.199 | 0.108 | 4.86E-02 | 9.07E-02 |
| TY-104 | 0 | 0 | 0.323 | 1.48E-02 | 5.19 | 2.05 | 0.345 | 0.478 | 0.111 | 0.121 | 0 | 0 |
| TY-105 | 0 | 0 | 0.24 | 1.81E-02 | 3.81 | 2.59 | 0.344 | 0.43 | 0.136 | 0.149 | 0 | 0 |
| TY-106 | 0 | 0 | 9.25E-02 | 7.48E-04 | 0.263 | 0.104 | 1.75E-02 | 2.42E-02 | 5.63E-03 | 6.14E-03 | 5.4 | 0 |



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**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in $\mu$g/g, and Sr-90, Cs-137, and Pu-239 in $\mu$Ci/g (cont'd).**

| Tank | $Sr^{2+}$ | $Mn^{4+}$ | $Ca^{2+}$ | $K^{+}$ | $OH^{-}$ | $NO_3^{-}$ | $NO_2^{-}$ | $CO_3^{2-}$ | $PO_4^{3-}$ | $SO_4^{2-}$ | $SiO_3^{2-}$ | $F^{-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U-101 | 0 | 0 | 7.40E-02 | 2.41E-04 | 10.8 | 5.50E-02 | 8.05E-03 | 1.66 | 0.352 | 7.22E-02 | 1.36E-03 | 0 |
| U-102 | 1.69E-05 | 3.59E-03 | 4.29E-02 | 5.38E-02 | 7.71 | 4.91 | 2.1 | 0.656 | 0.14 | 0.248 | 7.54E-02 | 8.16E-02 |
| U-103 | 1.35E-05 | 3.60E-03 | 3.92E-02 | 5.38E-02 | 7.25 | 4.99 | 2.15 | 0.57 | 0.121 | 0.245 | 7.62E-02 | 8.09E-02 |
| U-104 | 2.72E-10 | 1.29E-03 | 7.87E-02 | 3.16E-02 | 7.79 | 2.64 | 1.06 | 0.812 | 0.197 | 0.154 | 1.85 | 8.98E-02 |
| U-105 | 1.62E-05 | 3.93E-03 | 4.29E-02 | 5.89E-02 | 7.97 | 5.41 | 2.34 | 0.631 | 0.133 | 0.269 | 8.36E-02 | 8.71E-02 |
| U-106 | 1.75E-05 | 4.37E-03 | 4.59E-02 | 5.96E-02 | 8.81 | 5.39 | 2.48 | 0.725 | 0.141 | 0.276 | 8.77E-02 | 6.94E-02 |
| U-107 | 1.26E-05 | 3.24E-03 | 5.11E-02 | 4.64E-02 | 13.4 | 4.42 | 2.1 | 0.389 | 7.69E-02 | 0.204 | 6.91E-02 | 6.46E-02 |
| U-108 | 1.41E-05 | 4.47E-03 | 5.54E-02 | 5.91E-02 | 8.82 | 5.41 | 2.58 | 0.516 | 9.99E-02 | 0.264 | 8.71E-02 | 6.63E-02 |
| U-109 | 1.26E-05 | 4.76E-03 | 5.03E-02 | 6.41E-02 | 10.9 | 5.87 | 2.81 | 0.64 | 0.122 | 0.291 | 9.68E-02 | 7.21E-02 |
| U-110 | 0 | 0 | 7.66E-02 | 2.85E-03 | 3.87 | 0.334 | 0.157 | 0.309 | 1.21 | 4.95E-02 | 5.52E-02 | 0.144 |
| U-111 | 8.85E-06 | 2.40E-03 | 3.31E-02 | 3.53E-02 | 5.14 | 3.27 | 1.56 | 0.287 | 0.11 | 0.154 | 5.28E-02 | 5.37E-02 |
| U-112 | 0 | 0 | 9.47E-02 | 3.50E-03 | 9.48 | 0.319 | 0.513 | 9.47E-02 | 0.87 | 3.24E-02 | 4.54E-02 | 0.108 |
| U-201 | 0 | 0 | 9.66E-02 | 1.18E-03 | 33.4 | 0.457 | 0.767 | 9.66E-02 | 1.90E-06 | 6.71E-03 | 1.61E-02 | 2.34E-06 |
| U-202 | 0 | 0 | 9.66E-02 | 1.18E-03 | 33.4 | 0.457 | 0.767 | 9.66E-02 | 0 | 6.71E-03 | 1.61E-02 | 0 |
| U-203 | 0 | 0 | 8.85E-02 | 7.23E-03 | 30.4 | 1.52 | 1.58 | 9.22E-02 | 6.64E-03 | 2.40E-02 | 3.25E-02 | 8.18E-03 |
| U-204 | 0 | 0 | 8.05E-02 | 9.79E-04 | 27.8 | 0.381 | 0.639 | 8.05E-02 | 0 | 5.59E-03 | 1.34E-02 | 0 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in μg/g, and Sr-90, Cs-137, and Pu-239 in μCi/g (cont'd).**

