6.0 PRESENT SANITARY LANDFILL – 2001 UPDATE

This section presents the CY 2001 groundwater quality data for the Present Sanitary Landfill (Landfill), previously known as OU 7, which is located in the Buffer Zone north of the IA. Throughout 2001, groundwater monitoring was conducted in accordance with the requirements of the RFCA (RFCA, 1996) as set forth in the IMP (K-H, 2000a). The Present Sanitary Landfill occupies approximately 44 acres (including the Landfill and East Landfill Pond) at the western end of the No Name Gulch drainage (Figure 6-1). It utilizes a surface and subsurface water intercept and diversion system to route surface run-on and upgradient groundwater around the facility, and a leachate collection and treatment system to improve the water quality of leachate exiting the toe of the Landfill near the west end of the East Landfill Pond. The Landfill served as a former solid waste disposal facility for RFETS and is currently scheduled for cover and final closure beginning in March 2003 with completion estimated to occur in late 2003.

6.1 Operating History of the Present Sanitary Landfill

The Present Sanitary Landfill began operating in August 1968 for the disposal of Rocky Flats sanitary waste. However, records indicate that, prior to 1986, some hazardous waste was disposed of at the Landfill. Therefore, in 1986, the Landfill was classified as an RCRA-regulated unit and disposal of hazardous constituents in the Landfill was halted. The Landfill remained in operation, accepting only sanitary waste until March 1998. At that time the Landfill was placed in contingent operational status because it was nearing capacity and was seeded to stabilize soils and control erosion. Currently, all RFETS sanitary waste is transferred to an offsite Subtitle D sanitary waste landfill for disposal. The following paragraphs provide a brief summary of historical Present Sanitary Landfill operations.

In September 1973, tritium was detected in leachate draining from the Landfill. In response to this detection, a sampling program was initiated to determine the location of the tritium source. In addition, monitoring of waste prior to burial was initiated to prevent further disposal of radioactive material, and interim-response measures were undertaken to control the generation and migration of Landfill leachate. Interim-response measures included the construction of two ponds (the East and West Landfill Ponds) immediately east of the Landfill, and the installation of a subsurface leachate-collection system and subsurface intercept system for diverting groundwater around the Landfill. Ditches were also constructed to control surface water. Groundwater diverted from the Landfill by the intercept system is directed eastward around waste materials and discharges either to the East Landfill Pond or east of the East Landfill Pond dam at surface water monitoring locations SW099 and SW100.

Between 1977 and 1981, the leachate-collection trench was buried beneath waste during Landfill expansion (DOE, 1996c). The west embankment and West Landfill Pond were removed in 1981, and two slurry walls were constructed, extending from the ends of the north and south groundwater-interceptor ditches. These slurry walls, ranging in depth from 10 to 25 feet, were reportedly keyed into bedrock.

In 1995, a gravity flow treatment system was constructed to collect contaminated groundwater and leachate flowing from the eastern end of the Present Sanitary Landfill. The Passive Seep Interception and Treatment System (PSITS) became operational in early 1996 and was designed to treat Landfill leachate to eliminate F039-listed wastes prior to discharge into the East Landfill Pond.

The Annual RCRA Groundwater Monitoring Reports for RFETS (DOE, 1990; 1991a, 1992d, 1993c, 1994c, 1995, and 1996a) describe chemical and physical aspects of groundwater for 1989 through 1995 at the Present Sanitary Landfill. The *Phase I RCRA Facility Investigation/Remedial Investigation Work Plan for Operable Unit 7: Present Sanitary Landfill* (DOE, 1991b) presents additional information regarding construction, operation, regulatory history, and site characterization. Subsequent groundwater monitoring activities conducted under the RFCA during calendar years 1996, 1997, 1998, and 1999 are presented in annual Present Sanitary Landfill Groundwater Monitoring Reports (DOE, 1997b; 1998a, 1999, and 2000).

A closure plan for the Present Sanitary Landfill was developed in the IM/IRA decision document (DOE, 1996b), in accordance with the RFCA and applicable Colorado hazardous-waste regulations. Post-closure groundwater monitoring of the Landfill will be performed in accordance with the requirements of the IMP.

6.2 Summary of Previous Investigations

In 1992, groundwater from surficial deposits within and around the Present Sanitary Landfill had concentrations of major anions, total dissolved solids (TDS), dissolved metals, and radionuclides that were elevated relative to mean background concentrations/activities. Some VOCs were also detected. The infrequent occurrence of VOCs in UHSU bedrock indicated that, at that time, the Landfill had not adversely impacted groundwater in UHSU bedrock, even though some contamination of groundwater had occurred in surficial materials overlying the bedrock.

In 1993, the groundwater chemistry at the Present Sanitary Landfill was generally consistent with conditions of 1992 (DOE, 1994c). The 1993 statistical comparisons of upgradient versus downgradient UHSU groundwater at the Landfill indicated statistically significant increases in downgradient concentrations of dissolved metals and major anions. Neither radionuclides nor VOCs showed a statistically significant difference in upgradient versus downgradient activities or concentrations, respectively.

Analysis of 1994 data by ANOVA indicated statistically significant differences in upgradient versus downgradient groundwater quality in the UHSU for radionuclides, dissolved metals, anions, and TDS (DOE, 1995). In the UHSU bedrock, there were statistically significant differences in upgradient versus downgradient groundwater quality for dissolved metals, anions, and TDS. For 1995 data, statistical comparisons of upgradient versus downgradient UHSU groundwater at the Landfill indicated statistically significant increases in levels of dissolved metals, uranium isotopes, anions, and TDS. Activities of total americium-241, plutonium-239/240, and tritium did not show statistically significant differences between upgradient and downgradient UHSU groundwater.

Analysis of the 1996 data tended to confirm the results of previous sampling (DOE, 1997f). Detected analytes and concentration ranges during 1996 were generally consistent with corresponding data from prior years. Nitrate and tritium were evaluated using ANOVA techniques and were determined to be statistically similar in upgradient versus downgradient samples. As in prior investigations, there was no indication of VOC contamination in downgradient wells. For 1997, statistical analyses of groundwater data indicated that the trends of potential contaminants detected in the downgradient wells did not appear to be increasing with time, resulting in no reportable exceedances for 1997 (DOE, 1998b).

Results of hydrogeologic investigations of the Present Sanitary Landfill suggest that the groundwater-intercept system may not completely isolate the Landfill from the surrounding groundwater. Hydraulic assessments for specific areas on the north, west, and south sides of the groundwater-intercept system indicate that groundwater may flow into the Landfill on the north side where the leachate collection system may not have been completely keyed into bedrock (DOE, 1996b). In addition, previous reports indicate that the leachate collection trench was buried beneath waste during Landfill expansion (DOE, 1996b). Therefore, the clay cutoff wall no longer extends to the surface of the Landfill; this would allow groundwater to flow across the clay cutoff wall if the water table were to rise sufficiently. Landfill wastes do not extend to the surface-water interceptor ditch.

6.3 Current Groundwater Monitoring Program

The Present Sanitary Landfill at RFETS currently operates under CDPHE and EPA guidelines for solid waste disposal sites and facilities. The current groundwater-monitoring program was instituted in accordance with the RFCA, as further defined for RCRA units in the IMP. RCRA groundwater monitoring is conducted to detect potential releases of contamination beyond an established point of compliance based on comparisons of upgradient to downgradient groundwater quality. Under the IMP, if significant impacts to groundwater quality are detected in downgradient RCRA wells and contaminant concentrations are observed to increase with time, then the results are reported to EPA and CDPHE and an investigation into possible causes is initiated. Special attention is given to groundwater contaminants listed in the ALF for Surface Water, Groundwater, and Soils document, Attachment 5 (RFCA, 1996), which if exceeded trigger an evaluation, remedial action, and/or management action. Non-ALF constituents, such as the major cation metals sodium, potassium, calcium, and magnesium, are not reportable under RFCA, and therefore not emphasized in this report. Figure 6-1 illustrates the location of existing and abandoned monitoring wells in relationship to relevant surface and subsurface features at the Landfill.

Changes to the Site groundwater monitoring program implemented in 2001 are outlined in the IMP (K-H, 2001a). This Plan specifies the monitoring and reporting requirements for the Present Sanitary Landfill, including well identification, sampling frequency, analytical requirements, and reporting.

