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Focused Analysis of Remediation Alternatives for Groundwater Plume Expansion and Seepage to Surface Water

West Valley Demonstration Project – North Plateau Strontium-90 Plume
West Valley, New York

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LIST OF ACRONYMS

ALARA	As Low As Reasonably Achievable
bgs	Below Ground Surface
CDDL	Construction and Demolition Debris Landfill
CDP	Comprehensive Decommissioning Plan
CEC	Cation Exchange Capacity
DCG	Derived Concentration Guide
DOE	U.S. Department of Energy
EID	Environmental Information Document
EIS	Environmental Impact Statement
FRS	Fuel Receiving and Storage
LLW2	Low Level Waste Water Treatment Facility
meq/g	Milliequivalents per Gram
MNA	Monitored Natural Attenuation
NPGRS	North Plateau Groundwater Recovery System
NPV	Net Present Value
O&M	Operations and Maintenance
OM&M	Operations, Maintenance, and Monitoring
pCi/L	Picocuries per Liter
PRB	Permeable Reactive Barrier
PTW	Permeable Treatment Wall
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RFP	Request for Proposal
Pu-241	Plutonium-241
Sr-90	Strontium-90
SWS	Slack Water Sequence
TBU	Thick Bedded Unit
Tc-99	Technetium-99
WNYNSC	Western New York Nuclear Service Center (approximately 3,300 acres)
WVDP	West Valley Demonstration Project (approximately 200 acres)
WVNS or WVNSCO	West Valley Nuclear Services Company
Y-90	Yttrium-90

FOCUSED ANALYSIS OF REMEDIATION ALTERNATIVES FOR GROUNDWATER PLUME EXPANSION AND SEEPAGE TO SURFACE WATER

West Valley Demonstration Project – North Plateau Strontium-90 Plume
West Valley, New York

1.0 INTRODUCTION

Geomatrix Consultants, Inc. (Geomatrix) was retained by West Valley Nuclear Services Company (WVNSCO) to prepare this focused Analysis of Remediation Alternatives Report to address mitigation of Strontium-90 (Sr-90) migration in groundwater from the North Plateau area of the West Valley Demonstration Project (WVDP).

1.1 PROJECT BACKGROUND

The Western New York Nuclear Service Center (WNYNSC) property comprises approximately 3,300 acres of northern Cattaraugus County (Figure 1). A portion of the property known as the "North Plateau" was used to process commercial nuclear fuel from 1966 to 1972. Commercial nuclear fuel reprocessing activities were terminated in 1972 and decontamination activities started for planned upgrades. In 1982, the U.S. Department of Energy (DOE) assumed operational control of the WVDP premises (approximately 200 acres) to solidify high-level liquid radioactive waste using vitrification technology at the then newly designed/constructed Vitrification Facility also located on the North Plateau. WVDP buildings and structures on the North Plateau are shown on Figure 2.

A Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) of the WVDP was initiated in the early 1990s and identified elevated gross beta concentrations in groundwater samples collected from the subsurface near the nuclear fuel reprocessing building. In 1993, sampling and analysis of surface water in a ditch known as the "swamp ditch" identified elevated gross beta concentrations near the edge of the North Plateau. A subsurface soil and groundwater sampling program was subsequently conducted in 1994 (referred to as the 1994 Geoprobe® Investigation) to characterize the lateral and vertical extent of the elevated gross beta concentration on the North Plateau and identify the contributing radioisotopes. Strontium-90 and its daughter product, yttrium-90, were found to be the primary contributors to the measured gross beta concentrations. Subsequent Geoprobe® investigations conducted in 1997 and 1999 refined the distribution of the beta-emitters in soil and groundwater, and further characterized hydrogeologic conditions on the North Plateau. These investigations and routine environmental sampling programs have identified a plume of impacted groundwater extending approximately 1,000 feet in a northeasterly direction from the Process Building area to the swamp ditch. Sampling data have shown that the plume is slowly advancing in a north-northeasterly direction and discharges to topographical low areas contiguous to the swamp ditch and the swamp ditch itself. As a result of this discharge, Sr-90 is detected in surface water flowing from the North Plateau beyond the WVDP premises.

In 1995, the North Plateau groundwater recovery system (NPGRS) was installed and operated to collect and remove Sr-90 from impacted groundwater near the leading edge of the plume west of the Low Level Waste Treatment Facility lagoons. The NPGRS was effective in limiting the seepage of impacted groundwater to the ground surface in a topographic low west and southwest of the Construction and Demolition Debris Landfill (CDDL) (see Figure 2) but did not completely mitigate advance of the plume toward the swamp ditch. In 1999, a pilot permeable treatment wall (PTW) was constructed on a small segment of the eastern portion of the plume to demonstrate the feasibility of plume mitigation using passive in-situ fixation technology. No other treatment technologies have been employed to address the plume.

1.2 REMEDIAL ACTION OBJECTIVES

Releases of Sr-90 from the North Plateau to surface water do not pose a public health and safety concern with public access located at the boundary of the 3,300 acre Western New York Nuclear Service Center (Center). In 2005, the maximum potential radiation exposure (dose) due to North Plateau releases was calculated to be 0.035 millirem for the year compared to regional background radiation of approximately 295 millirem annually.

An evaluation was done in 2003 to estimate the potential peak dose to an off site member of the public assuming continued expansion of the plume (URS, July 2003, revised December 2006). It was projected that maximum strontium-90 release for one year would occur in approximately 2029 and assuming that public access to the site is at the boundary of the 3,300 acre Center the maximum potential dose would be approximately 0.051 millirem for the year.

The technology evaluation presented herein is focused on consideration of measures that could be taken to improve current containment of the Sr-90 contamination in the groundwater on the North Plateau. The Remedial Action Objectives (RAO) reflect the focus on containment and are not regulatory driven. They are not intended to address future site decommissioning actions, although this evaluation does consider compatibility of technologies that could potentially be used to contain the Sr-90 within the current site with strategies that may be considered for future decommissioning.

In this context, the RAO for the mitigation of Sr-90 migration in groundwater from the North Plateau are as follows:

- RAO 1: Reduce or eliminate Sr-90 presence in groundwater seepage leaving or potentially exiting the premises to as low as practically achievable, with a goal to be less than the DOE Derived Concentration Guide (DCG) of 1,000 pCi/L.

- RAO 2: Minimize the future expansion of the Sr-90 plume beyond its current mapped limits (described in Section 2.1.5).

- RAO 3: Ensure that a technology selected for current containment of the Sr-90 plume does not preclude any strategies for addressing the plume during site decommissioning.

2.0 SUMMARY OF ENVIRONMENTAL CONDITIONS

This section describes the physical setting, provides geologic and hydrogeologic information pertinent to the WVDP and describes the nature and extent of Sr-90 contamination in groundwater at the North Plateau.

2.1 PHYSICAL SETTING

Numerous geologic and hydrogeologic investigations have been completed at the WVDP property since the 1960s. Much of the pertinent information regarding the overall physical site setting is described in reports titled "Environmental Information Document (EID), Volume I: Geology" (WVNCSO, 1993) and "EID Volume III: Hydrology" (WVNSCO, 1993). Subsequently, investigations conducted to characterize the Sr-90 groundwater plume provided detailed geologic information for the shallow unconsolidated materials on the North Plateau affected by the Sr-90 groundwater plume. Relevant investigations included: Geoprobe® investigations conducted in 1994, 1997, and 1999, Pumping Test Analysis Report September 1996 (Dames & Moore, 1996), and Supplemental Hydrogeologic Investigation of the North Plateau Pilot Permeable Treatment Wall (WVNSCO, 2002). A summary of geologic and hydrogeologic conditions provided in these reports pertinent to the migration of Sr-90 at the North Plateau is presented in the following sections. Site features discussed below are located as shown on Figure 2.

2.1.1 Geology

The WVDP lies in the glaciated northern portion of the Appalachian Plateau Physiographic Province. The features and geology resulted from repeated glaciation in Western New York, which has covered the plateau with a complex of alluvial outwash deposits, lacustrine sediments, and till (sequence from ground surface down). These unconsolidated materials fill a deep trough in the bedrock that parallels the Buttermilk Creek drainage basin. On the North Plateau in the vicinity of the Sr-90 plume, sediments characteristic of an alluvial fan (sand and gravel) overlie a deep sequence of till. The four stratigraphic units affecting the transport of Sr-90 at the North Plateau include:

- Fill
- Thick Bedded Unit (TBU)
- Slack Water Sequence (SWS)

- Lavery till

Each of these units is described in the following paragraphs. They are described in reverse stratigraphic sequence (bottom to top) because the "top of till" affects the occurrence and thickness of shallower units.

The Lavery till is predominantly an olive gray, silty clay glacial till with scattered lenses of silt and is considered to be unweathered in the North Plateau area. The till is reported to be a relatively impermeable base to the overlying sand and gravel units (WVNCSO, 1993). The till ranges in thickness from 40 ft (south of the Main Plant area) to more than 100 ft (beneath the CDDL). In the top of the Lavery till is a distinctive geologic unconformity with a southwest to northeast trending channel ending near Frank's Creek (WVNSCO, 1993). This channel in the Lavery till is filled with a well sorted sequence of medium to coarse grained sediments that is identified as SWS.

The SWS is a depositional meandering sequence that filled in a topographic southwest to northeast trending channel in the Lavery till. It exists as an aerially limited geologic unit about 190–600 ft in width and about 2,000 ft long with the narrowest point occurring less than 100 ft west of lagoon 4 (Figure 3). It is composed of 4 to 6 inch thick layers of fine to coarse gravels and typically clean medium to coarse sands, separated by 8 to 18 inch thick layers of brown silt and medium to fine brown sands that are dense and continuous. To the north, the SWS is truncated by the stream channel cut by Frank's Creek. It thins and pinches out both east and west along the channel edge (Figure 3). The SWS varies in thickness from 0 to 15 ft thick. The thickest sequences are beneath the Fuel Receiving and Storage (FRS) building and the narrow area west of lagoon 5. The SWS is differentiated from the overlying TBU primarily by its interbedded stratigraphy.

The TBU is a poorly sorted, massive, silty sand and gravel layer that typically ranges from 4 to 15 ft thick (with a maximum thickness of approximately 25 feet) and overlies the SWS and Lavery till. The thickest areas are south of the CDDL near the northern end of the plateau and where the SWS is present west of waste water treatment lagoons 4 and 5. The TBU extends to the north, west, and east edges of the North Plateau where it is truncated by the stream valleys carved by Frank's Creek, Quarry Creek, and Erdman Brook which has exposed the contact between the Lavery till and the TBU.

Above the TBU is a discontinuous layer of fill ranging in thickness from 0 to 10.5 ft and locally spread across the North Plateau near lagoons 4 and 5. This layer is recompacted original silt and clay sediment generated during earlier site construction activities.

2.1.2 Hydrogeology

Groundwater flows principally through the surficial sand and gravel deposits (TBU and SWS) on the North Plateau under unconfined conditions. The low permeability till below the sand and gravel units is considered an aquitard, and groundwater flow through the till is considered negligible compared to flow through the surficial deposits. The depth to groundwater is at the ground surface in the swamp ditch and within a few feet of the ground surface in topographically depressed areas southeast of the swamp ditch. Elsewhere, the depth to groundwater is approximately 4 to 8 feet below grade. Groundwater depths are significantly influenced by heavy precipitation events. Water levels in the sand and gravel deposits can rise rapidly (several feet over the course of a few days) in response to significant recharge events (water level data recorded by transducer/data loggers for WP-1 through WP-10 during the week January 17, 1996). The cause of the rapid rise in water levels is believed to be permeable surface soil which allows rapid infiltration of surface water and a rather thin saturated thickness (generally less than 15 feet).

The groundwater flow direction is generally north-northeast from the Main Plant area (Figure 4). The TBU and SWS are hydraulically connected, but stratification of the SWS produces localized semi-confined conditions in areas where the SWS is thickest. (i.e., west of lagoon 5). The hydraulic gradient in the surficial sand and gravel deposits is approximately 0.031.

Hydraulic conductivity values for the sand and gravel deposits were reported using analysis of slug test data and pumping well data. The arithmetic mean hydraulic conductivity value calculated from slug tests for wells screened in the surficial sand and gravel deposits is 1.9 X 10^{-3} cm/s (EID Volume III, WVNSCO, 1993). The hydraulic conductivity value calculated from pump test data by analyzing drawdown in wells near the PTW is approximately 4.0 X 10^{-3} cm/s (WVNSCO, 2002). Pumping test analysis of extraction wells at the NPGRS reported higher hydraulic conductivity values; ranging from 2.4 X 10^{-2} cm/s to 3.8 X 10^{-2} cm/s (Dames & Moore, 1996). Based on limited treatment capacity at the time of testing, short-term pumping tests were performed (60-minute pumping tests). The reported values were derived from non-stabilized pumping conditions. Analysis of early drawdown data obtained under such conditions can yield hydraulic conductivity values with a high bias.

The average groundwater flow velocity in the sand and gravel deposits was calculated to be 18.6 m/yr (61 ft/yr) (WVNSCO, 1993).