| Tank | Pu-239 (μCi/g) | U-238 (μg/g) | Cs-137 (μCi/g) | Sr-90 (μCi/g) |
|---|---|---|---|---|
| A-101 | 4.29E-02 | 1.45E+03 | 155 | 79.8 |
| A-102 | 0.243 | 1.46E+04 | 83.5 | 511 |
| A-103 | 9.48E-02 | 1.45E+03 | 161 | 128 |
| A-104 | 7.03 | 629 | 176 | 9.00E+03 |
| A-105 | 1.04 | 2.95E+04 | 396 | 9.67E+03 |
| A-106 | 1.62 | 3.66E+04 | 142 | 2.54E+03 |
| AN-101 | 2.32E-02 | 900 | 83 | 35.8 |
| AN-102 | 5.82E-02 | 1.95E+03 | 194 | 89.6 |
| AN-103 | 7.17E-02 | 2.19E+03 | 154 | 88.4 |
| AN-104 | 4.85E-02 | 1.55E+03 | 140 | 68.3 |
| AN-105 | 6.62E-02 | 2.10E+03 | 194 | 89.1 |
| AN-106 | 3.84E-02 | 1.32E+03 | 132 | 55 |
| AN-107 | 4.43E-02 | 1.43E+03 | 168 | 62.4 |
| AP-101 | 6.71E-03 | 192 | 10.6 | 8.18 |
| AP-102 | 2.95E-02 | 1.01E+03 | 102 | 42.3 |
| AP-103 | 1.16E-02 | 339 | 58 | 12.5 |
| AP-104 | 0 | 0 | 0 | 0 |
| AP-105 | 6.69E-02 | 1.91E+03 | 106 | 82.7 |
| AP-106 | 2.78E-02 | 798 | 39.8 | 33.4 |
| AP-107 | 0 | 0 | 0 | 0 |
| AP-108 | 1.24E-02 | 383 | 34.2 | 15.4 |
| AW-101 | 7.54E-02 | 2.21E+03 | 160 | 95.3 |
| AW-102 | 4.49E-02 | 1.29E+03 | 76.3 | 57.7 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in μg/g, and Sr-90, Cs-137, and Pu-239 in μCi/g (cont'd).**

| Tank | Pu-239 (μCi/g) | U-238 (μg/g) | Cs-137 (μCi/g) | Sr-90 (μCi/g) |
|---|---|---|---|---|
| AW-103 | 0.383 | 536 | 2.06 | 1.74 |
| AW-104 | 7.49E-03 | 101 | 26.5 | 22.9 |
| AW-105 | 0.163 | 856 | 36.9 | 27.4 |
| AW-106 | 4.88E-02 | 1.40E+03 | 75.1 | 60.8 |
| AX-101 | 6.69E-02 | 2.48E+03 | 166 | 209 |
| AX-102 | 1.87 | 1.07E+04 | 182 | 2.64E+03 |
| AX-103 | 0.164 | 4.86E+03 | 179 | 1.24E+03 |
| AX-104 | 1.04 | 2.95E+04 | 396 | 9.67E+03 |
| AY-101 | 0.354 | 5.21E+03 | 50.2 | 515 |
| AY-102 | 0.195 | 5.08E+03 | 14.3 | 179 |
| AZ-101 | 0.144 | 6.10E+03 | 1.76E+03 | 1.50E+03 |
| AZ-102 | 0.191 | 989 | 1.02E+03 | 950 |
| B-101 | 1.14 | 2.61E+04 | 17.6 | 1.36E+03 |
| B-102 | 4.72E-02 | 3.15E+04 | 13.1 | 10 |
| B-103 | 9.12E-03 | 1.65E+04 | 13.5 | 10.9 |
| B-104 | 1.31E-02 | 239 | 10.5 | 2.53 |
| B-105 | 1.02E-02 | 809 | 13.7 | 9.6 |
| B-106 | 9.50E-03 | 938 | 14.4 | 11.3 |
| B-107 | 5.93E-03 | 106 | 9.42 | 8.90E-02 |
| B-108 | 8.31E-03 | 670 | 12.7 | 7.64 |
| B-109 | 0.136 | 4.10E+03 | 41.3 | 13.7 |
| B-110 | 2.60E-02 | 436 | 5.87 | 139 |
| B-111 | 0.148 | 3.96E+03 | 53.9 | 1.29E+03 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in μg/g, and Sr-90, Cs-137, and Pu-239 in μCi/g (cont'd).**