For the CY 2001 reporting period, Upgradient Wells 5887, 70193, 70393, and 70493, and Downgradient Wells 4087, 52894, 52994, and B206989 were sampled on a quarterly basis to determine compliance with RFCA, as set forth in the IMP. Table 6-1 summarizes sampling activities and shows the hydrostratigraphic unit monitored and

material screened for these wells. The limited number and position of these wells makes it infeasible to construct potentiometric surface maps and concentration isopleth maps, thus current and future reports will only assess impacts to or from the landfill at the upgradient and downgradient landfill boundaries.

Table 6-1 Well Completion Information and CY 2001 Sampling Summary for Present Sanitary Landfill Wells

Well	Hydro-Stratigraphic Unit	Screened Material	Quarterly Sampling Summary			
			Q1	Q2	Q3	Q4
Upgradient Wells						
5887	UPPER	ALLUVIUM	V,W,N,M,T,U	V,W,N,M,T,U	V,W,N,M,T,U	V,W,N,M,T,U
70193	UPPER	BEDROCK	V,W,N,M,T,U	V,W,N,M,T,U	V,W,N,M,T,U	V,W,N,M,T,U
70393	UPPER	ALLUVIUM	V,W,N,M,T,U	V,W,N,M,T,U	V,W,N,M,T,U	V,W,N,M,T,U
70493	UPPER	BEDROCK	V,W,N,M,T,U	V,W,N,M,T,U	V,W,N,M,T,U	V,W,N,M,T,U
Downgradient Wells						
4087	UPPER	ALLUVIUM	V,W,N,M,T,U	V,W,N,M,T,U	V,N,M,T,U	Dry
52894	UPPER	ALLUVIUM	Dry	Dry	V,W,N,M,T,U	Dry
52994	UPPER	BEDROCK	V	V	V	V
B206989	UPPER	BEDROCK	V,N,M,T	V	V,W,N,M,T,U	V,W,N,M.T,U

Notes: V=Volatile organic compounds, W=Water quality parameters, N=Nitrate/nitrite, M=Metals, T=Tritium, U=Uranium isotopes

Groundwater elevations for active wells were measured quarterly as directed in the IMP. Quarterly groundwater samples were analyzed for radionuclides (tritium [liquid scintillation counting] and uranium isotopes [alpha spectroscopy]), VOCs (EPA 524.2), metals (CLP-SOW), and major anions (TDS [EPA 160.1], sulfate [SW846], fluoride [EPA 300.0], and nitrate/nitrite [EPA 353.1]), in accordance with Appendix E-2 of the IMP. The absence of complete analyte suites in most quarters for the downgradient wells listed in Table 6-1 is caused by sample volume limitations (see dry and lacked water [LW] codes in Figures 6-2 through 6-5) imposed by slow recharge and/or thin saturation conditions. The alluvium and weathered bedrock at these localities are frequently dry or thinly saturated because the dam for the East Landfill Pond acts as a barrier to alluvial groundwater flow from the west. In addition, ET through valley bottom vegetation consumes much of the available shallow groundwater in the No Name Gulch drainage during the summer months. For these reasons, it is normally not possible to collect complete sample sets for each quarterly sampling period during the year.

Some historical potential contaminants-of-concern (PCOCs), such as semivolatile organic compounds (SVOCs), were not included in the sampling program as a result of PCOC screening conducted during the IMP DQO process and acceptance of the plan by EPA and CDPHE. Table 6-2 lists the constituents monitored for in wells within and near the Present Sanitary Landfill. The records of analyses and evaluations are currently maintained in compliance with Code of Colorado Regulations *6 CCR 1007-2*.

Table 6-2 Chemical and Radiological Constituents Monitored at the Present Sanitary Landfill

Volatile Organic Compounds	Volatile Organic Compounds	Metals
1,1,1,2-Tetrachloroethane	Cis-1,2-Dichloroethene	Cadmium
1,1,1-Trichloroethane	Cis-1,3-Dichloropropene	Calcium
1,1,2,2-Tetrachloroethane	Dibromochloromethane	Chromium
1,1,2-Trichloroethane	Dibromomethane	Cobalt
1,1-Dichloroethane	Dichlorodifluoromethane	Copper
1,1-Dichloroethene	Ethylbenzene	Iron
1,1-Dichloropropene	Hexachlorobutadiene	Lead
1,2,3-Trichlorobenzene	Isopropylbenzene	Lithium
1,2,3-Trichloropropane	Methylene Chloride	Magnesium
1,2,4-Trichlorobenzene	Naphthalene	Manganese
1,2,4-Trimethylbenzene	n-Butylbenzene	Mercury
1,2-Dibromo-3-chloropropane	n-Propylbenzene	Molybdenum
1,2-Dibromoethane	o-Chlorotoluene	Nickel
1,2-Dichlorobenzene	p-Chlorotoluene	Potassium
1,2-Dichloroethane	4-Isopropyltoluene	Selenium
1,2-Dichloropropane	sec-Butylbenzene	Silver
1,3,5-Trimethylbenzene	Styrene	Sodium
1,3-Dichlorobenzene	tert-Butylbenzene	Strontium
1,3-Dichloropropane	Tetrachloroethene	Thallium
1,4-Dichlorobenzene	Toluene	Tin
Bromobenzene	Trans-1,3-Dichloropropene	**Water Quality Parameters**
Bromochloromethane	Trichloroethene	Fluoride
Bromodichloromethane	Trichlorofluoromethane	Nitrate/Nitrite
Bromoform	Vinyl Chloride	Sulfate
Bromomethane	**Metals**	Total Dissolved Solids
Carbon Tetrachloride	Aluminum	**Radionuclides**
Chlorobenzene	Antimony	Tritium
Chloroethane	Arsenic	Uranium-233/234
Chloroform	Barium	Uranium-235
Chloromethane	Beryllium	Uranium-238

6.4 Physical Characteristics of the Groundwater System

6.4.1 Description of the "Uppermost Aquifer"

The "uppermost aquifer" is equivalent to the UHSU as described in Section 1.0 and in previous RFETS reports (EG&G, 1995a; 1995b, and 1995c). At most of RFETS, including the area of the Present Sanitary Landfill, the UHSU is composed of unconsolidated surficial deposits and weathered bedrock. The unconsolidated deposits consist of Qrf, Qc, Qvf, and artificial fill. The Qrf and artificial fill (landfilled wastes and soil-cover materials) are present upgradient of and within the Landfill; Qc and Qvf are present downgradient of the Landfill. Weathered claystones and weathered sandstones (where present) that are in direct hydraulic communication with the overlying surficial deposits are also considered part of the "uppermost aquifer". The weathered claystones are generally more permeable than unweathered bedrock. Unweathered claystones are not considered as part of the uppermost aquifer, rather they are included as part of the LHSU. Bedrock wells were assigned to a hydrostratigraphic unit based on

geochemical data from the well, hydraulic conductivity measurements (where available), and geological information from borehole logs.

The Qrf is 25 to 30 feet thick on the northwest, west, and southwest sides of the Landfill, and 10 to 15 feet thick on the divides north and south of the East Landfill Pond. Qc is 1 to 5 feet thick on the slopes around the East Landfill Pond and below the dam. The Qvf ranges in thickness from 3 to 8 feet in the Landfill area and becomes thicker downstream (to the east). The thickness of artificial fill increases from about 5 feet at the perimeter of the Landfill to about 45 feet near the centerline of the valley (DOE, 1996c). Weathered bedrock thickness varies considerably in the vicinity of the Landfill, ranging from approximately 4 to 35 feet, as indicated by weathered bedrock isopach mapping of the area (EG&G, 1995a).

In the past, the average depth to groundwater ranged from 5 to 15 feet in surficial deposits, excluding artificial fill (EG&G, 1995b). Within the Landfill, groundwater was found at approximately 20 feet at the western end, 16 feet in the middle, and 33 feet at the eastern end (DOE, 1996c). The depth to groundwater in weathered bedrock is generally greater than in the overlying surficial deposits because of steep downward vertical gradients in bedrock materials. The saturated thickness of UHSU deposits varies widely across the Landfill, with the thickest sections found in the Qrf at the western end. The thinnest saturated sections are found in Qc and Qvf deposits east of the East Landfill Pond and in the Qrf along the south divide. EG&G (1995b) reported saturated thickness ranging from 0 to 20 feet for surficial deposits at the Landfill.

Geometric mean hydraulic conductivities, calculated from field tests of the different geologic units, are given in Section 6.4.4.