2.1.3 Surface Water

The North Plateau of the WVDP is drained by three streams (Frank's Creek, Erdmann Brook, and Quarry Creek) (Figure 2) and several unnamed tributaries that flow to Quarry Creek. Quarry Creek and its unnamed tributaries run along the north and west sides of the plateau. Frank's Creek flows along the east side of the North Plateau. Erdman Brook borders the south side of the North Plateau and divides the north and south plateaus. A gauging station was established on the North Plateau to collect continuous surface water discharge data from the swamp ditch (monitoring point WNSWAMP). Surface water flow through the WNSWAMP monitoring station was reported to be seasonally variable with average daily flow rates ranging from 35 gpm (June through August 2006) to 300 gpm (March 2006). Groundwater containing Sr-90 seeps out of the TBU at the swamp ditch and in a topographically depressed area southwest of the CDDL that flows via a small drainage swale to the swamp ditch. This groundwater discharge produces baseline flow in the swamp ditch. Flow in the swamp ditch increases by an order of magnitude or more from surface water runoff that occurs during significant precipitation events and snow melt.

2.1.4 North Plateau Geochemistry

Chemical constituents in North Plateau groundwater and surface water have been assessed through subsurface investigations and quarterly environmental sampling programs. The 1998 Geoprobe® sampling program characterized groundwater quality near (plume core area) and downgradient from the Main Plant. The Geoprobe® sampling program analyzed groundwater samples for:

- Radiological parameters (alpha, beta, and gamma emitters)
- Metals (i.e., calcium, iron, potassium, magnesium, sodium, strontium {non-rad})
- Non-metals (i.e., chloride, alkalinity, sulfate, hardness, total dissolved solids)

Test results indicate no gamma-emitting radioisotopes were detected in groundwater. Only trace level activities of beta emitter radioisotopes other than Sr-90 were detected in the core area. Technetium-99 (Tc-99) was detected at a maximum concentration of 156 pCi/L (DCG for Tc-99 is 100,000 pCi/L). Plutonium-241 (Pu-241) was also detected at very low activities (about 100 times less than the DCG for Pu-241). Maximum activities for detected alpha emitters were between 100 to 1,000 times below respective DCGs.

A review of limited inorganic water quality data collected from the site, including from the 1998 data collection program (West Valley Nuclear Services Company, 1999) indicates that groundwater is characterized as a calcium-chloride type water (Figure 5). There is some indication that water occurring in deeper flow horizons near the boundary with the underlying Lavery Till may be characterized with higher calcium and chloride concentrations. Calcium, having a similar ionic charge (+2) to strontium, is an important cation when strontium is a target constituent as calcium affects strontium sorption onto soil by competing for cation exchange sites. Reported calcium concentrations ranged from 77 mg/L to 214 mg/L. Total hardness concentrations, based primarily on the presence of calcium and magnesium ions, ranged from 213 to 684 mg/L. This range of hardness values is considered to be “hard” or “very hard” when groundwater quality is considered in design of water treatment facilities. Total alkalinity and bicarbonate alkalinity were generally equivalent (as expected for near neutral pH conditions) and typically ranged from about 100 to 200 mg/L.

The potential presence of organic chemicals in North Plateau groundwater has been investigated during the WVDP RFI. Low concentrations of chemicals used as organic solvents have been identified in the vicinity of the CDDL. However, the distribution of chemical presence is limited and would not be expected to impact remedial alternatives evaluated in this report.

2.1.5 Nature and Extent of Sr-90 Contamination

Sr-90, and its daughter product yttrium-90 (Y-90), have been monitored in groundwater samples collected from the TBU and SWS units for over 10 years. The source of the plume’s activity is in the subsurface beneath the former Process Building or Main Plant (Figure 2). The plume has migrated from the source area toward the northeast following the trend of the SWS and the predominant groundwater flow direction. The plume has reached the swamp ditch located north of the CDDL. Figure 6 depicts the plume extent with contoured Sr-90 concentrations in groundwater (isopleths) for September 2006 sampling data.

Hydrodynamic processes (advection, dispersion, diffusion) cause the plume to spread and elongate over time from the predominant groundwater flow path. Geochemical processes (sorption, desorption) naturally attenuate the strontium ions to the soil matrix causing the plume to migrate at a substantially slower rate than the rate of groundwater flow (plume retardation). Radioactive decay of the Sr-90 (half-life of approximately 29 years) will reduce the Sr-90 concentration in soil and groundwater. For example, 25% of the original Sr-90 concentration will remain in soil and groundwater after two half-lives of decay (about 58 years). Sr-90 adsorbed to soil producing a groundwater concentration equivalent to the DOE DCG of 1,000 pCi/L will require approximately 200 years of decay to produce a Sr-90 concentration in groundwater that would meet the EPA Sr-90 drinking water Maximum Contaminant Level (MCL) of 8 pCi/L. The half-life of Y-90 is less than three days and is considered to be in equilibrium in the presence of Sr-90.

The retardation of Sr-90 transport in groundwater at the North Plateau is evident through an examination of plume expansion since the initial 1994 investigation. Plume expansion is shown on Figure 7. Comparing the position of the 1997 10,000 pCi/L groundwater isopleth to the 2006 10,000 pCi/L groundwater isopleth, it appears the plume has advanced approximately 70 feet on the west side of the plume, approximately 50 feet at the plume middle, and approximately 200 feet on the east side of the plume. These distances are far less than the transport distance calculated by advection alone (groundwater flow velocity of approximately 60 feet/yr). The differential rate in plume advancement caused the formation of what has been described as a west (or 1st) and an east (or 2nd) lobe. The presence of lower hydraulic conductivity TBU materials between the PTW and the NPGRS also affects the rate of plume migration. The operation of the NPGRS and subsequent installation of the PTW has also affected transport conditions of the plume. Therefore, the current configuration should not be considered a natural steady-state condition. A modeling assessment with the NPGRS omitted from future plume predictions may provide insight to likely plume configurations and movement to optimize preferred interim remedial actions. Overall, it appears that the plume has advanced at a rate of less than 1/3 the groundwater flow velocity which indicates a low soil-partitioning coefficient (Kd) for Sr-90 in the saturated zone.

2.2 CURRENT SITE REMEDIATION PROGRAMS

The NPGRS was installed in 1995 and consists of three groundwater extraction wells designated RW01, RW02, and RW03. The wells operate to minimize migration of the western lobe of the Sr-90 plume. Each extraction well is approximately 15 feet deep and is equipped with variable speed pumps that operate to maintain a near constant level of drawdown. In 2005/2006, average pumping rates for the extraction wells were as follows: RW01 – 4.3 gpm; RW02 – less than 1 gpm; and RW03 – 2.2 gpm. Sr-90 concentrations in groundwater recovered from the wells during that time were in the approximate range of 20,000 to 80,000 pCi/L. Recovered groundwater is treated at the on-site Low Level Waste (water) Treatment Facility (LLW2). The treatment system consists of three skid mounted ion exchange columns sometimes referred to as “Skid B”. The design hydraulic capacity of the North Plateau groundwater treatment system is approximately 25 gpm. The NPGRS has removed approximately 7 Curies of Sr-90 from approximately 43 million gallons of processed groundwater since 1995. The NPGRS captures Sr-90 contaminated groundwater, but does not completely mitigate migration of the western plume lobe.

A pilot-scale permeable treatment wall (PTW) was constructed in 1999 in the eastern lobe to test in-situ fixation (as promoted by ion exchange) as a passive groundwater mitigation technology on the North Plateau. The pilot PTW is a subsurface trench backfilled with clinoptilolite, a zeolite mineral selected as a treatment medium due to its ability to adsorb Sr-90 ions (through ion exchange) from groundwater. The PTW technology is a remediation concept also referred to as a Permeable Reactive Barrier (PRB). The pilot PTW was designed to be a small-scale but fully penetrating treatment zone constructed across the sand and gravel units into the surface of the Lavery till. The objective of the pilot PTW was to test the PRB technology in treating Sr-90 affected groundwater beneath the North Plateau with the intended focus to treat groundwater in both the TBU and SWS. The pilot program was intended to help assess whether the technology could successfully remove Sr-90 from the aqueous system in situ, and even if deficient, identify those design and construction issues important for implementing a potential full-scale system.

An evaluation of monitoring data, as collected by WVDP, indicates that the PTW is effective in removing Sr-90 from groundwater inside the PTW through ion exchange although the pilot system is too short in length to mitigate the advance of Sr-90 in the east lobe. The various evaluations of monitoring data also have indicated performance deficiencies related to implementation details and not necessarily due to the potential effectiveness of the technology. The pilot test evaluations have been undertaken by WVDP and various subcontractors; a summary of the pilot program effectiveness is described in Section 3.3.2. Because the pilot program successfully showed that Sr-90 can be removed in-situ through a PTW installation, and also provided information on construction and design issues that can be overcome, this technology is seen as a potential full-scale remedy for managing Sr-90 affected groundwater at the site as described in Section 3.3.

The DOE has undertaken an evaluation of alternatives for the management of radioactive waste materials at the WVDP in preparation of a facility decommissioning Environmental Impact Statement (EIS). Contamination reduction at the Sr-90 plume source area, among other response actions to address the highest concentrations of Sr-90, is being considered in the EIS for facility decommissioning. As indicated in Section 1.2, the remedial alternatives analysis presented herein considers potential consistency with the overall facility decommissioning program.

3.0 TECHNOLOGY SCREENING

Potentially applicable technology options to attain the RAO include:

- Physical barriers
- Hydraulic barriers
- In-situ fixation/stabilization
- Monitored natural attenuation

3.1 PHYSICAL BARRIERS

The use of low permeability physical barriers to groundwater flow (such as a slurry wall) would be of limited use in controlling the further expansion of the plume. To be effective, the barrier would have to be implemented with a groundwater extraction system to prevent flow around or above the barrier. Without groundwater extraction, the plume will spread internally and groundwater may seep to the land surface at various locations near the barrier. When employed with groundwater extraction, there is a benefit of the physical barrier in that the rate of pumping required to capture and control the plume is reduced compared to groundwater extraction alone. However, for a downgradient barrier wall installed across a large area where the overall natural hydraulic gradient is substantial, the reduction would be limited. Physical barrier walls for plume containment are therefore dropped from further consideration.

Physical barriers, in particular paving or lining of drainage swales, could be used to reduce groundwater seepage to surface water. The hydrogeologic (and topographic) characteristics of the swamp ditch and vicinity limit the feasibility of using a physical barrier to mitigate the discharge of Sr-90 to surface water. If the ditch were to be lined with low permeability material without concurrent hydraulic control, groundwater prevented from seeping to the ditch will continue to flow to seepage points further downgradient. These seepage points are located along the west side of the Erdmann Brook/Frank's Creek Valley and could be as close as 100 feet from the swamp ditch. Natural attenuation (including radioactive decay) cannot be relied upon to reduce Sr-90 concentrations over such a short distance because of the time required to naturally reduce the mass and activity of the Sr-90 in groundwater. The use of physical barriers without concurrent hydraulic control is therefore dropped from further consideration in development of remedial alternatives.

As suggested above, the risk of Sr-90 discharge from downgradient seepage points can be alleviated by withdrawing groundwater to create a hydraulic depression beneath the ditch. Therefore, the use of physical barriers (ditch lining or paving) is retained for consideration if employed with collocated hydraulic controls designed to depress the water table underlying the ditch, thereby, maintaining the hydraulic sink partially controlling local flow and transport.

3.2 HYDRAULIC BARRIERS

Hydraulic controls can be effective in reducing groundwater seepage to surface water (particularly when employed with physical barriers as described above), and in creating hydraulic barriers to plume expansion. Two hydraulic control technologies, groundwater interceptor trench drains and groundwater extraction wells are retained for further consideration in development of remedial alternatives. The hydraulic control alternatives require treatment of the pumped groundwater to remove Sr-90 prior to discharge to surface water.

3.3 IN-SITU FIXATION/STABILIZATION

In-situ fixation/stabilization technologies are less widely used than physical or hydraulic barriers, but could be effective components of the remedial program at the site. Given the objective of mitigating further expansion of the Sr-90 plume, the in-situ technology would require placement in the downgradient portion of the impacted groundwater. At this location, it would be critical that the in-situ application not significantly reduce the hydraulic conductivity of the groundwater flow system as such a reduction would tend to divert upgradient groundwater and potentially drive the plume to the ground surface or currently unimpacted areas. Therefore, in-situ fixation technologies involving chemical additions and fixation are not applicable to areas outside the core of the plume and are not retained for further analysis in this report. PRB technology, however, can be designed and implemented to perform without significantly diverting groundwater flow and can be oriented in a variety of configurations to increase capture and treatment potential based on the local hydraulic and hydrochemical conditions. PRB technology, therefore, is retained for further consideration in development of remedial alternatives. Because large scale application of this technology is a relatively recent development (compared to physical and hydraulic barriers), additional information concerning the application of this technology is presented below.