| Tank | Pu-239 (μCi/g) | U-238 (μg/g) | Cs-137 (μCi/g) | Sr-90 (μCi/g) |
|---|---|---|---|---|
| B-112 | 6.58E-02 | 2.20E+03 | 84.4 | 47.2 |
| B-201 | 9.77E-03 | 0 | 0 | 0 |
| B-202 | 1.00E-02 | 0 | 0 | 0 |
| B-203 | 9.88E-03 | 0 | 0 | 0 |
| B-204 | 9.88E-03 | 0 | 0 | 0 |
| BX-101 | 0.869 | 1.99E+05 | 2 | 789 |
| BX-102 | 0.126 | 1.50E+05 | 0.394 | 2.38 |
| BX-103 | 0.136 | 2.33E+05 | 4.52 | 5.09 |
| BX-104 | 2.62E-02 | 1.27E+05 | 76.9 | 39 |
| BX-105 | 6.86E-03 | 2.49E+05 | 12 | 9.02 |
| BX-106 | 7.52E-02 | 2.32E+04 | 112 | 58.5 |
| BX-107 | 1.02E-02 | 113 | 14.8 | 0.258 |
| BX-108 | 1.15E-02 | 113 | 16.5 | 0.147 |
| BX-109 | 5.57E-03 | 2.11E+04 | 4.82 | 14 |
| BX-110 | 3.73E-02 | 1.07E+03 | 48.1 | 20.9 |
| BX-111 | 9.63E-02 | 3.36E+03 | 120 | 70.7 |
| BX-112 | 1.57E-02 | 316 | 22.4 | 3.01 |
| BY-101 | 9.64E-02 | 3.12E+04 | 140 | 70.1 |
| BY-102 | 9.89E-02 | 1.35E+03 | 125 | 74.6 |
| BY-103 | 0.13 | 314 | 130 | 78.6 |
| BY-104 | 6.27E-02 | 795 | 82 | 47.5 |
| BY-105 | 7.50E-02 | 1.26E+03 | 95.5 | 56.6 |
| BY-106 | 9.30E-02 | 422 | 117 | 69.9 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in μg/g, and Sr-90, Cs-137, and Pu-239 in μCi/g (cont'd).**

| Tank | Pu-239 (μCi/g) | U-238 (μg/g) | Cs-137 (μCi/g) | Sr-90 (μCi/g) |
|---|---|---|---|---|
| BY-107 | 6.69E-02 | 639 | 85.4 | 50.5 |
| BY-108 | 3.43E-02 | 1.02E+03 | 48.3 | 26.6 |
| BY-109 | 9.76E-02 | 2.01E+03 | 121 | 73.3 |
| BY-110 | 6.27E-02 | 643 | 81.2 | 46.5 |
| BY-111 | 0.101 | 1.43E+03 | 125 | 75.6 |
| BY-112 | 0.104 | 435 | 130 | 78.3 |
| C-101 | 0.566 | 3.47E+04 | 1.26 | 6.19 |
| C-102 | 1.02 | 3.16E+04 | 1.23 | 1.59 |
| C-103 | 1.15 | 4.10E+03 | 55.4 | 1.28E+03 |
| C-104 | 0.941 | 2.82E+04 | 41 | 749 |
| C-105 | 0.527 | 1.74E+04 | 1.49 | 2.7 |
| C-106 | 3.67 | 2.52E+04 | 67.3 | 4.20E+03 |
| C-107 | 0.392 | 1.78E+04 | 9.55 | 443 |
| C-108 | 3.72E-03 | 1.84E+04 | 248 | 6.3 |
| C-109 | 8.23E-04 | 3.17E+04 | 865 | 1.36E+03 |
| C-110 | 5.93E-03 | 105 | 9.44 | 8.35E-02 |
| C-111 | 0.176 | 9.27E+03 | 123 | 0.42 |
| C-112 | 0.109 | 3.47E+04 | 863 | 121 |
| C-201 | 2.03E-03 | 1.48E+05 | 0.263 | 5.65E+03 |
| C-202 | 0 | 0 | 0 | 1.25E+04 |
| C-203 | 3.08E-03 | 2.24E+05 | 0.399 | 2.14E +03 |
| C-204 | 2.63E-03 | 1.92E+05 | 0.34 | 3.65E+03 |
| S-101 | 0.162 | 4.71E+03 | 123 | 223 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in μg/g, and Sr-90, Cs-137, and Pu-239 in μCi/g (cont'd).**