6.4.2 Potentiometric Surface

Groundwater is present in surficial deposits and artificial fill, and in bedrock sandstones and claystones in the area of the Present Sanitary Landfill. Groundwater flow patterns in the UHSU tend to mimic the surface topography. Within Landfill wastes, groundwater flows toward the center of the Landfill, then flows eastward toward the East Landfill Pond. Outside the Landfill, groundwater generally flows eastward within saturated UHSU surficial deposits, except near stream valleys, which disrupt UHSU flow patterns and function as drains for UHSU groundwater. For example, near the East Landfill Pond, groundwater flows from the north, west, and south toward the pond because of its topographically low position in the No Name Gulch drainage. Groundwater entering the pond mixes with surface water and is discharged by evaporation or is pumped to Pond A-3. To a limited extent, pond waters percolate downward into underlying bedrock materials or laterally through the dam. Any groundwater seepage past the dam into the lower drainage would flow eastward along the stream course until discharged via ET, surface water, or as lateral subsurface flow at the east RFETS boundary.

Groundwater elevations in monitoring wells are measured at least quarterly. Water levels in the surficial deposits of the UHSU are characterized by seasonal variations of as much as 10 feet. The water table elevation is generally lowest in late winter and early spring, prior to recharge by snowmelt, and highest during June and July. Groundwater elevations in the weathered bedrock of the UHSU typically show seasonal variations of as much as 15 feet.

6.4.3 Vertical Hydraulic Gradients

The vertical hydraulic gradient is the ratio of the differences in water levels measured concurrently in two adjacent wells with different screened intervals, and the vertical distance between the two measuring points, which are specified here as the midpoint of each screened interval. Vertical hydraulic gradient calculations provide a means to evaluate whether groundwater flow has a potential for movement either downward or upward through geologic media.

Most of the Present Sanitary Landfill Well Pairs have been abandoned or deactivated in recent years in preparation for landfill closure. Consequently, current water level data are unavailable for calculation of vertical gradients. The results of historical vertical hydraulic gradient calculations at eight Landfill Monitoring Well Pairs (70093/70193, 70193/70293, 70493/70593, 70693/70893, 72393/72093, 1086/0986, 0786/0886, and B206989/B207089) monitored through 1995 (DOE, 1996a) provide information relevant to understanding groundwater conditions at the Landfill. The calculated vertical hydraulic gradients for all Well Pairs, except 72393/72093, indicate a downward (recharging) component of flow, with values ranging from 0.022 to 1.099 ft/ft. The significance of downward gradients at Well Pairs 0786/0886 and B206989/B207089, located near the bottom of No Name Gulch, are, however, potentially invalid considering that the water levels in the bedrock wells at these locations recharge slowly and never fully recover between sampling episodes. At well pair 72393/72093, situated within the center of the Landfill, groundwater had an upward (discharging) vertical gradient ranging from 0.020 to 0.026 ft/ft. Historical data from all Well Pairs indicate that vertical hydraulic gradients have generally remained constant over time. This condition may exist because disturbances to the Landfill hydrologic system have been minimal in recent years. In addition, groundwater flow within the deeper portions of the UHSU and in LHSU bedrock is relatively insensitive to fluctuations in seasonal water levels and other short-term transient effects because of the prevalent low permeability character of bedrock materials.

6.4.4 Average Linear Groundwater-Flow Velocities

The average linear groundwater flow velocity has historically been calculated for three flowpaths in UHSU surficial deposits and three flowpaths in UHSU bedrock in the vicinity of the Present Sanitary Landfill (DOE, 1996b). Most of the Well Pairs were deactivated in 1995 in preparation for Landfill closure. However, the variables used in calculating flow velocities (hydraulic conductivity, porosity, and hydraulic gradient) have effectively remained constant over time. Hence, the following discussion summarized from the 1995 RCRA Groundwater Monitoring report is considered indicative of current conditions in the Present Sanitary Landfill.

Migration rates for conservative, dissolved constituents approximate the average linear groundwater flow velocity; however, attenuated, volatile, biodegradable, or redox-sensitive species can exhibit migration rates much lower than the average linear groundwater flow velocity. The values of hydraulic conductivity used for surficial deposits and bedrock of the UHSU are the geometric means of hydraulic-conductivity values for each unit at the Landfill, and include results of historic slug tests (DOE, 1994c). Values of hydraulic conductivity used for flow velocity calculations are 1.1×10^{-4} centimeters/second (cm/sec) for surficial deposits (including landfill wastes) and 5.3×10^{-7} cm/sec for UHSU bedrock materials. The assumed effective porosity for all units is 0.1 (DOE, 1991b).

Using these data, the calculated average linear groundwater flow velocities in fill materials range from approximately 1 foot per year at the west end of the Landfill to approximately 160 feet per year at the eastern face of the Landfill. Calculated average linear groundwater flow velocities in UHSU bedrock at the Landfill ranged from approximately 0.20 feet to 0.22 feet per year beneath the Landfill, to approximately 0.07 feet to 0.41 feet per year downgradient of the Landfill (DOE, 1996a). The calculated average linear groundwater flow velocities for UHSU bedrock in 1995 were similar to those reported in the *1994 Annual RCRA Groundwater Monitoring Report* (DOE, 1995).

6.5 Groundwater Quality at the Present Sanitary Landfill

The assessment of groundwater chemistry at the Present Sanitary Landfill includes an evaluation of the spatial distribution of groundwater constituents in and around the Landfill, and a statistical evaluation of the chemistry of downgradient groundwater with respect to upgradient groundwater, as specified in *6 CCR 1007-2* and the IMP. Statistical comparisons between downgradient and upgradient groundwater data were made using the methodology described in the *1995 Annual RCRA Groundwater Monitoring Report* (DOE, 1996a) and *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities* (EPA, 1992b).

Figures 6-2 through 6-5 depict the analytical results for each well in individual box-plots. To show as much data as possible without overcrowding, box-plots for VOCs and metals include only those analytes that were detected above the contract required detection limit (CRDL) in upgradient and downgradient wells. Analytes that were not detected during the entire sampling year have been omitted from the box plots. All data for radionuclides and water quality parameters are presented.

6.5.1 Spatial Distribution of Groundwater Constituents

6.5.1.1 Upgradient Wells

Currently, four wells (5887, 70193, 70393, and 70493) monitor groundwater chemistry in the UHSU immediately upgradient of the Present Sanitary Landfill. Wells 5887 and 70393 are completed in UHSU alluvial materials and wells 70193 and 70493 are completed in UHSU bedrock. All four wells yielded complete quarterly sample sets for a total of 16 upgradient samples per analyte.

As shown in Figure 6-2, concentrations of the water quality parameters (fluoride, nitrate/nitrite, sulfate, and TDS) fall below background concentrations reported for these analytes in the *1993 Background Geochemical Characterization Report* (EG&G, 1993a). A similar situation exists for all of the metal and radionuclide analytes detected in these wells (see Figures 6-3 and 6-4, respectively). Except for the major cations (calcium, magnesium, sodium, potassium, and strontium), the concentrations of most metal analytes were undetected or were reported below the CRDL.

During 2001, alluvial Well 70393 yielded detections of seven chlorinated VOCs, including TCE (22.6 µg/L maximum), PCE (7 µg/L maximum), carbon tetrachloride (0.54 µg/L maximum); 1,1,1-TCA (19.4 µg/L maximum); 1,1-DCE (15.2 µg/L maximum), cis-1,2-DCE (0.1 µg/L maximum), and chloroform (0.26 µg/L maximum). Weathered Bedrock Well 70493, paired with Alluvial Well 70393, contained generally lower concentrations and less consistent detections of the types of VOCs found in the overlying alluvium. VOCs found in this well included TCE (1.3 µg/L maximum), PCE (0.2 µg/L maximum); 1,1,1-TCA (0.54 µg/L maximum); 1,1-DCE (0.3 µg/L maximum), and a single detection of methylene chloride (0.2 µg/L). Alluvial well 5887 contained only methylene chloride (0.32 µg/L maximum). Weathered Bedrock Well 70193 contained only PCE (0.1 µg/L maximum). These results are generally consistent with the results of previous monitoring (DOE, 1998), which determined that the PU&D Yard was the source of this contamination. Results for all other VOC constituents monitored in upgradient wells were below detection.

6.5.1.2 Downgradient Wells

Four wells located east of the East Landfill Pond embankment are used to monitor the chemistry of downgradient groundwater in the UHSU (Wells 4087, 52894, 52994, and B206989). Wells 52994 and B206989 monitor groundwater in the UHSU bedrock and Wells 4087 and 52894 monitor the quality of alluvial groundwater. All of the well locations are consistent with *6 CCR 1007-2*, which allows alternate placement of monitoring wells downgradient of an interim status facility where existing physical obstacles prevent installation of wells at the boundary.