3.3.1 Technical Aspects of Permeable Reactive Barriers

PRB technology has been applied commercially as an in situ groundwater treatment method since the early 1990s (Warner and Sorel, 2003). The basic concept is to engineer a subsurface zone (chiefly by trenching, mixing, or injection) that can destroy or immobilize target chemical constituents in-situ while allowing groundwater to continue to flow downgradient through the treatment area. Treatment can be provided by physical, chemical, and biological processes promoted by the type of material (granular or liquid) that is placed, mixed, or injected into the subsurface treatment zone. The hydraulic goal for the PRB is that no unintended significant loss, or diversion of hydraulic flow in the vicinity of the PRB occurs (unintended hydraulic performance can occur from affects due to construction, treatment material permeability, and chemical/biochemical reactions within the PRB). The feasibility of the PRB system further depends upon the following:

- Sustainability (with respect to both hydraulics and treatment performance).
- Cost effectiveness (compared to other remedial options).
- Low operation and maintenance requirements.
- Consistency with land use options (present and future).
- Regulatory and stakeholder acceptance (present and future).

PRB technology has been successfully applied at other governmental facilities to promote treatment of dissolved metals, petroleum hydrocarbon constituents, and chlorinated hydrocarbon constituents. Commercial PRB's have been applied successfully as full-scale groundwater remedies in the United States since 1994 (Warner and Sorel, 2003). A brief performance history of PRB technology is provided in the following paragraphs.

3.3.2 Historical PRB Performance

The PRB has been an innovative groundwater treatment technology since being introduced in 1991 by researchers at the University of Waterloo, Ontario, Canada as a way to passively treat chemically-affected groundwater in situ (Gilham and O'Hannesin, 1994). The first research system, which utilized a treatment matrix composed of granular zero-valent iron, successfully degraded chlorinated aliphatic compounds without the use of power or other active means to control the gradient or direction of groundwater flow. That research led to the first commercial installation of PRB technology at a former semi-conductor facility in northern California (Warner and Sorel, 2003). Since the installation of that PRB in late 1994, performance monitoring has been used to assess its effectiveness in treating target chemicals and in evaluating the aging of the PRB to determine whether any long-term maintenance would be required for it to maintain its treatment objectives (Warner, et al., 2005).

Although the first PRBs were chiefly intended to treat groundwater affected by organic constituents, the technology has been applied to remedy groundwater affected by metals and other inorganic constituents. Early installations focused on treatment of groundwater affected by chromium (e.g., Puls, et al., 1995) and uranium (Fuller, et al, 2003) among other compounds. The Remediation Technology Development Forum (RTDF) (http://www.rtdf.org/permbarr) maintains an active site where summaries of approximately one hundred full-scale and pilot-scale installations developed since 1995 are provided. Additionally, the Interstate Technology Regulatory Council (ITRC) has developed several guidance documents that provide technical information, including performance information and lessons learned, pertaining to PRB technology (http://www.itrcweb.org/gd_PRB.asp).

Because the PRB is a concept rather than an "off-the-shelf" remedy, it can be designed to meet the intention of the remedial objectives at a site. That means that the system can be designed geometrically, for specific flow conditions, and for specific target chemicals to achieve certain goals. The treatment material, which generally is a solid matrix, but can be a liquid with some designs, has included granular iron, activated carbon, phosphatic minerals, compost, crushed limestone, sand, gravel, and other materials. The key is to match the geochemical performance expected for a given treatment material to the goals to destroy, reduce, or immobilize the target chemical(s) in groundwater. Granular zero-valent iron has been used to destroy chlorinated hydrocarbon compounds because of the corrosion reaction involving iron and water creates reducing conditions and surface reactions that cause the target chemicals to be instable (Gilham and O'Hannesin, 1994). Granular iron also can promote the reduction of oxidized metals (such as hexavalent chromium) and thus remove such metals from the aqueous system (Puls, et al., 1995).

For the West Valley site, an appropriate chemical method to remove Sr-90 from groundwater has been the use of ion-exchange processes. A natural material that promotes ion-exchange includes zeolite minerals for which many types have significant cation-exchange-capacity values sufficient to exchange Sr-90 in groundwater for a like cation within the zeolitic mineral structure. Because zeolitic minerals generally are abundant and can be provided in granular form, they make ideal candidates to be used within a PRB system – the zeolite has a greater density than water, is structurally competent, and can be handled by most construction equipment without unusual or special needs or health and safety concerns.

This concept led to the consideration of a zeolitic PRB for treating Sr-90 affected groundwater at West Valley. Testing by Brookhaven National Laboratory (Fuhrman, 1995) evaluated this idea initially and testing by researchers at the University at Buffalo (e.g., Rabideau, 1998, 1999) followed. An installation of a small PRB for Sr-90 in groundwater at the Chalk River reservation in Ontario, Canada (Lee, 1998) occurred prior to the pilot PTW installation at West Valley.

Historically, PRBs appear to have performed well, though there are reports of installations with unintended performance. Most PRBs are believed to perform well with regards to chemical treatment (verbal communication, M. Duchene, EnviroMetal Technologies, Inc., 2007). For example, the earliest installed commercial PRB (1994) continues to function appropriately to reduce chemical mass in the affected groundwater flow system (Warner, et al., 2005). Treatment to or near water-quality objectives appear to be common and are demonstrated by reviewing PRB summaries in the various RTDF, ITRC and other technical references. PRBs with less than intended performance appear to be characterized with poor hydraulic performance. That is, unacceptable mounding, plugging, or flow diversion would limit the ability of the PRB to effectively treat groundwater as intended. Reasons for lack of hydraulic performance are often due to: (1) difficult construction; (2) inappropriate placement; (3) inappropriate thickness for full treatment; (3) gaps in the PRB due to poor construction; (4) unanticipated local conditions including excess surface recharge that affects flow conditions and anthropogenic affects, including nearby pumping. Deep PRBs are often installed using jetting or injection methods that create thin, deep zones of treatment material. Difficulty in placing the injected material to depth, or incomplete placement due to geological or construction issues, also may create unintended and poor PRB performance. Aging of PRBs does occur; permeability loss where the chemical treatment results in mineral precipitation or coating of the treatment material is a known and acknowledged process that must be addressed during the design stage of the project. Loss of reactivity or ion-exchange capacity with time are items that are to be attended to early in the design program; measures to lessen these potential effects on the total performance and economic vitality of the remedial program should be considered.

3.3.3 Site-Specific Applicability

As indicated in Section 2.2, a pilot test of the PRB concept (referred to as the pilot PTW) was implemented at the WVDP in 1999. The treatment matrix for the PTW was composed of the mineral clinoptilolite, a zeolite whose general solid solution formula is [(Ca, Mg, Na_2,

$K_2)(Al_2Si_{10}O_{24}.8H_20)]$. Clinoptilolite is one of about 40 known zeolites and one of several natural zeolites that are commercially mined and distributed. The intent of using this material was to effectively reduce the concentration of Sr-90 affected groundwater by promoting ion-exchange between Sr-90 dissolved in the groundwater and less affinitive cations within the mineral structure of the zeolite. Several programs researching the potential efficacy of the zeolite treatment on the site plume were carried out under the direction of WVNSCO (e.g., Rabideau., et al., 1999; Van Venschoten, et al., 2001). Zeolites, such as clinoptilolite, are minerals well known for their ability to exchange cations readily. The potential ability for a material to promote such exchange is referred to as the cation exchange capacity (CEC) which typically is reported as either moles or as milliequivalents (meq) of exchangeable cation per gram (or 100 grams) of zeolite. The CEC for clinoptilolite generally is shown as between about 1.6 and 2.2 meq/g. Other zeolites have higher CEC values, but may not be appropriate for use in a PTW because of a number of factors including material strength, availability in large amounts, and cost. Clinoptilolite generally is readily available and is widely used in commercial applications that call for natural zeolites.

Other zeolite minerals also may have properties appropriate for use as a treatment media within a PTW application. These minerals including chabazite (general solid solution formula is $[(Na_6K_6)(Al_{12}Si_{24}O_{72}).40H_2O)]$ and mordenite (general solid solution formula is $[(Na_8)(Al_8Si_{40}O_{96}).24H_20]$. Both chabazite and mordenite are commercially available and generally are known to have CEC values greater than clinoptilolite (ranging from approximately 2.3 meq/g for mordenite up to about 3.7 meq/g for chabazite). The potential use of these minerals as the PTW treatment material (or as a mixture with clinoptilolite) would be evaluated during design studies if a PTW alternative is selected as a full-scale remedy.

The pilot PTW at the WVDP was installed in 1999 as a test focused on treating a portion of what was referred to as the “2nd lobe” or eastern lobe of the Sr-90 plume beneath the North Plateau of the site. Initial mitigation of the “1st lobe” or western lobe of the Sr-90 plume located beneath the western portion of the North Plateau currently had been (and currently is being) addressed by the groundwater recovery and aboveground ion exchange treatment system (NPGRS) installed in 1995.

The pilot PTW was installed as an approximately 30-foot long by 26-foot deep by 7-foot thick “continuous” PTW (i.e., lateral hydraulic barriers were not installed to direct groundwater flow into the PTW). The system was constructed using conventional trench and fill techniques where the PTW trench was stabilized using sealed sheet piles to create a cofferdam-type structure prior to excavating native soil from the interior of the cofferdam structure. The sheet piles were installed to a depth of approximately 36 feet below ground surface (bgs) or approximately 10 to 12 feet below the anticipated contact between the upper water-bearing material and the underlying low permeability till. The native material within the cofferdam was dewatered prior to excavation using 8-inch dewatering wells installed prior to the excavation, and was kept dry during placement of the treatment material. Unmixed zeolitic material (i.e., 100 percent clinoptilolite as delivered) was placed to fill the cofferdam to near ground surface with the exception of an approximately 1.5 foot zone of gravel ("1-inch roundstone") that was placed at the upgradient front (south) of the pilot PTW. A horizontal drainpipe was placed at the bottom of the gravel section; the connecting riser pipe with pump assembly is located at the eastern end of the gravel section. Once the excavation was filled, the sealed sheet piles were removed starting at the west end of the pilot PTW. The sheet piles were installed in August 1999 and removed in November 1999.

WVNS and associated contractors assessed the performance of the pilot PTW on several occasions. Initial performance assessment focused on hydraulic, engineering, and treatment issues (e.g., Geomatrix, 2001; Berkey, 2000). The results of these assessments generally indicate that the PTW technology can be applied to mitigate migration of Sr-90 in groundwater under the site conditions specific to the WVDP provided that proper adherence to certain technical design considerations is maintained. Within 6 months following installation of the PTW, monitoring data indicated that:

- Sr-90 concentrations were non-detect (or close to non-detect) in groundwater samples collected from with in the PTW

- Concentrations of potassium (K^+) began to increase in downgradient monitoring wells; the concentration of K^+ being the ion replaced by Sr-90 (and other cations) within the zeolite

- Concentrations of Sr-90 in certain downgradient monitoring wells began to decrease from pre-installation values.

Longer-term data have shown that increases of Sr-90 concentration within the PTW do occur, however (WVNSCO, 2006). For example, a significant increase of Sr-90 to an activity level from near non-detect to near 200 pCi/L has occurred since approximately late 2001 in groundwater samples from Well WP-37 located in the eastern section of the PTW, although only minor increases (<50 pCi/L) have been reported for samples from adjacent wells WP-38 and WP-39 where those increases were reported to begin in approximately 2005, or 6 years after installation of the pilot PTW. Other wells have seen some increase beginning around 2005. A detailed evaluation of this data has yet to be performed, however, a preliminary evaluation is that: (1) well WP-37 may be installed to a depth that either pierces the bottom of the PTW and thus captures untreated water or captures untreated water due to gaps or inconsistency in the zeolite placement; (2) a front of very high Sr-90 activity groundwater (e.g., >110,000 pCi/L) migrated to the PTW (as seen by activities in samples from upgradient wells such as NP01-22 which lead to incomplete, though still very effective, ion-exchange within the PTW; and (3) some ion-exchange capacity may have been exceeded in portions of the PTW. Prior to any installation of a full-scale PTW, if this alternative is selected, a detailed evaluation of the pilot PTW data to date is recommended.

The performance assessment also indicated that the pilot PTW did not perform as expected with respect to hydraulic behavior due mostly to construction issues and PTW placement including:

- Incomplete keying of the PTW into the underlying Lavery Till.
- Likely smearing of fine-grained horizons caused by the sheet-pile installation and extraction portion of the PTW construction.
- Excess surface water recharge into the PTW during the first 6 months following its installation.

Although the testing has not shown complete treatment by the PTW, it has demonstrated important positive aspects of the technology for the site:

1. Sr-90 can be successfully removed from groundwater by in situ ion exchange using PTW technology.
2. Construction and scale-effects are important to achieving treatment objectives (these are conditions that can be overcome with appropriate design and engineering).
3. The zeolite material achieves treatment for at least 5 years. The treatment also appears to be effective at very high ambient activity levels based on treatment of an apparent

groundwater front with Sr-90 activity levels where activity levels were reduced potentially from approximately 110,000 pCi/L to less than 50 pCi/L.

The results of the pilot PTW project demonstrated that with appropriate design and implementation the PRB technology is feasible for groundwater remediation at the North Plateau. Additional evaluation of the potential longevity of the PTW would be evaluated during design studies for a full-scale remedy.

The PRB technology could also be applied at the swamp ditch seepage face as a means to reduce Sr-90 concentrations in the discharge to surface water without forcing impacted groundwater to downgradient seeps (see discussion of physical barriers above). PRB/PTW technology is therefore retained for both groundwater and seep remediation.