| Tank | Pu-239 (μCi/g) | U-238 (μg/g) | Cs-137 (μCi/g) | Sr-90 (μCi/g) |
|---|---|---|---|---|
| S-102 | 4.29E-02 | 1.57E+03 | 133 | 68.7 |
| S-103 | 5.45E-02 | 2.05E+03 | 167 | 103 |
| S-104 | 0.194 | 6.53E+03 | 125 | 349 |
| S-105 | 4.13E-02 | 1.78E+03 | 164 | 71.2 |
| S-106 | 0.153 | 3.55E+03 | 167 | 68.2 |
| S-107 | 0.814 | 1.68E+04 | 56.7 | 193 |
| S-108 | 4.51E-02 | 1.91E+03 | 174 | 81.4 |
| S-109 | 8.73E-02 | 2.55E+03 | 165 | 73.4 |
| S-110 | 0.14 | 3.81E+03 | 125 | 211 |
| S-111 | 8.15E-02 | 2.72E+03 | 170 | 152 |
| S-112 | 5.51E-02 | 2.08E+03 | 175 | 79.2 |
| SX-101 | 4.72E-02 | 3.48E+03 | 115 | 326 |
| SX-102 | 5.66E-02 | 2.30E+03 | 168 | 151 |
| SX-103 | 6.37E-02 | 2.57E+03 | 173 | 107 |
| SX-104 | 5.40E-02 | 2.61E+03 | 154 | 189 |
| SX-105 | 5.80E-02 | 2.73E+03 | 169 | 166 |
| SX-106 | 5.25E-02 | 1.88E+03 | 160 | 76.7 |
| SX-107 | 2.44E-02 | 1.16E+04 | 83.9 | 1.50E+03 |
| SX-108 | 1.16E-02 | 1.06E+04 | 62.1 | 1.50E+03 |
| SX-109 | 7.48E-02 | 7.24E+03 | 161 | 576 |
| SX-110 | 4.60E-02 | 1.98E+04 | 127 | 2.24E+03 |
| SX-111 | 3.71E-02 | 1.47E+04 | 108 | 1.74E+03 |
| SX-112 | 3.10E-02 | 1.30E+04 | 95.9 | 1.60E+03 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in μg/g, and Sr-90, Cs-137, and Pu-239 in μCi/g (cont'd).**

| Tank | Pu-239 (μCi/g) | U-238 (μg/g) | Cs-137 (μCi/g) | Sr-90 (μCi/g) |
|---|---|---|---|---|
| SX-113 | 2.24E-03 | 718 | 11.1 | 146 |
| SX-114 | 6.94E-02 | 1.18E+04 | 157 | 1.13E+03 |
| SX-115 | 5.41E-02 | 4.44E+03 | 125 | 439 |
| SY-101 | 6.34E-02 | 2.24E+03 | 189 | 93.4 |
| SY-102 | 0.797 | 82.8 | 28.5 | 3.11 |
| SY-103 | 5.20E-02 | 1.84E+03 | 164 | 76.5 |
| T-101 | 1.32 | 3.71E+04 | 28.9 | 16.8 |
| T-102 | 0.738 | 4.19E+04 | 0.836 | 0.998 |
| T-103 | 0.85 | 3.55E+04 | 2.16 | 2.17 |
| T-104 | 1.26E-02 | 121 | 18.1 | 0.441 |
| T-105 | 1.33E-02 | 43.1 | 6.35 | 6.07E-02 |
| T-106 | 0.944 | 1.80E+04 | 10.6 | 0.771 |
| T-107 | 5.70E-03 | 101 | 9.07 | 8.03E-02 |
| T-108 | 8.82E-03 | 708 | 11 | 6.3 |
| T-109 | 1.10E-02 | 1.16E+03 | 12.2 | 11 |
| T-110 | 1.13E-02 | 13.3 | 0.179 | 2.15E-02 |
| T-111 | 1.08E-02 | 11.3 | 0.189 | 3.06E-02 |
| T-112 | 9.49E-03 | 9.86 | 0.216 | 4.40E-02 |
| T-201 | 9.77E-03 | 0 | 0 | 0 |
| T-202 | 1.00E-02 | 0 | 0 | 0 |
| T-203 | 1.00E-02 | 0 | 0 | 0 |
| T-204 | 1.00E-02 | 0 | 0 | 0 |
| TX-101 | 0.616 | 1.40E+04 | 56.3 | 573 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in μg/g, and Sr-90, Cs-137, and Pu-239 in μCi/g (cont'd).**