In general, the sampling conditions experienced at downgradient well locations during 2001 were not characteristic of previous years, with groundwater availability limited by extremely dry conditions. Complete sample suites could only be collected from Wells 4087 (3 quarters collected; except for water quality parameters [WQPs] in 3rd quarter), 52894 (1 quarter collected), and B206989 (2 quarters collected). Despite repeated visits to the well to obtain additional sample aliquots, no samples besides VOCs could be collected from Well 52994 (4 quarters of VOCs). Dry well conditions were prevalent at all wells during the remaining quarters. The statistical significance of these data relative to upgradient groundwater quality will be evaluated in Section 6.5.2.

As shown in Figure 6-2, concentrations of some WQPs (fluoride, nitrate/nitrite, sulfate, and TDS) exceed the background concentrations of these analytes. Fluoride was above background concentrations in Wells 4087 (2 mg/L maximum) and 52894 (2.1 mg/L maximum). Nitrate/nitrate exceeded background levels in B206989 (60 mg/L

maximum) along with sulfate (2800 mg/L maximum) and TDS (5200 mg/L). TDS was also above background in well 4087.

The majority of the metals were detected with a "U" or "B" qualifier, signifying that the concentration of these metals were low enough to occur below the instrument detection limit (IDL) or between the CRDL and IDL, respectively. These metals were also commonly reported at low concentrations in many upgradient samples. However, several metals were detected above background concentrations in two downgradient wells. Chromium (44.5 µg/L) and lithium (148 µg/L) were detected in well 4087; copper (16 µg/L), iron (390 µg/L), lithium (2140 µg/L), selenium (303 µg/L), and strontium (6470 µg/L maximum) were detected in B206989 (Figure 6-3). Although several metals, including molybdenum, nickel, and vanadium are not shown on Figure 6-3, statistical comparisons were performed for these analytes in upgradient and downgradient wells. These metals are not shown on Figure 6-3 because they are mostly "B" qualified data. Elevated concentrations of the non-hazardous metals sodium, potassium, calcium, and magnesium were also detected in downgradient wells. These metals have no ALF groundwater action levels and, consequently, are not shown in Figure 6-3.

Radionuclide analytes were all detected below background activities in downgradient monitoring wells (Figure 6-4). One VOC, methylene chloride, was detected in downgradient well 52894 at a very low concentration (0.93 µg/L) (Figure 6-5).

6.5.2 Statistical Evaluation of Groundwater Constituents

According to the IMP, the decision logic for RCRA designated wells requires the performance of a comparison of pooled upgradient groundwater sample means to individual downgradient well sample means in order to evaluate potential contaminant releases from the regulated unit into the "uppermost aquifer". This type of comparison is usually accomplished using statistical analysis procedures such as described in *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities* (EPA, 1992b). An assessment of the 1999 individual downgradient well data sets indicated that the number of sample analyses in all sets (maximum three samples) were insufficient for performing nonparametric analysis (minimum four samples) on an individual well basis. This situation was due to dry conditions in all of the downgradient wells for at least one sampling quarter. To provide adequate data for nonparametric statistical analysis, which applies to the majority of analytes based on normality testing results of the data sets, it was necessary to pool the 1999 downgradient well data for comparison to the upgradient data. Because of the lack of groundwater availability during 2001, this same approach to pooling downgradient well data had to be utilized.

Table 6-3 presents a sampling and detection summary for groundwater analytes that were detected at least once during 2001. Statistical comparisons were not performed for analytes with upgradient sample means that were equal to or greater than downgradient sample means; analytes with less than 10 percent quantifiable results; or analytes with less than four quantifiable results, as recommended by EPA guidance (EPA, 1992b) for nonparametric analysis. A sufficient number of samples were collected from upgradient and downgradient well groups to perform pooled

statistical comparisons for all analytes with more than a 10 percent detection rate. VOCs were excluded from statistical analysis because it has been shown that upgradient Landfill groundwater is contaminated relative to downgradient Landfill groundwater (Figure 6-5) because of the PU&D Yard VOC plume. Data for antimony, arsenic, barium, beryllium, cobalt, lead, silver, thallium, tin, zinc, tritium, and fluoride met the sample volume criteria, but either less than four quantifiable results were present or the upgradient sample means were equal to or greater than downgradient means. Mercury was not detected in any upgradient or downgradient wells. Thus, these analytes were excluded from statistical evaluation. Conclusions concerning these analytes are described following the discussion of statistical comparisons.

For analytes with greater than 10 percent quantifiable results, parametric ANOVA or nonparametric Wilcoxon Rank-Sum testing was performed, depending on the percentage of non-detections present in the sample groups and sample distribution characteristics. All UHSU results (alluvial and bedrock) were grouped by analyte into upgradient and downgradient data sets to simplify analyses and provide adequate data to perform statistical testing. This approach is justifiable because all downgradient wells are closely located in a well defined, narrow drainage that defines the sole groundwater flowpath leading from the Landfill. Based on EPA guidance for statistical evaluations involving two data groups (EPA, 1992a), the Wilcoxon Rank-Sum test (also known as the Mann-Whitney U test) was selected to perform nonparametric comparisons in place of the Kruskall-Wallis test. The reader is referred to the EPA guidance document for further description of the statistical methods and parameters used in this section.

Table 6-3 Groundwater Sample Summary for Detected Analytes in Landfill Wells – CY2001

Parameter	Number of Samples		Number of Detections[1]		Percent Detections		Sample Mean	
	Up-Gradient	Down-Gradient	Up-Gradient	Down-Gradient	Up-Gradient	Down-Gradient	Up-Gradient	Down-Gradient
Water Quality (mg/L)								
Fluoride	16	5	16	3	100.0	60.0	0.404375	1.36
Nitrate/Nitrite, as N	16	7	16	7	100.0	100.0	3.275	17.93857
Sulfate	16	5	16	5	100.0	100.0	23.1	1211.24
Total Dissolved Solids	16	6	16	6	100.0	100.0	167	2216.333
Metals (µg/L)								
Aluminum	14	7	10	6	71.43%	85.71%	25.91	31.60
Antimony	15	7	2	4	13.33%	57.14%	.78	1.27
Arsenic	17	7	5	3	29.41%	42.86%	1.12	1.46
Barium	16	7	16	7	100.00%	100.00%	77.77	29.23
Beryllium	16	7	5	2	31.25%	28.57%	0.17	0.54
Cadmium	16	7	8	6	50.00%	85.71%	0.24	0.58
Calcium	16	7	16	7	100.00%	100.00%	24287.50	248371.43
Chromium	17	7	10	7	58.82%	100.00%	0.76	10.59
Cobalt	16	7	0	1	0.00%	14.29%	0.87	0.68
Copper	17	7	15	7	88.24%	100.00%	1.73	5.46
Iron	16	7	12	5	75.00%	71.43%	26.12	68.83
Lead	17	7	5	3	29.41%	42.86%	0.70	0.76
Lithium	16	7	15	7	93.75%	100.00%	8.00	693.57
Magnesium	16	7	16	7	100.00%	100.00%	5291.88	96285.71
Manganese	16	7	15	6	93.75%	85.71%	1.50	6.97
Mercury	13	6	0	0	0.00%	0.00%	0.05	0.05
Molybdenum	16	7	9	6	56.25%	85.71%	1.28	4.83