3.4 MONITORED NATURAL ATTENUATION

The term "natural attenuation" refers to naturally-occurring processes in soil and groundwater that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in those media. These in-situ processes include biodegradation, dispersion, dilution, adsorption, volatilization, chemical or biological stabilization, destruction, and radioactive decay of constituents. Environmental monitoring programs conducted at the North Plateau have demonstrated that, in addition to the hydrogeologic conditions described in Section 2.1, natural attenuation processes occur. Sorption to soil and radioactive decay are major attenuation factors affecting Sr-90 transport.

Under certain conditions, the natural geochemical equilibrium can be augmented to enhance the natural attenuation (MNA/EA) of constituents. Chemically amending groundwater chemistry to enhance attenuation could also be considered an in-situ fixation technology. Enhanced attenuation possibilities for Sr-90 in North Plateau groundwater include: sodium bicarbonate addition to promote mineralized encapsulation of Sr-90 (calcite and strontianite precipitation); augmentation of existing microbes to develop ureolytic bacteria to promote calcite precipitation; and injection of calcium-citrate-phosphate solution promote apatite [$Ca_6(PO_4)10(OH)_2$] precipitation with adsorption of Sr-90 to the apatite with permanent Sr-90 substitution for calcium with the natural radioactive decay of Sr-90. As indicated in Section 3.3, in-situ fixation technologies involving chemical additions and precipitation are not applicable to areas outside the core of the plume due to potential impacts on soil permeability.

Monitored natural attenuation (MNA) is a technology option that would enhance the effectiveness of technologies selected as alternatives to satisfy the RAO for the North Plateau and is retained for further consideration.

4.0 REMEDIAL ACTION ALTERNATIVES

4.1 DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

The first RAO (RAO 1) listed in Section 1.2 is to reduce or eliminate groundwater seepage to the swamp ditch such that Sr-90 presence in surface water exiting the premises is as low as practically achievable, but at minimum remains below the DCG of 1,000 pCi/L. In developing alternatives to address this RAO, Geomatrix has assumed that the presence of Sr-90 in the swamp ditch at or above the DCG is a result of seepage of impacted groundwater to the ditch and from seepage to topographically low areas southwest of the CDDL that flow to the swamp ditch. It is assumed that the contribution of Sr-90 in surface water runoff to the swamp ditch from the North Plateau is low relative to the DCG. Surface water sampling and analytical results support this assumption (see Section 2.1.3).

All technologies retained in Section 3.0 could be employed to reduce the concentration of Sr-90 in the swamp ditch water. A physical barrier, such as placement of a low permeability lining in exposed sections of the ditch would reduce the Sr-90 concentration by impeding the seepage of groundwater to the surface water. If a physical barrier to seepage is installed without hydraulic control measures to lower the water table, groundwater would still find a route to surface water beyond the lined portion of the ditch. Some additional attenuation of Sr-90 concentrations would likely occur as groundwater flows to new seepage locations. However, without hydraulic control or in-situ removal of Sr-90 from the flowing groundwater, there would remain some likelihood that Sr-90 concentrations would remain above the DCG in seepage to surface water beyond the emplaced physical barrier.

For this reason, emplacement of a physical barrier to groundwater seepage is not a feasible stand-alone alternative for attaining RAO 1. However, this technology is feasible for use in concert with hydraulic barrier technologies. The alternatives described in Sections 4.7 and 4.8 below incorporate the physical barrier used in concert with the hydraulic barrier technologies.

An effective hydraulic barrier would accomplish the following:

1. Prevent further plume migration across the hydraulic barrier alignment.

2. Reduce, over time, the concentration of Sr-90 in groundwater downgradient of the hydraulic barrier alignment, including that in any groundwater seepage to surface water.

3. Lower the water table and/or hydraulic gradient in the vicinity of the swamp ditch thereby reducing the driving force for groundwater seepage to surface water.

These hydraulic barrier objectives are achievable through implementation of either of the following hydraulic control options:

1. Interceptor trench drain system

2. Groundwater extraction wells.

Implementation of hydraulic barrier technologies would require treatment of the pumped groundwater to remove Sr-90 prior to discharge to surface water. Reinjection of collected groundwater could be implementable (essentially recirculating a portion of the plume and allowing the radioactive decay to proceed), however, this would have significant impact on the water table elevation potentially resulting in migration of the plume beyond its current extent and to new seepage areas. Therefore, re-injection is not retained as a component of hydraulic barrier technologies evaluated in Section 5. For alternatives incorporating hydraulic barriers, it has been assumed that ex-situ groundwater treatment will be accomplished by ion exchange processes.

As discussed in Section 3.0, due to the constraint that impacted groundwater should not be diverted around the in-situ treatment area, only the permeable reactive barrier technology is retained for incorporation into remedial alternatives. A PTW could be installed within the groundwater plume to remove Sr-90 from groundwater as it flows through the wall. The PTW is composed of media which will preferentially sorb Sr-90 from the flowing water fixing it in place within the media. The PTW would contribute to attainment of RAO 1 by reducing the concentration of Sr-90 in groundwater which could potentially discharge to surface water.

The PTW can be installed as a passive barrier without groundwater pumping (passive PTW). Alternatively, groundwater pumping from within the PTW can be employed to direct groundwater flow through the PTW and limit flow around the unit (active PTW). However, the groundwater pumped from the active PTW may, at some point, have to be treated as higher Sr-90 concentrations migrate into the wall and zeolite adsorption sites become occupied.

PRB technology can be applied within the seepage face of the ditch (see Section 3.3.3). By excavating the seepage face and replacing the excavated material with a mixture of zeolite and stone, the ditch itself can be incorporated into the remedy, making use of the natural groundwater discharge zone. In the analyses of alternatives presented in Section 5, it has been assumed that PRB construction at the swamp ditch will not substantially impede seepage to the ditch. However, detailed analysis of the hydraulic effect of modifying the seep area and swamp ditch would be necessary during system design.

All alternatives developed and discussed herein would rely on MNA for that portion of the Sr-90 plume beyond the limits of the remedial action. MNA relies on natural physical-chemical processes (including dispersion, natural ion-exchange, and radioactive decay) to reduce the migration of Sr-90 in the groundwater system. Two general approaches have been used to develop alternative configurations which rely on MNA to different degrees. For the first configuration, the groundwater remediation application (i.e., the extraction well line, interceptor trench or PTW) would be located perpendicular to groundwater flow across the plume at the approximate 10,000 pCi/L isopleth. The second configuration places the groundwater remediation application farther downgradient at the approximate 100 pCi/L isopleth. The second configuration relies on MNA for remediation of downgradient groundwater to a lesser degree than the first.

Implementation of remedial technologies will involve working with contaminated soil and groundwater and there is a potential for exposure to radioactive material. In 1999, approximately 8,500 cubic feet of soil were excavated to install the pilot PTW. The wall was placed in an area of the plume where Sr-90 levels in groundwater were in a range of 10,000 to 80,000 pCi/L. Design considerations for PTW construction included an assessment of potential worker exposure issues, as well as, proper soil management which included packaging and disposal. PTW construction projections of soil contamination indicated that the most contaminated soil (approximately 110 pCi/g beta-gamma) would meet WVDP requirements for containment (45 pCi/g beta-gamma), but not for containerization (4,500 pCi/g) per *WVDP-304 technical Basis for Contaminated Soil Management and WVDP-010 WVDP Radiological Controls Manual*. As Low As Reasonably Achievable (ALARA) requirements were considered during the PTW design review and an ALARA Review Checklist (WV-2404) was completed. The review concluded that no action levels were identified that would require a formal ALARA review. It was recognized that environmental contamination control was the key issue and not external human exposure. All of the alternatives developed herein to address the RAO will encounter contaminated soil and groundwater having Sr-90 levels that are similar to or less than those encountered during PTW construction. Therefore, implementing any of the alternatives described in this section would not pose a significantly greater worker exposure risk or present new soil management issues.

Remedial action alternatives developed using the approach described above are presented below.

4.2 ALTERNATIVE 1: MAINTAIN CURRENT APPROACH

This alternative does not include any additional response actions. This alternative would include continued operation and maintenance of the NPGRS and monitoring the natural attenuation (MNA) through radioactive decay and plume retardation of Sr-90 in groundwater. As described in Section 2.2, groundwater is pumped from three extraction wells at the NPGRS and treated at the LLW2. While this alternative does not meet the RAO, it provides a basis for comparing other alternatives.

4.3 ALTERNATIVE 2: SEEPAGE FACE PRB/INTERCEPTOR TRENCH DRAIN

Alternative 2 is based on hydraulic control of the plume along a transect situated south of the CDDL. This hydraulic control would be implemented 100 to 200 feet from the swamp ditch seepage area and would be unlikely to depress the water table sufficiently to eliminate the groundwater discharge to the swamp ditch. Therefore, for Alternative 2 the seepage face PRB is more appropriate for seepage control than ditch lining. This alternative includes the following components:

1. Surface water controls and swamp ditch seepage face PRB

2. Interceptor trench drain located south of the CDDL.

3. Groundwater treatment using ion exchange processes currently in use at the Site.

These components are shown on Figure 8 and described below.

4.3.1 Surface Water Controls and Swamp Ditch Seepage Face PRB

The surface controls and swamp ditch seepage face PRB would be implemented as follows:

1. Re-grade upslope areas as appropriate (based on topographic survey and other pre-design investigations) to divert surface water runoff from upgradient areas to the adjacent drainage system west of the swamp ditch. This may necessitate construction of a berm to convey water to the northwest separating the upslope areas beyond the plume

limits from the drainage way that flows in an easterly direction to the culvert pipe.

2. Install PRB composed of zeolite and aggregate within the swamp ditch, as described below.

The location of the swamp ditch seepage face PRB would be determined based on the results of pre-design sampling. Based on the groundwater monitoring results to date, the seepage of impacted groundwater appears to occur primarily within the 175 foot section of the swamp ditch immediately west of the piped section and to the surface seep area which conveys seepage and runoff from the south to the north approximately 50 feet west of the western margin of the CDDL. In the analyses of alternatives presented herein, it is assumed that the seepage face PRB will be installed within these areas (see Figure 6). The location is subject to confirmation or revision based on pre-design sampling of the seeps and drainage water.

The PRB would be constructed and placed in the ditch in a manner such that erosion and compaction is minimized. Construction methods and materials would be specified as part of the detailed remedial design. For the purpose of this analysis, the following construction has been assumed.

1. The areas of the ditch where the PRB will be placed will be excavated to remove approximately 3 feet of soil from the ditch. Along the adjacent shoulders, a 5-foot width will be excavated to a depth of 3 feet.

2. The PRB will be comprised of zeolite and stone. It will be placed to form a layer 2 feet thick following the contour of the excavated ditch and shoulders (see below).

3. A permeable geotextile material will be placed above the PRB layer.

4. The geotextile will be anchored with a one foot thick layer of stone placed to follow the contour of the PRB layer.

The stone component of the seepage face PRB is necessary to provide structural support and resistance to compaction. Material specification would be part of detailed remedial design, but it is likely that a mean rock diameter (D_{50}) of 6-inches would be appropriate. The stone would be placed to achieve a good interlocking of stones (hand placement may be required). The PRB would be placed as follows:

1. Place one layer of stones (approximately 6 inches).

2. Place zeolite into the voids, carefully manipulating rocks as appropriate to allow zeolite to fill the voids.

3. Repeat this procedure (one layer of stones at a time) until the thickness of the PRB reaches the specified depth of 2 feet (pre-design studies would be required to establish appropriate PRB thickness).

A critical component of the seepage face PRB design is to maintain sufficient permeability so as not to restrict the seepage to the point where groundwater flow is diverted elsewhere. Detailed analysis of the hydraulic effect of modifying the seep area and swamp ditch would be required as part of the system design.

The performance of the seepage face PRB would be monitored by periodic collection of surface water samples from the swamp ditch. The estimated lifespan of the seepage face PRB would be estimated based on pre-design studies and on the performance monitoring data. A contingency plan would be developed to address Sr-90 breakthrough at a level above the DCG or other limit as deemed appropriate. At such time, it will be necessary to evaluate whether the groundwater remedy to contain plume expansion, in this case the hydraulic barrier, has been sufficiently effective that seepage face treatment is no longer required. This will entail groundwater monitoring in the soils below and adjacent to the PRB. If seepage face treatment is found to be no longer required, the seepage face PRB would simply be removed and disposed according to DOE guidelines. Conversely, if it is determined that discharging groundwater represents a continued concern with respect to Sr-90 concentration, the seepage face PRB could be replaced by removing the material, segregating the stone for reuse, disposal (according to DOE guidelines) of used zeolite, and rebuilding the PRB with fresh zeolite as described above. In lieu of replacement (if necessary), another possibility would be construction of a treatment cell filled with zeolite equipped with an overflow structure to pass storm flow. The treatment cell would be located near the discharge to Frank's Creek. Should continued seepage treatment be necessary beyond the functional life of the seepage face PRB, supplemental design studies would be required to assess the most appropriate treatment method.