| Tank | Pu-239 (μCi/g) | U-238 (μg/g) | Cs-137 (μCi/g) | Sr-90 (μCi/g) |
|---|---|---|---|---|
| TX-102 | 4.57E-02 | 4.68E+03 | 132 | 57.2 |
| TX-103 | 3.01E-02 | 1.04E+03 | 83.2 | 36.1 |
| TX-104 | 3.24E-02 | 8.88E+04 | 87.6 | 40.4 |
| TX-105 | 4.62E-02 | 5.98E+03 | 136 | 53.7 |
| TX-106 | 4.53E-02 | 2.59E+03 | 130 | 62.4 |
| TX-107 | 8.94E-03 | 8.62E+04 | 21.9 | 11 |
| TX-108 | 3.55E-02 | 7.36E+03 | 104 | 41.6 |
| TX-109 | 1.25E-02 | 115 | 17.7 | 0.158 |
| TX-110 | 4.40E-02 | 1.49E+03 | 124 | 51.1 |
| TX-111 | 4.35E-02 | 1.45E+03 | 121 | 50.2 |
| TX-112 | 4.49E-02 | 1.69E+03 | 138 | 52.3 |
| TX-113 | 3.84E-02 | 1.28E+03 | 121 | 35.4 |
| TX-114 | 4.30E-02 | 1.68E+03 | 136 | 47.3 |
| TX-115 | 4.71E-02 | 2.04E+03 | 150 | 52.1 |
| TX-116 | 2.00E-02 | 1.26E+03 | 58.6 | 17.4 |
| TX-117 | 3.16E-02 | 1.50E+03 | 122 | 26.1 |
| TX-118 | 2.72 | 863 | 71.1 | 31.8 |
| TY-101 | 1.62E-02 | 599 | 334 | 5.05 |
| TY-102 | 2.73E-02 | 1.33E+03 | 69.7 | 30.7 |
| TY-103 | 1.92E-02 | 1.02E+04 | 203 | 21 |
| TY-104 | 3.04E-03 | 2.40E+04 | 0.967 | 15.9 |
| TY-105 | 3.58E-03 | 1.81E+04 | 1.06 | 19.7 |
| TY-106 | 4.59E-04 | 3.63E+03 | 0.146 | 2.4 |

**Hanford defined waste tank inventories (Agnew, 1996). Chemical constituents are reported in mole/liter, U-238 in μg/g, and Sr-90, Cs-137, and Pu-239 in μCi/g (cont'd).**

| Tank | Pu-239 (μCi/g) | U-238 (μg/g) | Cs-137 (μCi/g) | Sr-90 (μCi/g) |
|---|---|---|---|---|
| U-101 | 3.44E-03 | 2.51E+05 | 0.446 | 3.9 |
| U-102 | 5.02E-02 | 3.58E+04 | 147 | 70.9 |
| U-103 | 5.13E-02 | 2.24E+04 | 149 | 72.9 |
| U-104 | 3.98E-02 | 1.19E+05 | 152 | 27.3 |
| U-105 | 5.43E-02 | 2.42E+04 | 157 | 77.7 |
| U-106 | 5.40E-02 | 3.45E+04 | 151 | 82.1 |
| U-107 | 0.343 | 6.65E+03 | 130 | 62.5 |
| U-108 | 0.229 | 7.77E+03 | 161 | 84.3 |
| U-109 | 0.134 | 1.77E+04 | 167 | 87.7 |
| U-110 | 5.56E-03 | 4.53E+04 | 7.95 | 0.772 |
| U-111 | 3.83E-02 | 1.50E+03 | 119 | 85.4 |
| U-112 | 0.236 | 4.56E+03 | 14.5 | 110 |
| U-201 | 1.26 | 2.16E+04 | 1.3 | 1.05 |
| U-202 | 1.26 | 2.16E+04 | 1.29 | 1.04 |
| U-203 | 1.03 | 1.80E+04 | 32 | 11.8 |
| U-204 | 1.12 | 1.92E+04 | 1.15 | 0.928 |