Parameter	Number of Samples		Number of Detections[1]		Percent Detections		Sample Mean	
	Up-Gradient	Down-Gradient	Up-Gradient	Down-Gradient	Up-Gradient	Down-Gradient	Up-Gradient	Down-Gradient
Nickel	16	7	10	7	62.50%	100.00%	2.28	5.74
Potassium	16	7	14	7	87.50%	100.00%	984.06	7716.71
Selenium	17	7	14	7	82.35%	100.00%	4.18	126.99
Silver	15	7	4	1	26.67%	14.29%	0.44	0.24
Sodium	16	7	16	7	100.00%	100.00%	12931.25	421542.86
Strontium	16	7	16	7	100.00%	100.00%	158.56	3067.43
Thallium	15	7	3	4	20.00%	57.14%	1.27	1.54
Tin	16	7	1	1	6.25%	14.29%	1.88	2.54
Vanadium	16	7	10	4	62.50%	57.14%	1.06	1.24
Zinc	16	7	12	6	75.00%	85.71%	7.74	7.21
Radionuclides (pCi/L)								
Tritium	16	7	2	2	12.50%	28.57%	-211.44	-52.60
U-233/234	16	6	8	6	50.00%	100.00%	0.44	29.02
U-235	16	6	5	6	31.25%	100.00%	0.05	0.89
U-238	16	6	8	6	50.00%	100.00%	0.24	19.00
Volatile Organic Compounds (µg/L)								
1,1,1-Trichloroethane	16	7	8	0	50.00%	0.00%	N/D	N/D
1,1-Dichloroethene	16	7	6	0	37.50%	0.00%	N/D	N/D
Carbon Tetrachloride	16	7	3	0	18.75%	0.00%	N/D	N/D
Chloroform	16	7	2	0	12.50%	0.00%	N/D	N/D
Cis-1,2-Dichloroethene	16	7	1	0	6.25%	0.00%	N/D	N/D
Methylene Chloride	16	7	2	1	12.50%	14.29%	N/D	N/D
Tetrachloroethene	16	7	6	0	37.50%	0.00%	N/D	N/D
Trichloroethene	16	7	8	0	50.00%	0.00%	N/D	N/D

[1] = No corrections made for non-detects, N/D = Not determined for VOCs because most detections are estimated ("J" qualified) values

Downgradient groundwater quality monitored at Wells 4087, 52894, and B206989 indicates that concentrations of several WQPs and selected hazardous trace metals exceed concentrations reported for Upgradient Wells 5887, 70193, 70393, and 70493 (Figure 6-2 and 6-3). All other non-radioactive ALF groundwater constituents in downgradient groundwater, including VOCs, were detected at or below upgradient concentration levels.

Table 6-4 summarizes the results of statistical comparisons for the upgradient and downgradient data groups. Statistically significant differences (at the 1 percent significance level) in upgradient versus downgradient groundwater quality were found for sulfate, TDS, calcium, copper, lithium, magnesium, molybdenum, selenium, vanadium, U-233/234, U-235, and U-238. These results are similar to those reported in previous RCRA and Present Sanitary Landfill groundwater monitoring reports (see Section 6.2).

Table 6-4 Comparative Statistics for Groundwater Analytes with <90% Sample Non-Detections, Downgradient Sample Means Greater than Upgradient Sample Means, and More Than Four Quantifiable Results – CY 2001

Parameter	Shapiro-Wilk Normality Test				ANOVA		Wilcoxon Rank-Sum Test	
	W_x	$W_{Ln\ x}$	$W_{n,0.05}$	Distribution Type	p-value	Significant Difference	p-value	Significant Difference
Water Quality (mg/L)								
Nitrate/Nitrite (as N)	0.593	0.900	0.916	Non Parametric			0.6159	No
Sulfate	0.510	0.774	0.916	Non Parametric			**0.0011**	**Yes**
TDS	0.519	0.761	0.914	Non Parametric			**0.0011**	**Yes**
Metals (ug/L)								
Aluminum	0.286	0.781	0.914	Non Parametric			0.5135	No
Cadmium	N/A	N/A	N/A	Non Parametric			0.0704	No
Calcium	0.554	0.742	0.916	Non Parametric			**0.0002**	**Yes**
Chromium	N/A	N/A	N/A	Non Parametric			0.651	No
Copper	N/A	N/A	N/A	Non Parametric			**0.0072**	**Yes**
Iron	N/A	N/A	N/A	Non Parametric			0.792	No
Lithium	0.549	0.830	0.916	Non Parametric			**0.0009**	**Yes**
Magnesium	0.549	0.766	0.916	Non Parametric			**0.0002**	**Yes**
Manganese	N/A	N/A	N/A	Non Parametric			0.2585	No
Molybdenum	N/A	N/A	N/A	Non Parametric			**0.0046**	**Yes**
Nickel	N/A	N/A	N/A	Non Parametric			0.028	No
Potassium	0.549	0.815	0.916	Non Parametric			0.0169	No
Selenium	N/A	N/A	N/A	Non Parametric			**0.0085**	**Yes**
Sodium	0.634	0.763	0.916	Non Parametric			**0**	**Yes**
Strontium	0.536	0.778	0.916	Non Parametric			0.094	No
Vanadium	0.678	0.928	0.916	Lognormal			**0.0088**	**Yes**
Radionuclides (pCi/L)								
U-233/234	N/A	N/A	N/A	Non Parametric		Unknown	**0.0007**	**Yes**
U-235	N/A	N/A	N/A	Non Parametric		Unknown	**0.0043**	**Yes**
U-238	N/A	N/A	N/A	Non Parametric		Unknown	**0.0007**	**Yes**

N/A = not applicable
Significant difference in downgradient to upgradient sample groups shown in bold typeface

Antimony, arsenic, beryllium, cobalt, lead, molybdenum, silver, tin, vanadium, and zinc were all "B" qualified indicating they were detected at low concentrations between the IDL and CRDL. Mercury was not detected in either upgradient or downgradient wells. Aluminum (46.2 µg/L), barium (14 µg/L), cadmium (1.3 µg/L), manganese (30.9 µg/L), and thallium (4.5 µg/L) were detected in B206989 below background levels.

6.5.3 Trend Plots and Data Interpretation

Concentration plots of analytes in downgradient wells that exceed upgradient concentrations are presented on pages A-68 through A-71 at the end of Appendix A of this Annual Report. Trend lines (least square regression analysis) have been added for analytes that exhibit a noticeable upward trend. Concentration trends for most of the other analytes tend to fluctuate somewhat, but are generally flat or declining with no obvious trend. These concentration plots generally indicate that potentially contaminated groundwater from the Landfill is not currently migrating eastward past the East Landfill Pond dam at concentrations greater than in the past. Specifically, sulfate, TDS, calcium, copper, lithium, magnesium, molybdenum, selenium, U-235, and U-238 concentrations in all downgradient wells do not appear to be increasing. Although concentrations of calcium, lithium, selenium and U-238 appear to be increasing, statistical analyses of the trend lines indicate the upward slope is apparent and cannot be differentiated from zero. However, vanadium and U-233/234 concentrations in Well B206989 show evidence of a statistically

significant upward trend, making these analytes reportable occurrences under RFCA. The magnesium concentration in well B206989 also appears to be rising; however, this constituent is non-hazardous and lacks RFCA groundwater action levels.

Just because downgradient analyte concentrations do not appear to be increasing statistically over upgradient analyte concentrations, and upgradient versus downgradient analyte concentrations currently appear to be in a steady-state condition, does not mean that contaminated groundwater is no longer migrating past the East Landfill Pond dam. There is still a hydraulic gradient in the downgradient direction.

The elevated concentrations of inorganic and radiological analytes in downgradient groundwater can be caused by several factors. Some potential causes include:

- Lateral underflow of Landfill leachate beneath the pond and dam through UHSU bedrock materials, and
- a secondary contaminant source that is upgradient of the well, but is not associated with the Landfill or pond.

Concentrations of several analytes in the Landfill leachate and pond water have historically been relatively low and as such do not appear to be Landfill related. For example, the mean concentrations of lithium (55 µg/L), and selenium (1.97 µg/L) at surface water monitoring station SW097 (Landfill leachate), and lithium (82 µg/L) at SW098 (East Landfill Pond) (DOE, 1996a; Tables 2-2 and 2-3), are significantly lower than concentrations found in well B206989 groundwater. In addition, concentrations of calcium, sulfate, TDS, U-233/234, U-235, and U-238 are also significantly lower in surface water monitoring stations SW097 and SW098 than concentrations of these analytes detected in B206989. However, concentrations of copper, magnesium, molybdenum, and vanadium are significantly higher at these surface water-monitoring locations than in groundwater samples collected from B206989. These results suggest that these constituents may be due to Landfill leachate migrating beneath the pond and dam to downgradient areas.

In addition, elevated concentrations of lithium (199 µg/L), selenium (504 µg/L), sulfate (1517 mg/l), TDS (3633 mg/l), U-233/234, U235, and U-238 have been detected in samples from UHSU bedrock well B206889, located to the south and upgradient of well B206989. Concentrations of these constituents are significantly above the concentrations in B206989. Elevated concentrations of some or all of these constituents have been found in other contaminant plumes, including the SPP and IHSS 119.1.