4.3.2 Interceptor Trench Drain

4.3.2.1 Description

The existing NPGRS would be shut down and replaced with an interceptor trench drain. The interceptor trench would be installed south of the access road to the CDDL near the 10,000 pCi/L isopleth as depicted on recent data (Figure 6). The interceptor trench would be oriented across the width of the plume (approximately 275 feet across), perpendicular to groundwater flow and constructed to the base of the thick bedded unit (TBU). In the central portion of the interceptor trench, where the slack water sequence (SWS) constitutes a distinct water bearing unit, a single pumping well would be installed through the base of the interceptor trench drain into the SWS (Figure 8).

The average depth of the interceptor trench drain is estimated to be 16 feet and extend to the top of the Lavery till across most of the plume width. Where the SWS fills the linear trough in the till (see Figure 3), the trench bottom would extend to the top of the SWS. It would be approximately 275 feet in length and approximately 4 feet wide (width of a trench box). A temporary well point dewatering system and/or sump pumps would be used to facilitate trench excavation of saturated soils and placement of a perforated drain pipe and washed stone backfill. Collected water would be treated at the LLW2 treatment system. The drain pipe would extend the entire trench length and the washed stone would surround the drain pipe and extend approximately 4 feet below the ground surface. Fine-grained soil would be used to backfill the trench to grade.

Groundwater would be pumped from the SWS well and from two lift stations within the interceptor trench. Pumped groundwater would be treated using available treatment capacity at the LLW2 and/or providing additional treatment capacity using ion exchange treatment technology.

4.3.2.2 Groundwater Pumping Rates

The groundwater flow to the trench drain was estimated to be 24 gpm using an analytical solution for flow to a drainage trench provided in Powers (1993). The equation, assumptions and analytical solution are presented in Appendix A. Hydraulic testing data from slug test analysis, NPGRS pumping, and a pumping test conducted in the pilot PTW were considered in the analysis. Results of pumping tests conducted in the SWS were used to estimate the required pumping rate from the SWS extraction well of 3 gpm.

In total, the steady state pumping rate from the groundwater interceptor trench drain and the single pumping well screened within the SWS is estimated to be approximately 27 gpm.

4.4 ALTERNATIVE 3: SEEPAGE FACE PRB/GROUNDWATER EXTRACTION WELLS

This alternative is similar to Alternative 2 except the interceptor trench drain is replaced with a line of extraction wells (along the same alignment). Alternative 3 would also not be expected to create sufficient drawdown at the swamp ditch to eliminate seepage and therefore incorporates the swamp ditch PRB rather than ditch lining to address RAO 1. Components of Alternative 3 are:

1. Surface water controls and swamp ditch seepage face PRB

2. Groundwater extraction well line located south of CDDL.

3. Groundwater treatment using ion exchange processes currently in use at the Site (expanded to handle increased flow).

These components are shown on Figure 9 and described below.

4.4.1 Surface water controls and swamp ditch seepage face PRB

For Alternative 3, the surface water controls and swamp ditch seepage face PRB would be as described in Section 4.3.1, above.

4.4.2 Groundwater Extraction Wells

4.4.2.1 Description

The existing NPGRS would be shut down and replaced with a line of groundwater extraction wells. The wells would be installed south of the access road to the CDDL near the 10,000 pCi/L isopleth and oriented across the width of the plume as depicted on recent data (Figure 6). The extraction wells would be constructed with well screens extending to the top of the Lavery till through the TBU and SWS, where present. Extraction well depths would range from approximately 16 feet at the western side of the plume to approximately 28 feet at the eastern side of the plume where the SWS is present. An extraction well spacing of approximately 30 feet, based on NPGRS drawdown data, would require nine groundwater extraction wells to achieve hydraulic control across the plume. Since these wells are located in the TBU, the well spacing across the area with the SWS may be slightly different, which could be verified by pre-design pumping tests.

Groundwater would be pumped from the extraction well system to the LLW2 for treatment using available treatment capacity and additional treatment capacity provided by an ion exchange treatment skid. As indicated in Section 4.1, reinjection of a portion of the pumped groundwater could be considered an option for future cost reduction (if compatible with the eventual closure plan). However, this is not considered further in this analysis.

4.4.2.2 Groundwater Pumping Rates

The steady state pumping rate from the network of 9 groundwater extraction wells is estimated to be 45 gpm and would require additional treatment capacity at the LLW2. The estimated flow rate is based on an extrapolation of pumping rates and monitoring results from the NPGRS. Details of the flow rate estimate are presented in Appendix A.

4.5 ALTERNATIVE 4: SWAMP DITCH LINING/FAR DOWNGRADIENT INTERCEPTOR TRENCH DRAIN

This alternative is similar to Alternative 2, but achieves plume control farther downgradient (north of the CDDL). This could create drawdown below the swamp ditch sufficient to allow use of a low permeability ditch lining for seep control without the risk of forcing downgradient breakouts. Ditch lining would be used in lieu of a PRB. Components of Alternative 4 are:

1. Swamp ditch and seepage area lining.

2. Interceptor trench drain located north and east of the CDDL.

3. Groundwater treatment using ion exchange processes currently in use at the Site (expanded to handle increased flow).

These components are shown on Figure 10 and described below.

4.5.1 Swamp Ditch Lining

For Alternative 4, the swamp ditch and seepage area lining would be implemented as follows:

1. Re-grade upslope areas as appropriate (based on topographic survey and other pre-design investigations) to divert surface water runoff from upgradient areas to the

adjacent drainage system west of the swamp ditch. This may necessitate construction of a berm to convey water to the northwest separating the upslope areas beyond the plume limits from the drainage way that flows in an easterly direction to the culvert pipe.

2. Re-grade area of the swamp ditch west of the culvert and the seep area west of the CDDL.

3. Place a low permeability liner (e.g., high density polyethylene or other low permeability material) anchored with stone in the re-graded sections of the swamp ditch and seep area.

4.5.2 Interceptor Trench Drain

4.5.2.1 Description

The existing NPGRS would be shut down and replaced with an interceptor trench drain. The interceptor trench drain utilized in Alternative 4 would be located downgradient (north and east) of the CDDL as shown on Figure 10. This is generally beyond (downgradient of) the 100 pCi/L isopleth as depicted on recent data (Figure 6). The alignment is drawn so as not to require excavation within the CDDL. The trench drain would be approximately 1,000 feet in length with four lift stations. Extraction wells to penetrate the SWS are not included in this alternative since the saturated thickness of the sand and gravel deposits (including the SWS) decreases near the edge of the North Plateau and the trench drain could nearly fully penetrate the saturated deposits.

Except for its greater length and lack of an SWS recovery well, the trench drain construction would be as described in Section 4.3.2.

4.5.2.2 Groundwater Pumping Rates

The estimated groundwater flow rate for Alternative 4 is expected to be in the range of 65 to 75 gpm (estimated using the methodology described in Section 4.3.2.2) and would require additional treatment capacity at the LLW2.

4.6 ALTERNATIVE 5: SWAMP DITCH LINING/FAR DOWNGRADIENT GROUNDWATER EXTRACTION WELLS

This alternative is similar to Alternative 4 except the trench drain is replaced with a line of extraction wells. This alternative will also create drawdown below the swamp ditch sufficient to allow use of a low permeability ditch lining for seep control without the risk of forcing downgradient breakouts. Components of Alternative 5 are:

1. Swamp ditch lining.

2. Groundwater extraction well line approximately following the 100 pCi/L isopleth as depicted on recent data (Figure 6).

3. Groundwater treatment using ion exchange processes currently in use at the Site (expanded to handle increased flow).These components are shown on Figure 11 and described below.

4.6.1 Swamp Ditch Lining

For Alternative 5, the swamp ditch and seepage area lining would be as described in Section 4.5.1, above.

4.6.2 Groundwater Extraction Wells

4.6.2.1 Description

The existing NPGRS would be shut down and replaced with a line of groundwater extraction wells. The wells would be installed north of the access road to the CDDL generally near the 100 pCi/L isopleth and oriented across the width of the plume. In contrast to Alternative 4, which avoided traversing the CDDL with the trench drain, several of the extraction wells are located within the CDDL footprint. The presence of construction debris is not expected to pose a significant impediment to well drilling since much of the debris reportedly consisted of soil from facility construction activities.

The extraction wells would be constructed with well screens extending to the top of the Lavery till through the TBU and SWS, where present. Extraction well depths would range from approximately 15 feet at the western side of the plume to approximately 25 feet at the eastern side of the plume where the SWS is present. An extraction well spacing of approximately 30 feet, based on NPGRS drawdown data, would require 17 groundwater extraction wells to achieve hydraulic control across this portion of the plume.

Groundwater would be pumped from the extraction well system to the LLW2 for treatment using available treatment capacity and additional treatment capacity provided by ion exchange treatment skids. As indicated in Section 4.1, reinjection of a portion of the pumped groundwater could be considered an option for future cost reduction (if compatible with the eventual closure plan). However, this is not considered further in this analysis.

4.6.2.2 Groundwater Pumping Rates

The steady state pumping rate from the network of 17 groundwater extraction wells is estimated to be approximately 85 gpm and would require additional treatment capacity at the LLW2. The estimated flow rate is based on an extrapolation of pumping rates and monitoring results from the NPGRS.

4.7 ALTERNATIVE 6/6A: SEEPAGE FACE PRB/IN-SITU PLUME TREATMENT WITH PTW

As described in Section 4.1, passive (non-pumping) and active (pumping) PTW technologies were retained for analysis. Alternative 6 incorporates passive PTW technology and has the following components:

1. Surface water controls and swamp ditch seepage face PRB

2. Plume control by a passive PTW system installed south of the access road to the CDDL near the northern extent of the 10,000 pCi/L isopleth.

Alternative 6A incorporates active PTW technology. However, the groundwater withdrawal would serve the purpose of inducing flow through the PTW and not to create a widespread hydraulic depression. Therefore, the seepage face PRB is the appropriate seepage remedy for this alternative. Alternative 6A has the following components:

1. Surface water controls and swamp ditch seepage face PRB.

2. Plume control by an active PTW system installed south of the access road to the CDDL near the northern extent of the 10,000 pCi/L isopleth.

Components of these alternatives are shown on Figure 12 and 13 and are described below.

4.7.1 Alternative 6

4.7.1.1 Surface water controls and swamp ditch seepage face PRB

For Alternative 6, the surface water controls and swamp ditch seepage face PRB would be as described in Section 4.3.1, above.

4.7.1.2 Passive PTW

The existing NPGRS would be shut down and replaced with the passive PTW. As shown on Figure 12, the passive PTW would consist of an approximately 400-ft long northwest to southeast section, with two approximately 50-foot long lateral PTW sections trending southwest from each end of the 400-ft PTW components. The flow-through thickness of the PTW would range from approximately 2 to 4 feet (thicker sections are possible) and be composed of a high percentage mixture of granular clinoptilolite (or other appropriate zeolite based on the results of pre-design work). The greater flow-through thickness sections, which would be determined during design studies, would be placed in those areas where either the ambient Sr-90 migration flux, or the Sr-90 activity is sufficiently high to necessitate additional capacity within the PTW to sustain (i.e., greater than 10 years) the in-situ treatment of Sr-90 affected groundwater. Unlike the pilot PTW, an upgradient pea gravel development section is not proposed; however, a mixture of courser material (zeolite with a mixture of course silica sand) may be used depending on specific permeability requirements along the alignment and in accordance with using a single-pass trenching system (described in subsequent paragraphs), which cannot install vertical layering in the PTW. In addition, it appears the gravel wall in the small-scale pilot PTW promotes upward transport of Sr-90 from the SWS into the TBU and thus should not be a component in the full-scale wall to reduce design uncertainty. Although the upgradient pea gravel section was installed in the pilot PTW and was used somewhat for limited development of the PTW, we do not consider that the potential advantages of a pea gravel section exceed the benefits from using a single-pass trenching system (described in subsequent paragraphs) which cannot install the upgradient section.

Key aspects of the PTW design work would be to develop a system that will promote longevity of the remedy, while respecting cost, monitoring, and construction constraints. Although the treatment material within the PTW will effectively promote exchange of Sr-90 (a divalent cation) for monovalent cations such as sodium and potassium within the zeolite's structure, competition for the zeolite's exchange site from naturally occurring divalent cations dissolved in site groundwater will occur. Calcium and magnesium could decrease the long-term effectiveness of the PTW. Competitive ion-exchange also could promote the reversed exchange, or desorption, of Sr-90 into the zeolite's structure. Depending on the results of pre-design evaluation, potential methods to increase the potential longevity of the system include using zeolite minerals with greater CEC and increasing the volume of zeolite available for CEC (for example, increasing the thickness of the PTW or promoting a sustained slightly high pH following the preliminary work of Rabideau, 1998 that showed greater Sr partitioning in a slightly basic pH solution) in those areas where greater capacity is likely needed. Additional monitoring in specific portions of the PTW also may be appropriate. This design work will be important for final development of the remedies described by Alternatives 6, 6A, and 7.

No above ground treatment is required with this alternative.

4.7.2 Alternative 6A

4.7.2.1 Surface Water Controls and Swamp Ditch Seepage Face PRB

For Alternative 6A, the Surface water controls and swamp ditch seepage face PRB would be as described in Section 4.3.1, above.

4.7.2.2 Active PTW

The existing NPGRS would be shut down and replaced with the active PTW. Alternative 6A relies on the PTW operating in a hydraulically active mode where gradient control (to promote hydraulic capture greater than that provided by Alternative 6, including capture downgradient of the PTW) is provided by a series of extraction wells constructed within the PTW system. Individual extraction well pumping rates are expected to be low - approximately 1 gpm. As shown on Figure 13, the active PTW alignment and dimensions would be identical to the passive PTW. Construction and composition of the PTW are also similar except for 4 extraction wells installed within the PTW. The final number and location of extraction wells would be determined during design work for this Alternative. Also, any additional hydraulic control features, such as low permeability cut-off walls or sheet piles that can help to direct flow will be evaluated during design work. The currently proposed number and location is based on the reported occurrence of high activity Sr-90 groundwater, and where Sr-90 migration rates may be greatest (based on a review of Sr-90 monitoring results over time).

Groundwater pumped from the active PTW may require further treatment prior to discharge. The degree of treatment required (if any) would be the subject of predesign studies. In the analysis of alternatives presented below, treatment of extracted groundwater at the LLW2 is assumed after five years of active wall operation.

Groundwater extraction through the PTW can be achieved using either mechanical pumps or a series of siphon-driven pumps that would use hydraulic energy potential associated with the elevation difference downgradient of the PTW alignment. Mechanical pumps have the advantage to discharge either upgradient or downgradient of the PTW. Siphon-driven pumps would discharge treated water (treatment occurs within the PTW) to either Erdmann Brook or Frank's Creek. Selection of the siphon-driven pump groundwater extraction method would require specific design studies to asses Sr-90 removal efficiency of the selected zeolite material used in the PTW. In addition, supplemental treatment of extracted groundwater would need to be considered as a contingency with appropriate monitoring to address potential breakthrough of Sr-90 discharged from the PTW and to ensure compliance with permit conditions. The integration of PRB methodology with siphon principles was developed by the Savannah River National Laboratory. The concept has since been patented and commercialized which requires a site-specific license to implement.

4.8 ALTERNATIVE 7: SEEPAGE FACE PRB/FAR DOWNGRADIENT IN-SITU PLUME TREATMENT WITH PASSIVE PTW

Alternative 7 incorporates passive PTW technology at a further downgradient location and traverses the immediate vicinity of the swamp ditch. Depending on pre-design studies (see below) it may be determined that this PTW will attain RAO 1 without any seepage treatment using the seepage face PRB. However, this is uncertain and in the development of this alternative it has been assumed that the seepage face PRB will be deemed necessary. Alternative 7 has the following components:

1. Surface water controls and swamp ditch seepage face PRB

2. Plume control by a passive PTW system installed in the far downgradient area generally north of the 100 pCi/L isopleth as depicted on recent data (Figure 6).

These components are shown on Figure 14 and described below.

4.8.1 Surface water controls and swamp ditch seepage face PRB

For Alternative 7, the surface water controls and swamp ditch seepage face PRB would be as described in Section 4.3.1, above.

4.8.2 Far Downgradient Passive PTW

This alternative would be similar to Alternative 6, but would place the passive PTW downgradient of the 100 pCi/L isoconcentration contour near the northern and eastern perimeter of the CDDL (Figure 14). For this case, however, because the PTW would be far downgradient of high Sr-90 activity groundwater, the flow through thickness of the PTW may not need to be increased, as is likely for portions of the alignment in Alternative 6/6A. However, an evaluation of groundwater chemistry and Sr-90 flux rates will be used to design the specific details of this PTW alternative similarly as for Alternatives 6 and 6A. The PTW under this alternative is hydraulically passive; no pumping wells (by supplied power or by siphon) are included. Specifically, this PTW configuration also would account for the initial calcium loading to the zeolite that would occur prior to higher concentration of Sr-90 reaching the PTW; the design must ensure a longer-term viability than more southerly locations. Pre-design work, including using a groundwater flow model for the site, will focus on developing an appropriate orientation for the PTW and low permeability sections of the PTW system to reduce the potential impact of unintended hydraulic conditions, including mounding, unintended seeps, and flow diversions. Depending on the final design and orientation, the seepage face PRB may not be required. In the analysis of alternatives that follow, it has been assumed that the swamp ditch PRB will be implemented as part of Alternative 7.

5.0 EVALUATION OF REMEDIAL ALTERNATIVES

5.1 SUMMARY OF REMEDIAL ALTERNATIVES

In Section 4.0, eight remedial alternatives were developed:

- Alternative 1: Maintain Current Approach
- Alternative 2: Seepage Face PRB/Interceptor Trench Drain
- Alternative 3: Seepage Face PRB/Groundwater Extraction Wells
- Alternative 4: Swamp Ditch Lining/Far Downgradient Interceptor Trench Drain
- Alternative 5: Swamp Ditch Lining/Far Downgradient Groundwater Extraction Wells
- Alternative 6: Seepage Face PRB/In-Situ Plume Treatment with Passive Permeable Treatment Wall
- Alternative 6A: Seepage Face PRB/In-Situ Plume Treatment with Active Permeable Treatment Wall
- Alternative 7: Seepage Face PRB/Far Downgradient In-Situ Plume Treatment with Passive Permeable Treatment Wall

5.2 REMEDIAL ALTERNATIVE EVALUATION METHODS

5.2.1 General Evaluation Criteria

In the following subsections, each of the eight remedial alternatives is evaluated with respect to the following criteria:

- Implementability.
- Attainment of RAO (effectiveness).
- Additional data requirements.
- Cost of implementation (including data collection; costs for on-site groundwater treatment and low level radioactive waste disposal were provided by WVNSCO).

- Compatibility with the comprehensive plan for facility decommissioning of the North Plateau area (comprehensive decommissioning plan {CDP}).

Project-specific assumptions and methods with respect to the cost and compatibility criteria are discussed in the following subsections.

5.2.2 Basis of Cost Analyses

All eight alternatives (including Alternative 1) have similar performance monitoring requirements consisting of hydraulic head monitoring, groundwater sampling and analysis, data validation, discharge monitoring and reporting. Further upgradient hydraulic barrier and PTW alternatives (Alternatives 2, 3, 6 and 6A) are effective over a smaller cross section than further downgradient actions (Alternatives 4, 5 and 7) which may entail fewer performance monitoring locations. However, this monitoring cost advantage would be offset by the greater need for downgradient plume (i.e., MNA) monitoring compared to the further downgradient actions. Monitoring for Alternative 1 would likely require additional monitoring points throughout the plume and beyond the current limits of the plume. In the analysis presented below, Geomatrix has assumed an annual monitoring cost of $100,000 for each alternative. It is understood that the specific monitoring requirements will depend on the final design of the remedial action. However, the differences in monitoring requirements among the alternatives will be nominal and use of a constant value does not detract from the overall comparison of alternatives.

As discussed in Section 1.2, in the RFP WVNSCO specifies an operational period of 5 years for assessment of cost and effectiveness. However, in consideration of the possibility that certain components of the alternatives could be retained as part of (or during implementation of) the CDP, some assessment of longer term effectiveness is included. In addition, long term cost estimates (30-year) are provided in the cost tables in addition to the requested 5-year estimates.

5.2.3 Evaluation of Compatibility with CDP

As discussed in Section 2.2, the DOE has undertaken an evaluation of alternatives for the management of radioactive waste materials at the WVDP in preparation of a facility decommissioning EIS. Contamination reduction at the Sr-90 plume source area, among other response actions to address the highest concentrations of Sr-90, is being considered in the EIS. As indicated in Section 1.2, the remedial alternatives analysis presented herein considers potential consistency with the overall CDP for the North Plateau.

As the EIS is in progress and the elements of the CDP have not been identified, the assessment of compatibility requires some basic assumptions of the general strategies which may be employed in the future to reduce Sr-90 presence or mobility in groundwater at and near the source area (i.e., the core of the plume). In the analyses of alternatives for downgradient groundwater remediation presented below, Geomatrix has considered that the eventual remedy to address the core of the plume may employ the following technologies (alone or in combination):

- Groundwater extraction (with or without soil flushing)
- Excavation of Sr-90 impacted soil (saturated and unsaturated)
- Isolation of source area through installation of slurry walls, capping, and diversion of upgradient (inflowing) groundwater
- In-situ fixation using chemical additives to immobilize Sr-90
- PRB(s)
- Natural attenuation

The downgradient remediation alternatives evaluated herein are considered to function as an interim component of the long term remedy to be contained in the CDP. The compatibility is assessed according to the potential of the interim remediation alternative (evaluated herein) to impact (favorably or unfavorably) the long term measures in the CDP. A positive impact would enhance the effectiveness/implementability or reduce the cost of the long term measure. A negative impact would limit the effectiveness/implementability or increase the cost of a long term measure.

The interim nature of the downgradient alternatives evaluated herein is reflected in the use of a 5-year period for cost analyses. However, it is recognized that the interim period may last considerably longer than 5-years and that there will be costs associated with decommissioning or replacing certain components when they are no longer needed or reach the end of their functional lives. The decommissioning and/or replacement activities are discussed for each alternative and associated costs are included in 30-year cost estimates which are included for comparison (see Section 5.2.2, above).

5.3 ALTERNATIVE 1: MAINTAIN CURRENT APPROACH

Alternative 1 is a continuation of the current groundwater remediation consisting of pumping from 3 extraction wells and treatment at the LLW2.

Implementability

Alternative 1 is implementable and would not require construction of new facilities.

Effectiveness in Attaining RAO

Alternative 1 is not effective in attaining the RAO. Surface water discharge and plume expansion would not be mitigated.

Additional Data Requirements

There are no immediate additional data requirements with respect to design or implementation. The current groundwater monitoring program (performance monitoring) would continue, but may be augmented if the plume continues to expand.

Compatibility with Comprehensive Decommissioning Plan

Alternative 1 would likely not be incompatible with any eventual comprehensive remedy. Alternative 1 does not affect conditions within and near the core of the plume and should not inhibit the CDP. It captures a portion, but not all, of the groundwater migrating from the source area(s). Therefore, it is possible that Alternative 1 implemented in conjunction with source reduction and/or other comprehensive remediation approaches could provide some benefit with respect to reducing the rate of Sr-90 migration off the Site.

Under Alternative 1, the plume expansion to downgradient areas would be expected to continue. This would result in the expansion of Sr-90 presence in downgradient soils and could therefore increase the quantity of soil requiring mitigation as part of the CDP.

In the event the CDP requires shut down of the existing system (as do all alternatives discussed below), the decommissioning would not be a costly or expensive endeavor.

Cost

There are no capital costs for implementation of Alternative 1. Alternative 1 costs are associated with Operation and Maintenance (O&M) activities, primarily groundwater treatment and groundwater monitoring. The current system generates approximately 3.6 million gallons of water requiring treatment per year.

The cost estimate for implementation of Alternative 1 is presented in Table 1. The costs for treatment (including labor, laboratory analyses, resin changes, and disposal) are estimated to be $478,800 per year based on operational cost data provided by WVNSCO. For 5 years operation assuming a discount rate of 6%, the net present value (NPV) for implementation of Alternative 1 is approximately $2.0 million.

5.4 SURFACE WATER CONTROLS AND SWAMP DITCH SEEPAGE FACE PRB (COMMON TO ALTERNATIVES 2, 3, 6, 6A AND 7)

The surface water controls and swamp ditch seepage face PRB are common to Alternatives 2, 3, 6, 6A and 7. This component is evaluated separately in this section.

Implementability

Soil containing low levels of Sr-90 may become exposed during re-grading and excavation activities, and health and safety requirements typically used for excavation of soils would need to be in effect. The current applicable WVDP processes and procedures to address ALARA, contamination control, worker safety, and radioactive waste management would be employed to implement this alternative.

As described in Section 4.3.1, excavation of the seep area and swamp ditch would be required to make room for the PRB. Approximately 1,100 cubic yards of soil will require management as low-level radioactive waste.

The construction of the PRB should be performed in drier conditions. Provisions for stabilizing the work area and/or diverting runoff from the area need to be in place and implemented as necessary. No other significant impediments to construction are anticipated.

Effectiveness in Attaining RAO

The seepage face PRB would be effective in attaining RAO 1 at the existing seepage locations within the 175 foot section of the swamp ditch immediately west of the piped section and to the surface seep area which conveys seepage and runoff from the south to the north approximately 50 feet west of the western margin of the CDDL.

Although the PRB will be designed so as not to restrict the natural groundwater seepage to the swamp ditch, it is not expected to enhance or increase the rate of discharge to the ditch. Therefore, if the ditch is not currently acting as a fully penetrating groundwater discharge barrier, groundwater will continue to flow beneath the ditch toward downgradient groundwater seepage points located along the west side of the Erdmann Brook/Frank's Creek Valley. Therefore, the monitoring of downgradient seeps as is done currently would need to continue for the Alternatives incorporating the swamp ditch PRB.