As suggested above and reported in *1998 Groundwater Monitoring at the Present Sanitary Landfill* (DOE, 1999), in addition to the Landfill, the most likely cause for anomalous groundwater quality at well B206989 is an unknown secondary contaminant source located upgradient of well B206889. Regardless of their source, the absence of certain contaminants at high concentrations in Landfill groundwater and surface water indicate the presence of potential non-Landfill interference in interpreting downgradient weathered bedrock groundwater quality.

6.6 Conclusions

Groundwater conditions at the Present Sanitary Landfill in 2001 appear to be generally consistent with the results of previous monitoring. Statistical comparisons of upgradient versus downgradient UHSU groundwater at the Landfill were performed for analytes meeting the minimum evaluation criteria of <90 percent non-detections and at least four samples per upgradient and downgradient data set. Significant differences (at the 1 percent level) in upgradient compared to downgradient groundwater quality were found for sulfate, TDS, calcium, copper, lithium, magnesium, molybdenum, selenium, vanadium, U-233/234, U-235, and U-238. VOCs were not evaluated statistically because the percentage of non-detections exceeded 90 percent or because contaminants were found only in upgradient samples.

Although most analytes for which trend plots were constructed appear to be increasing in concentration in Downgradient Well B206989, these trends are apparent and not statistically significant. Only analytes U-233/234 and vanadium have statistically significant increasing concentration trends calculated for Well B206989. No other downgradient wells have produced samples with increasing concentrations of the analytes discussed in this section.

The increasing trends of vanadium and U-233/234 in Well B206989 represent groundwater quality exceedances that are reportable under the IMP. A more complete review of available groundwater and soils data associated with potential upgradient, non-Landfill contaminant sources appears to be warranted to investigate the elevated occurrences of these analytes in Downgradient Well B206989. The geochemistry of the specific analytes and their spatial distribution with regard to mobility and retardation potential must be evaluated as part of this review.

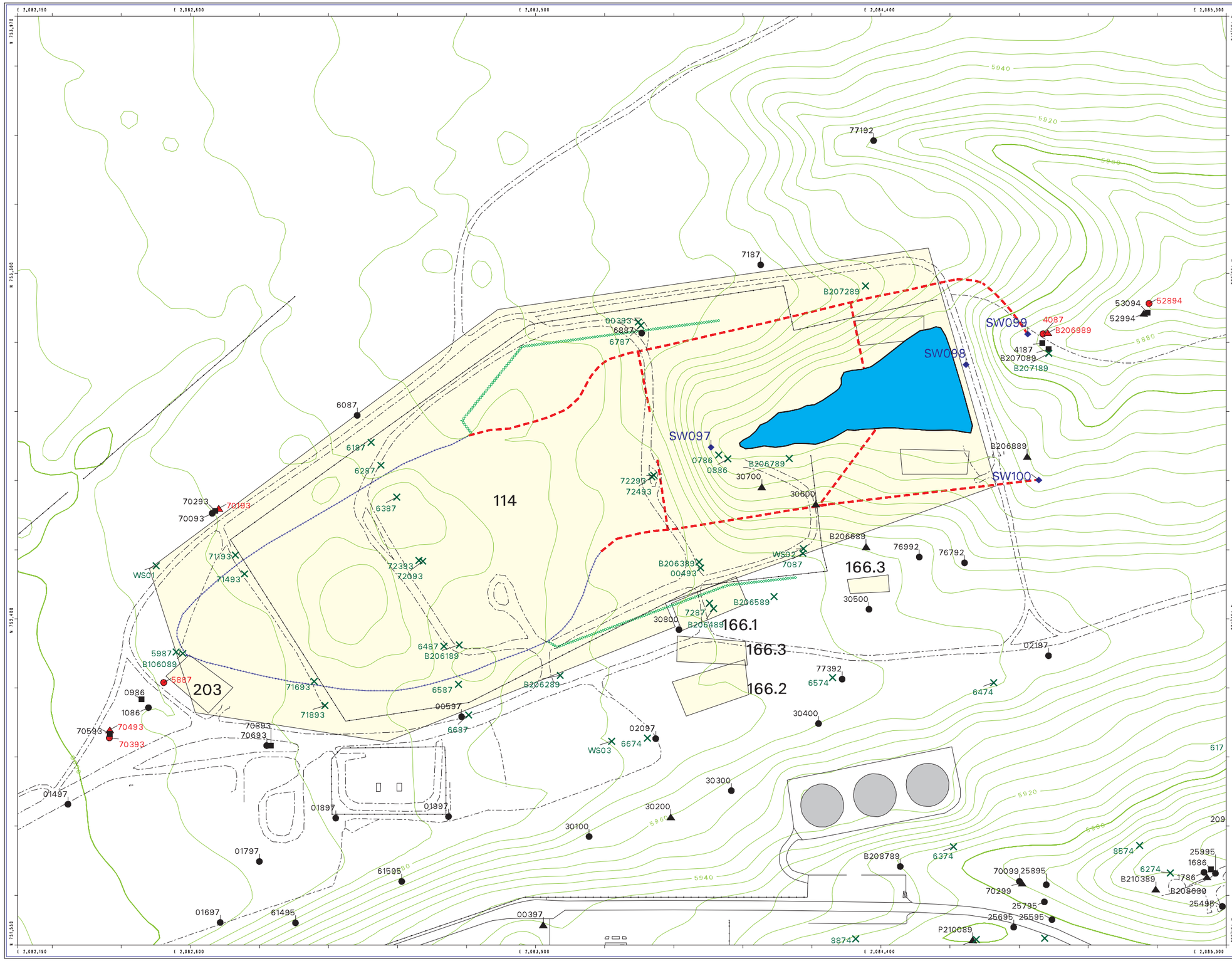

Figure 6-1

Groundwater Intercept and Diversion System Layout at the Present Sanitary Landfill

2001 Annual RFCA Groundwater Monitoring Report

EXPLANATION

- Groundwater Monitor Well UHSU Surficial Material
- Groundwater Monitor Well UHSU Bedrock
- Groundwater Monitor Well LHSU Bedrock
- Landfill Groundwater Monitoring Wells
- All Other Existing Wells
- Abandoned Wells
- Surface Water Monitoring Locations
- Individual Hazardous Substance Site
- Slurry Wall
- GW Intercept System - Perforated
- GW Intercept System - Non-Perforated
- East Landfill Pond
- Tanks
- Fences and other barriers
- Topographic Contour (20-Foot)
- Paved roads
- Dirt roads

Scale = 1 : 2970
1 inch represents approximately 248 feet

50 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by:

DynCorp
THE ART OF TECHNOLOGY

Prepared for:

KAISER•HILL COMPANY

November 07, 2002

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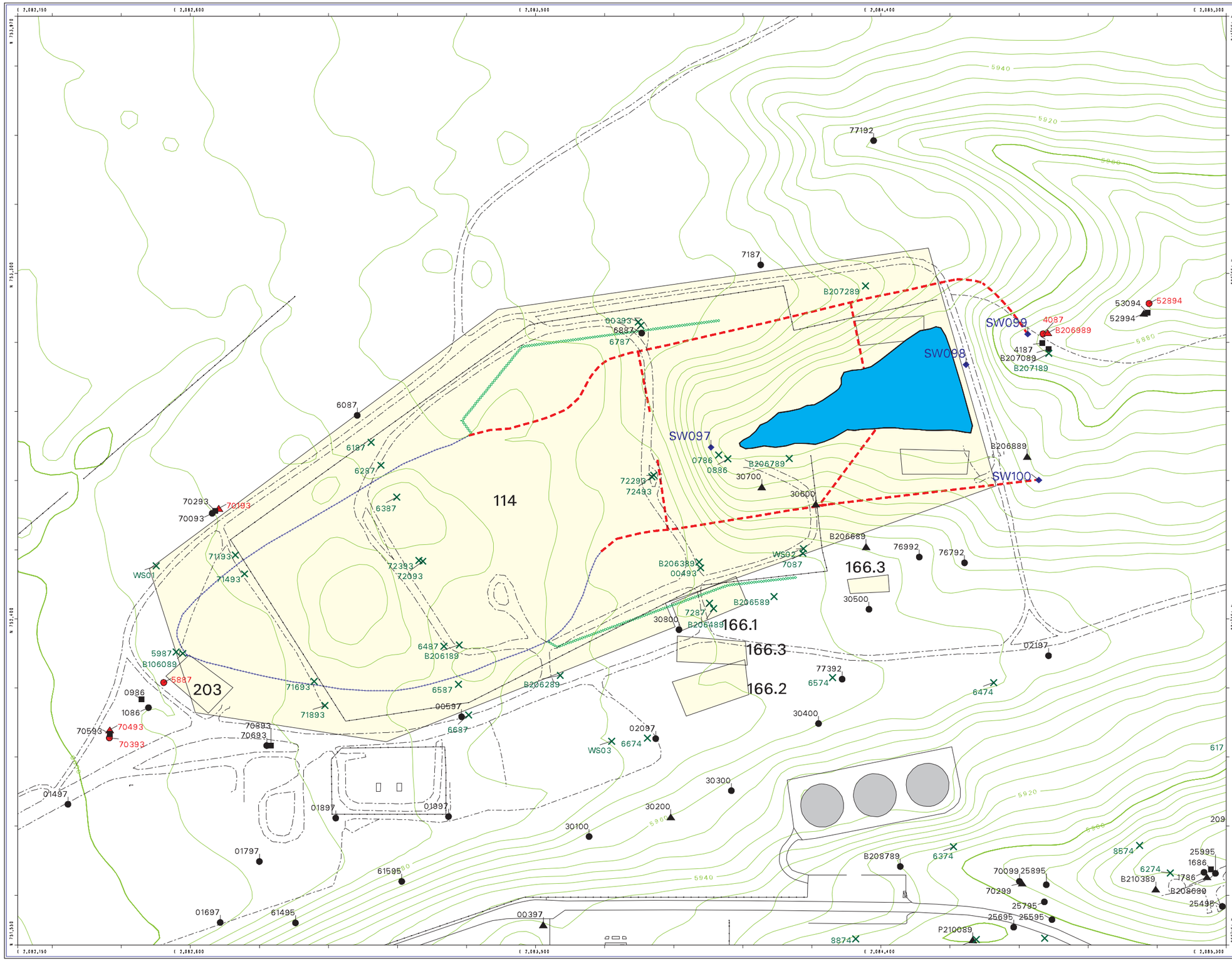