The performance of the seepage face PRB in treating seepage would be monitored by periodic collection of surface water samples from the swamp ditch. The estimated lifespan of the seepage face PRB would be estimated based on pre-design studies and on the performance monitoring data. A contingency plan would be developed to address Sr-90 breakthrough at a level above the DCG or other limit as deemed appropriate. At such time, it will be necessary to evaluate whether the groundwater remedy to contain plume expansion (hydraulic barrier or PTW) has been sufficiently effective that seepage face treatment is no longer required. This will entail groundwater monitoring in the soils below and adjacent to the PRB. If seepage face treatment is found to be no longer required, the seepage face PRB would simply be removed and disposed. Conversely, if it is determined that discharging groundwater represents a continued concern with respect to Sr-90 concentration, the seepage face PRB could be replaced by removing the material, segregating the stone for reuse, disposal of used zeolite, and rebuilding the PRB with fresh zeolite as described above.

In the (30-year) cost analyses presented below, Geomatrix has assumed the following:

1. Removal of the seepage face PRB after 5 years.

2. Replacement of the PRB is not required due to the effectiveness of the plume control measures.

Additional Data Requirements

A critical component of the seepage face PRB design is to maintain sufficient permeability so as not to restrict the seepage to the point where groundwater flow is diverted elsewhere. Detailed analysis of the hydraulic effect of modifying the seep area and swamp ditch would be required as part of the system design.

As indicated above, a surface water monitoring program would be required to verify that surface water concentrations in the swamp ditch and seeps downgradient of the swamp ditch remain below the DCG. Baseline (prior to implementation of controls) seep observations, flow estimates and sampling should be performed as a basis for evaluating system performance. A contingency plan should be developed which specifies a strategy for responding to persistent downgradient seepage above the DCG should this occur. This could include provisions for increased monitoring frequency and detailed assessment of the cause(s) and likely duration of the exceedance. Such an exceedance would be expected to be a temporary phenomenon which would be mitigated over time by the plume control measure (hydraulic barrier or PTW). The duration of the exceedance would depend upon the effectiveness of the plume control measure in reducing the Sr-90 concentration in groundwater migrating toward the seeps, the travel time between the plume control and the seeps, and attenuation mechanisms along the transport pathway.

Compatibility with Comprehensive Decommissioning Plan

There are no significant CDP compatibility issues posed by implementation of the swamp ditch seepage face PRB.

Cost

The estimated cost for implementation of the swamp ditch seepage face PRB is the same for Alternatives 2, 3, 6, 6A and 7 (approximately $700,000). The present worth value for removal and disposal of the PRB after 5 years would be approximately $400,000. The cost is broken out on the tabulated cost estimates for each of these alternatives (see below).

5.5 SWAMP DITCH LINING AND SURFACE WATER CONTROLS (COMMON TO ALTERNATIVES 4 AND 5)

The swamp ditch lining and surface water controls are common to Alternatives 4 and 5 (the downgradient hydraulic barrier alternatives). This component is evaluated separately in this section.

Implementability

The swamp ditch lining as described in Section 4.3 utilizes common methods of storm water management and drainageway stabilization and its construction would present no problems with respect to implementability.

Soil containing low levels of Sr-90 may become exposed during re-grading activities, and health and safety requirements typically used for excavation of soils would need to be in effect. The current applicable WVDP processes and procedures to address ALARA, contamination control, worker safety, and radioactive waste management would be employed to implement this alternative.

Effectiveness in Attaining RAO

The swamp ditch lining employed in concert with the collocated hydraulic barriers would be effective in attaining RAO 1. Since the lined section of the ditch would be within the depression effected by the extraction wells (Alternative 4) or trench drain (Alternative 5), groundwater flow which formerly seeped to the ditch would be captured, reducing or eliminated the risk of downgradient Sr-90 breakout.

It may be that the downgradient hydraulic controls alone could meet the RAOs without the ditch lining if a depression sufficient to dewater the seepage face along the impacted section of the ditch could be created. However, this level of dewatering would require more pumping than would be necessary to simply create a hydraulic gradient reversal between the ditch and the groundwater extraction trench or wells. Ditch lining provides a further benefit in that it prevents infiltration of surface water to the groundwater during high runoff conditions. Therefore, ditch lining is included as a component in Alternatives 4 and 5.

A surface water monitoring program would be required to verify the effectiveness of the hydraulic barrier and ditch lining. A contingency plan should be developed in the event discharge to surface water above the DCG is persistent.

Additional Data Requirements

As indicated above, a surface water monitoring program would be required to verify that surface water concentrations in the swamp ditch and in seeps downgradient of the swamp ditch remain below the DCG. Baseline (prior to implementation of controls) seep observations, flow estimates and sampling should be performed as a basis for evaluating system performance. A contingency plan should be developed which specifies a strategy for responding to exceedances of the DCG should this occur. This could include provisions for increased monitoring frequency and detailed assessment of the cause(s) and likely duration of the exceedance.

Compatibility with Comprehensive Decommissioning Plan

There are no significant compatibility issues if the swamp ditch controls are implemented with the far downgradient hydraulic barrier alternatives.

Cost

The estimated cost for implementation of the swamp ditch controls is the same for Alternatives 4 and 5 (approximately $40,000). The cost is broken out on the tabulated cost estimates for these alternatives (see below).

5.6 ALTERNATIVE 2: SEEPAGE FACE PRB/INTERCEPTOR TRENCH DRAIN

The Alternative 2 interceptor trench drain and groundwater treatment are evaluated in this subsection. The swamp ditch seepage face PRB used in Alternatives 2, 3, 6, 6A and 7 is evaluated in Section 5.4, however its cost is included in the cost evaluation for Alternative 2 below.

Implementability

The Alternative 2 interceptor trench drain relies on commonly used and demonstrated construction methods. Due to the depth of excavation required, shoring and/or use of trench boxes would be required. Most of the excavating would occur in saturated soils below the water table. Therefore dewatering of the excavation and management of the associated water produced will be required.

Approximately 650 cubic yards of soil would be excavated. Soil stockpiling prior to off-site disposal would be required and this presents the following implementability concerns:

- Soil will likely need to be dewatered or stabilized prior to shipment to the disposal facility, water generated will have to be collected and treated.

- Erosion controls and fugitive dust controls will be required.

- Temporary storage of 650 cubic yards of soil prior to packaging to allow dewatering, characterization, or other preparation for shipping and disposal.

These concerns are not insurmountable, but will add to the cost of implementation.

The trench drain excavation could expose workers to impacted soils. Sr-90 concentrations in the soils would likely exceed concentrations encountered further downgradient (e.g., the swamp ditch). Health and safety requirements typically used for excavation of soils in impacted areas of the North Plateau would need to be followed. The current applicable WVDP processes and procedures to address ALARA, contamination control, worker safety, and radioactive waste management would be employed to implement this alternative.

Recovery well installation in the SWS adjacent to the trench drain would involve conventional installation methods similar to those used to install the existing NPGRS. Discharge of treated groundwater would require modification of the WVDP State Pollution Discharge Elimination System (SPDES) Permit.

Effectiveness in Attaining RAO

The Alternative 2 trench drain and SWS recovery well would be effective in immediately intercepting the plume and preventing further migration across the trench alignment. Groundwater more than a few feet downgradient of the trench drain would continue to migrate to the north and some could eventually discharge to surface water via seeps downgradient of the swamp ditch (see discussion in Section 5.4, above). The effectiveness in attaining RAO 1 would depend on the natural attenuation of Sr-90 as it continues to migrate downgradient of the trench drain. Once the plume migration is cut off at the trench drain, Sr-90 concentrations in downgradient groundwater will decline. As indicated in Section 5.4, it is possible that the DCG could be temporarily exceeded in downgradient seeps. However, unless there is an unknown source of Sr-90 located north of the trench drain, any exceedance of the DCG in downgradient seepage should be a temporary phenomenon.

As described in Section 5.4, contingency planning for potential exceedance of the DCG in seepage downgradient of the swamp ditch should be a component of the detailed design of Alternative 2, should it be implemented.

Additional Data Requirements

The additional data requirements related to the swamp ditch seepage face PRB would be required as described in Section 5.4.

The geology and hydrogeology along the Alternative 2 trench drain alignment have been extensively studied. Additional data needs for trench drain design would likely include: a short duration Geoprobe investigation along the trench alignment, collection and analysis of soil and groundwater samples to evaluate mass flux for trench bottom depth optimization and soil and groundwater handling requirements and hydraulic testing of the SWS to optimize recovery well placement. It may be appropriate to conduct some investigation activities to refine the extent of the Sr-90 plume in the vicinity of the CDDL based on a fewer number of sampling points when compared to other areas of the North Plateau. This work could be completed within a 3 to 4 month timeframe.

Compatibility with Comprehensive Decommissioning Plan

The alternatives which include groundwater extraction can be considered compatible with the CDP if the hydraulic extraction components of the alternative are included in the CDP. Explanation follows.

Alternative 2 relies on an interceptor trench drain to mitigate further expansion of the plume and reduce the rate of groundwater flow to the vicinity of the swamp ditch. The trench drain will create a drawdown along its alignment increasing the hydraulic gradient measured from the core of the plume. This necessarily results in increased groundwater velocity from the core of the plume to the trench drain causing an increase in the rate at which groundwater containing higher levels of Sr-90 migrates toward the trench drain. Consequently, groundwater between the trench drain location and the core of the plume would become more contaminated more quickly than would occur in the absence of groundwater extraction. Therefore, it may be that the Alternative 2 trench drain could not be shut off when the comprehensive remedy is implemented unless some provision is included in the CDP which addresses the contaminated groundwater which has migrated toward the trench drain. The positive aspect of the plume cutoff at the location of the Alternative 2 trench drain is that it would prevent more highly contaminated groundwater from contaminating soils further downgradient than presently occurs. This could prove highly beneficial should a large scale soil excavation program be instituted as part of the CDP.

That said, the trench drain is the most efficient means to hydraulically control plume expansion. Drawdown caused by the trench drain can be precisely controlled to intercept groundwater primarily flowing from the upgradient side such that the total groundwater extraction rate can be minimized (relative to extraction wells for example). Thus the trench drain alternatives would produce less plume distortion than pumping from extraction wells. However, the distortion effect could still be significant and would have to be considered in development of the CDP.

Conversely, the Alternative 2 trench drain system would be highly compatible with the CDP if the remedy were designed to continue to mitigate plume expansion. It could be rather easily integrated with source reduction measures such as excavation of hot spots or soil flushing (e.g., flushing near and below the core area would have a down gradient capture point). It could also be incorporated as the primary means of long term groundwater remediation if the appropriate institutional controls are implemented at the Site to prevent exposure to the core of the plume.

In summary, the Alternative 2 interceptor trench drain would be compatible if incorporated into the CDP and incompatible if it were required to be terminated as part of the CDP.

Cost

Table 2 presents the estimated cost for implementation of Alternative 2. As with all alternatives requiring ex-situ groundwater treatment, the major cost (by far) is associated with treatment system O&M. The total capital cost for construction of Alternative 2 is estimated to be approximately $3.1 million. The annual O&M cost for the groundwater treatment system alone is estimated to cost approximately $1.9 million per year. When groundwater and permit monitoring costs (assumed to be $100,000 for all alternatives) are included, the Operations, Maintenance and Monitoring (OM&M) cost total approximately $2.0 million per year.

For 5 years operation assuming a discount rate of 6%, the NPV for implementation of

Alternative 2 is approximately $11.9 million. As discussed above, it could be appropriate to incorporate Alternative 2 on a long term basis into the CDP. While this report is not intended to address the CDP, for information purposes the NPV for 30 years operation of Alternative 2 would be approximately $30.9 million.

5.7 ALTERNATIVE 3: SEEPAGE FACE PRB/GROUNDWATER EXTRACTION WELLS

The Alternative 3 groundwater extraction well system and groundwater treatment are evaluated in this subsection. The swamp ditch seepage face PRB used in Alternatives 2, 3, 6, 6A and 7 is evaluated in Section 5.4, however its cost is included in the cost evaluation for Alternative 3 below.

Implementability

The Alternative 3 extraction well system relies on commonly used and demonstrated construction methods. It does not have the implementability concerns associated with large scale excavation alternatives. Extraction well installation would not require dewatering or soil stockpiling. Health and safety protocols previously used for well installation at the Site would be sufficient for the extraction well installations. The current applicable WVDP processes and procedures to address ALARA, contamination control, worker safety, and radioactive waste management would be employed to implement this alternative. Discharge of treated groundwater would require modification of the WVDP SPDES Permit.

Effectiveness in Attaining RAO

The Alternative 3 groundwater extraction well system would be effective in immediately intercepting the plume and preventing further migration across its alignment. The extraction wells would draw water from further downgradient than the Alternative 2 trench drain, but as a consequence would generate more water for treatment. Still, groundwater beyond the downgradient stagnation points would continue to migrate to the north and some could eventually discharge to surface water via seeps downgradient of the swamp ditch (see discussion in Section 5.4, above). As with Alternative 2, the effectiveness of Alternative 3 depends in part on the natural attenuation of Sr-90 as it continues to migrate downgradient of the extraction well line. Once the plume migration is cut off at the extraction well line, Sr-90 concentrations in downgradient groundwater will decline. As indicated in Section 5.4, it is possible that the DCG could be temporarily exceeded in seeps located downgradient of the swamp ditch. However, unless there is an unknown source of Sr-90 located north of the extraction well line, any exceedance of the DCG in downgradient seepage should be a temporary phenomenon. As described in Section 5.4, planning for such an occurrence should similarly be a component of the detailed design of Alternative 3, should it be implemented.