Figure 6-2

Water Quality Parameters (mg/L) above the Reported Detection Limit at the Present Sanitary Landfill

2001 Annual RFCA Groundwater Monitoring Report

EXPLANATION

- Groundwater Monitor Well UHSU Surficial Material
- Groundwater Monitor Well UHSU Bedrock
- Groundwater Monitor Well LHSU Bedrock
- Landfill Groundwater Monitoring Wells
- All Other Existing Wells
- Abandoned Wells
- Surface Water Monitoring Locations
- Individual Hazardous Substance Site
- Slurry Wall
- GW Intercept System - Perforated
- GW Intercept System - Non-Perforated
- East Landfill Pond
- Tanks
- Fences and other barriers
- Topographic Contour (20-Foot)
- Paved roads
- Dirt roads

NOTES:

BDL - Below Detection Limit
LW - Lacked Water
NS - Not Sampled/Dry Conditions

Source of GIS data available upon request.

Scale = 1 : 2970
1 inch represents approximately 248 feet

50 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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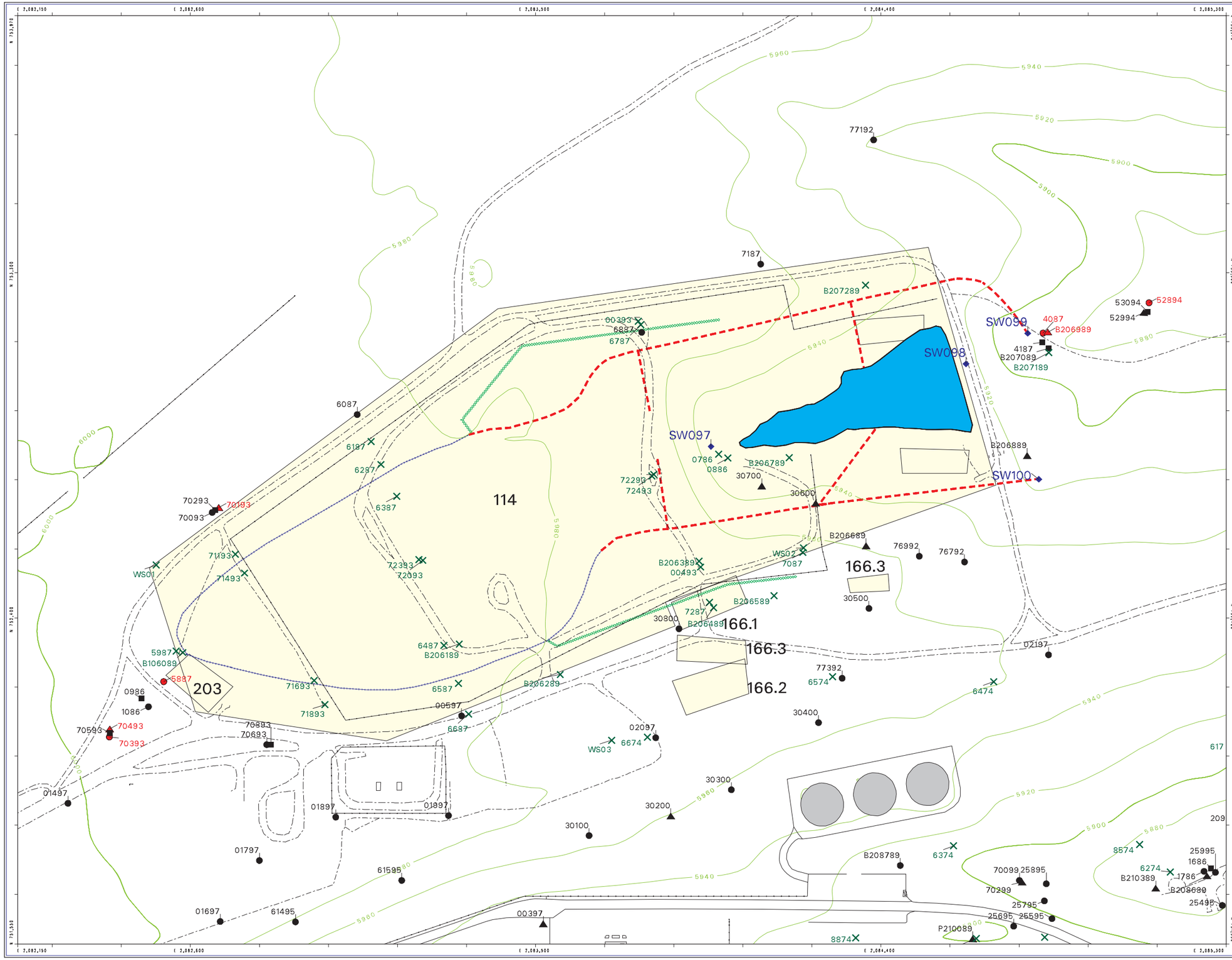

Figure 6-3

Selected Metals (ug/L) above the Reported Detection Limit at the Present Sanitary Landfill

2001 Annual RFCA Groundwater Monitoring Report

EXPLANATION

- Groundwater Monitor Well UHSU Surficial Material
- Groundwater Monitor Well UHSU Bedrock
- Groundwater Monitor Well LHSU Bedrock
- Landfill Groundwater Monitoring Wells
- All Other Existing Wells
- Abandoned Wells
- Surface Water Monitoring Locations
- Individual Hazardous Substance Site
- Slurry Wall
- GW Intercept System - Perforated
- GW Intercept System - Non-Perforated
- East Landfill Pond
- Tanks
- Fences and other barriers
- Topographic Contour (20-Foot)
- Paved roads
- Dirt roads

NOTES:
BDL - Below Detection Limit
NS - Not Sampled/Dry Conditions

Source of GIS data available upon request.

Scale = 1 : 2970
1 inch represents approximately 248 feet

50 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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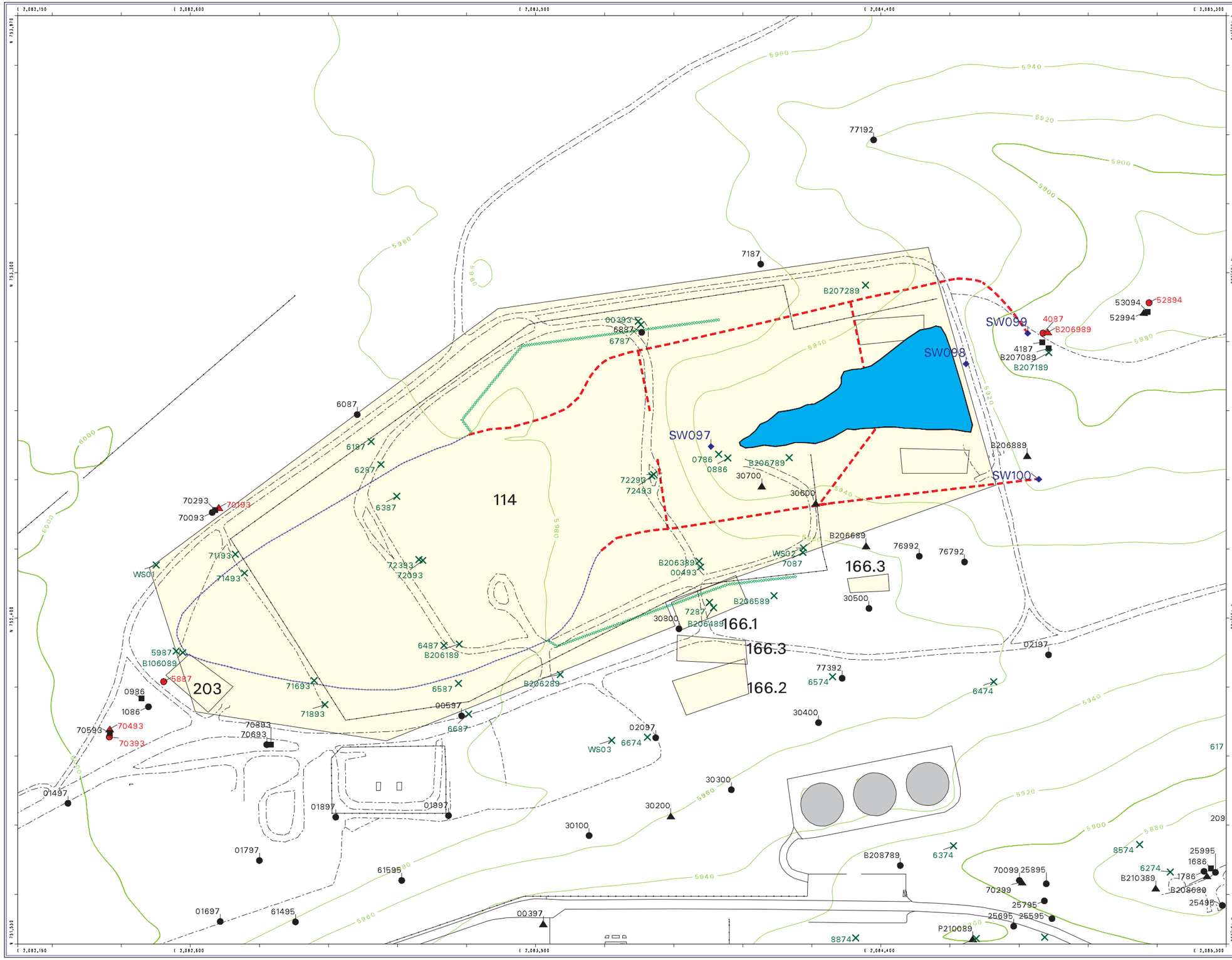

Figure 6-4

Tritium & Dissolved Uranium (pCi/L) above the Reported Detection Limit at the Present Sanitary Landfill

2001 Annual RFCA Groundwater Monitoring Report

EXPLANATION

- Groundwater Monitor Well UHSU Surficial Material
- Groundwater Monitor Well UHSU Bedrock
- Groundwater Monitor Well LHSU Bedrock
- Landfill Groundwater Monitoring Wells
- All Other Existing Wells
- Abandoned Wells
- Surface Water Monitoring Locations
- Individual Hazardous Substance Site
- Slurry Wall
- GW Intercept System - Perforated
- GW Intercept System - Non-Perforated
- East Landfill Pond
- Tanks
- Fences and other barriers
- Topographic Contour (20-Foot)
- Paved roads
- Dirt roads

NOTES:

BDL - Below Detection Limit
LW - Lacked Water
NS - Not Sampled/Dry Conditions

Source of GIS data available upon request.

Scale = 1 : 2970
1 inch represents approximately 248 feet

50 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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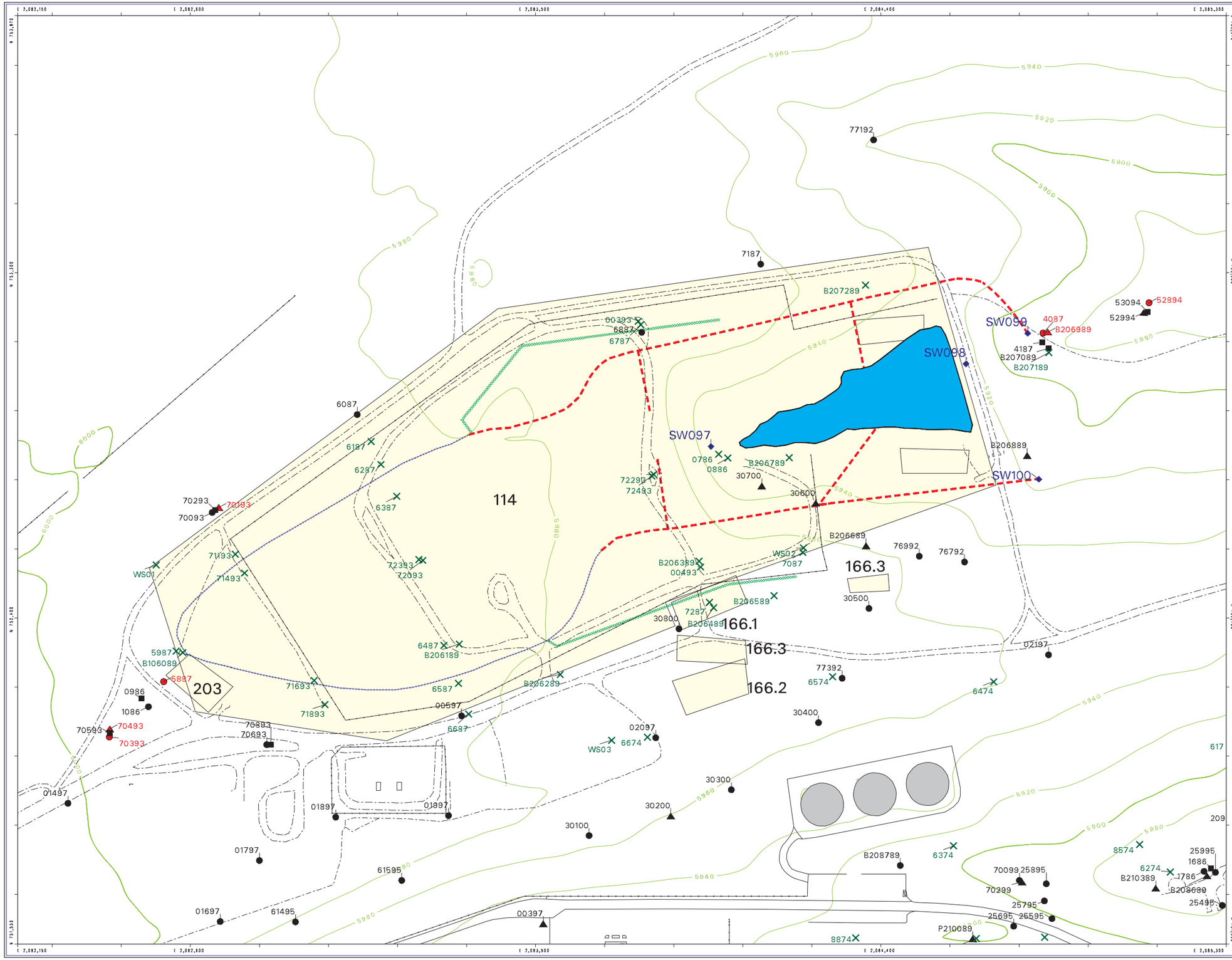

Figure 6-5

Volatile Organic Compounds (ug/L) above the Method Detection Limit at the Present Sanitary Landfill

2001 Annual RFCA Groundwater Monitoring Report

EXPLANATION

- Groundwater Monitor Well UHSU Surficial Material
- Groundwater Monitor Well UHSU Bedrock
- Groundwater Monitor Well LHSU Bedrock
- Landfill Groundwater Monitoring Wells
- All Other Existing Wells
- Abandoned Wells
- Surface Water Monitoring Locations
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- Dirt roads

NOTES:

BDL - Below Detection Limit

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50 0 100 200ft

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