Additional Data Requirements

The additional data requirements related to the swamp ditch seepage face PRB would be required as described in Section 5.4 The geology and hydrogeology along the Alternative 3 recovery well alignment have been extensively studied. Additional data needs for recovery well system design would likely include: a short duration Geoprobe investigation along the recovery well alignment, collection and analysis of soil and groundwater samples to evaluate mass flux for well placement optimization and soil and groundwater handling requirements and hydraulic testing of the SWS to optimize recovery well placement. It may be appropriate to conduct some investigation activities to refine the extent of the Sr-90 plume in the vicinity of the CDDL based on a fewer number of sampling points when compared to other areas of the North Plateau. This work could be completed within a three to four-month timeframe.

Compatibility with Comprehensive Decommissioning Plan

The Alternative 3 extraction well system is subject to the same limitations with respect to compatibility with the CDP as described above for the Alternative 2 trench drain system. The plume distortion would likely be more pronounced for the Alternative 3 extraction well system due to the higher total extraction rate and increased drawdown near the extraction wells (compared to the flow and drawdown predicted for the Alternative 2 trench drain). Alternative 3 shares the positive aspect of the plume cutoff at the location of the Alternative 3 extraction well line in that it also would prevent more highly contaminated groundwater from contaminating soils further downgradient than presently occurs. This could prove highly beneficial should a large scale soil excavation program be instituted as part of the CDP.

Similar to the Alternative 2 trench drain, the extraction system could be incorporated as a primary (or sole) component of the CDP for groundwater remediation. In summary, the Alternative 3 extraction well system would be compatible if incorporated into the CDP and incompatible if it were required to be terminated as part of the CDP.

<u>Cost</u>

Table 3 presents the estimated cost for implementation of Alternative 3. As with all alternatives requiring ex-situ groundwater treatment, the major cost (by far) is associated with treatment system O&M. The total capital cost for construction of Alternative 3 is estimated to be approximately $2.5 million. The O&M cost for the groundwater treatment system and monitoring is estimated to be $3.2 million per year.

For 5 years operation assuming a discount rate of 6%, the NPV for implementation of Alternative 3 is estimated at approximately $16.5 million. As discussed above, it could be appropriate to incorporate Alternative 3 on a long term basis into the CDP. While this report is not intended to address the CDP, for information purposes the NPV for 30 years operation of Alternative 3 would be approximately $47.5 million. The higher cost of Alternative 3 relative to Alternative 2 is due to the increased groundwater pumping rate required for Alternative 3.

5.8 ALTERNATIVE 4: SWAMP DITCH LINING/FAR DOWNGRADIENT INTERCEPTOR TRENCH DRAIN

The Alternative 4 interceptor trench drain and groundwater treatment are evaluated in this subsection. The swamp ditch lining used in Alternatives 4 and 5 are evaluated in Section 5.5, however its cost is included in the cost evaluation for Alternative 4 below.

<u>Implementability</u>

The Alternative 4 interceptor trench drain relies on commonly used and demonstrated construction methods. Due to the depth of excavation required, shoring and/or use of trench boxes would be required. The Alternative 4 trench drain traverses an area where the water table is near the ground surface. Most of the excavating would occur in saturated soils below the water table. Therefore dewatering of the excavation and management of the associated water produced will be required.

Approximately 2,400 cubic yards of soil would be excavated. Soil stockpiling prior to off-site disposal would be required and this presents the following implementability concerns:

- Soil will likely need to be dewatered or stabilized prior to shipment to the disposal facility, water generated will have to be collected and treated

- Erosion controls and fugitive dust controls will be required
- Temporary storage of 2,400 cubic yards of soil prior to packaging to allow dewatering, characterization, or other preparation for shipping and disposal.

The large volume of soil and water generated during implementation of Alternative 4 limit the feasibility of implementing this alternative.

The trench drain excavation could expose workers to impacted soils. Sr-90 concentrations in the soils would likely be lower than encountered further south near the Alternative 2 trench drain. Health and safety requirements typically used for excavation of soils in relatively unimpacted areas of the North Plateau would need to be followed. The current applicable WVDP processes and procedures to address ALARA, contamination control, worker safety, and radioactive waste management would be employed to implement this alternative. Discharge of treated groundwater would require modification of the WVDP SPDES Permit.

<u>Effectiveness in Attaining RAO</u>

Alternative 4 would be highly effective in attaining RAO 1 and 2. The Alternative 4 trench drain would be effective in immediately intercepting the plume and preventing further migration across its alignment. Given its location at the far downgradient extent of the plume (as approximately defined by the 100 pCi/L isopleth), continued migration of groundwater downgradient of the trench drain does not present a significant potential for resulting in exceedance of the DCGs in seepage to surface water. The hydraulic depression created in the vicinity of the swamp ditch would be expected to prevent diversion of flow to downgradient seeps. However, some contingency planning for potential exceedance of the DCG in downgradient seepage would still be appropriate.

<u>Additional Data Requirements</u>

Geologic and hydrogeologic investigation along the Alternative 4 trench drain alignment would be necessary as part of a pre-design study. Additional data needs for trench drain design would likely include: a Geoprobe investigation along the trench alignment, collection and analysis of soil and groundwater samples to evaluate mass flux for trench bottom depth optimization and soil and groundwater handling requirements. It may be appropriate to conduct some investigation activities to refine the extent of the Sr-90 plume in the vicinity of the CDDL based on a fewer number of sampling points when compared to other areas of the North Plateau.

This work could be completed within a four to five month timeframe.

Compatibility with Comprehensive Decommissioning Plan

The Alternative 4 trench drain would have far less effect on increasing migration from the core of the plume than alternatives employing further upgradient controls (closer to the core of the plume). However, the negative aspect is that the more concentrated portion of the Sr-90 plume would continue to migrate to the far downgradient cutoff location causing soils to become more contaminated along the way. This could increase the quantity of soil to be excavated or treated as part of the CDP. Alternative 4 would be compatible if it could be incorporated into the CDP in lieu of wholesale excavation of impacted soils.

Cost

Table 4 presents the estimated cost for implementation of Alternative 4. The total capital cost for construction of Alternative 4 is estimated to be approximately $4.7 million. Groundwater treatment costs for this alternative are extremely high--estimated to total approximately $4.5 million per year. The annual OM&M cost (including monitoring) for this alternative is estimated to be approximately $4.6 million per year.

For 5 years operation assuming a discount rate of 6%, the NPV for implementation of Alternative 4 is approximately $24.2 million. As discussed above, it could be appropriate to incorporate Alternative 4 on a long term basis into the CDP. While this report is not intended to address the CDP, for information purposes the NPV for 30 years operation of Alternative 4 would be approximately $68.7 million.

5.9 ALTERNATIVE 5: SWAMP DITCH LINING/FAR DOWNGRADIENT GROUNDWATER EXTRACTION WELLS

The Alternative 5 groundwater extraction well system and groundwater treatment are evaluated in this subsection. The swamp ditch lining used in Alternatives 4 and 5 are evaluated in Section 5.5, however its cost is included in the cost evaluation for Alternative 5 below.

Implementability

The Alternative 5 extraction well system relies on commonly used and demonstrated construction methods. It does not have the implementability concerns associated with the large scale excavation alternatives. Extraction well installation would not require dewatering or soil stockpiling. Health and safety protocols previously used for well installation at the Site would be sufficient for the extraction well installations. The current applicable WVDP processes and procedures to address ALARA, contamination control, worker safety, and radioactive waste management would be employed to implement this alternative. Discharge of treated groundwater would require modification of the WVDP SPDES Permit.

Effectiveness in Attaining RAO

Alternative 5 would be highly effective in attaining RAO 1 and RAO 2. The Alternative 5 extraction well line would be effective in immediately intercepting the plume and preventing further migration across its alignment. Given the extraction well line location at the far downgradient extent of the plume (as approximately defined by the 100 pCi/L isopleth), continued migration of groundwater further downgradient does not present a significant potential for resulting in exceedance of the DCGs in seepage to surface water. The hydraulic depression created in the vicinity of the swamp ditch would be expected to prevent diversion of flow to downgradient seeps. However, contingency planning for potential exceedance of the DCG in downgradient seepage would still be appropriate.

Additional Data Requirements

Geologic and hydrogeologic investigation along the Alternative 5 extraction well alignment would be necessary as part of a pre-design study. The pre-design work would involve work plan preparation, soil borings, sampling and analysis of soil/groundwater to evaluate mass flux for well placement optimization, and hydraulic testing. Work would be similar to the data requirements described in Section 5.8. It may be appropriate to conduct some investigation activities to refine the extent of the Sr-90 plume in the vicinity of the CDDL based on a fewer number of sampling points when compared to other areas of the North Plateau.

This work could be completed over a period of approximately four to five months.

Compatibility with Comprehensive Decommissioning Plan

The Alternative 5 extraction well system would have far less effect on increasing migration from the core of the plume than alternatives employing further upgradient controls (closer to the core of the plume). However, as with Alternative 4, the negative aspect is that the Sr-90 plume will continue to migrate to the far downgradient cutoff location causing soils to become more contaminated along the way. This could increase the quantity of soil to be excavated or treated as part of the CDP. Alternative 5 would be compatible if it could be incorporated into the CDP in lieu of widespread excavation of impacted soils.

Cost

Table 5 presents the estimated cost for implementation of Alternative 5. The total capital cost for construction of Alternative 5 is estimated to be approximately $2.7 million. Groundwater treatment costs for this alternative are the highest of any alternative--estimated to total approximately $5.9 million per year. The total annual O&M cost (including monitoring) for this alternative is estimated to be approximately $6.1 million per year.

For 5 years operation assuming a discount rate of 6%, the NPV for implementation of Alternative 5 is approximately $28.2 million. As discussed above, it could be appropriate to incorporate long term operation of Alternative 5 into the CDP. While this report is not intended to address the CDP, for information purposes the NPV for 30 years operation of Alternative 5 would be approximately $86.0 million.

5.10 ALTERNATIVE 6: SEEPAGE FACE PRB/IN-SITU PLUME TREATMENT WITH PASSIVE PTW

This alternative involves a combination of reducing/eliminating groundwater discharge at the swamp ditch by placement of the swamp ditch seepage face PRB as described in Section 5.4 and promoting plume control through *in situ* fixation of Sr-90 using a passive PTW. The swamp ditch seepage face PRB is evaluated in Section 5.4, however its costs are included in cost evaluation for Alternative 6 presented below.

The passive PTW would be installed south of the access road to the CDDL to mitigate the plume near the northern extent of the 10,000 pCi/L isoconcentration contour. The PTW would likely be oriented across the width of the plume as either a single treatment trench, or a series of treatment gates depending on mass discharge and hydraulic control needs, approximately perpendicular to groundwater flow. It would be constructed to the base of the TBU or SWS so to be keyed into the underlying low permeability Lavery till. Alternative 6 relies solely on the PTW operating in a passive mode (without the use of pumping or other active hydraulic control).

The following sections describe the feasibility of Alternative 6 for addressing the leading edge of the Sr-90 plume beneath the North Plateau.

Implementability

This alternative has high potential implementability. PTW technology has been pilot tested at the site; details regarding construction conditions, and methods to avoid unintended performance have been assessed previously (Geomatrix, 2001). The proposed PTW would consist of an approximately 400-ft long northwest to southeast section, with two approximately 50-foot long groundwater capturing wing PTW sections trending southwest from each end of the 400-ft PTW component. The flow through thickness of the PTW would range from approximately 2 to 3 foot flow through thickness and be composed of a high percentage mixture of granular clinoptilolite or other appropriate zeolite. Based on a review of the pilot PTW performance, a 2-ft section of zeolite appears appropriate for treating Sr-90 at activities of approximately 10,000 pCi/L or less (see Section 3.3). This consideration is based on monitoring data from wells within the pilot PTW that appeared to achieve compete reduction of Sr-90 for the first 5 years following installation of the pilot test until a high activity front exceeding 100,000 pCi/L interacted with the PTW and Sr-90 activity within the PTW rose slightly but still to less than 50 pCi/L for samples from PTW wells. For some portions of a full-scale PTW alignment, high Sr-90 migration rates may be anticipated; in these sections, the PTW design would call for greater treatment zone thickness.

The thicker sections, which would be determined during design studies, would be placed in those areas where either the ambient Sr-90 flow rate, or the Sr-90 activity is sufficiently high so as to provide additional total capacity for promoting sustainable (i.e., greater than 10 years) ion-exchange processes. Unlike the pilot PTW, an upgradient pea gravel development section is not proposed because of its limited benefit compared to the proposed construction method for the length of the PTW; however, a mixture of courser zeolite or silica sand may be used depending on specific permeability requirements along the alignment.

The treatment material within the PTW is intended to effectively promote sustained exchange of Sr-90 (a divalent cation) for monovalent cations such as sodium and potassium within the zeolite's structure. However, a constraint on the performance and longevity of the system will be competition for the zeolite's exchange site from naturally occurring divalent cations dissolved in site groundwater, including calcium and magnesium. Competitive ion-exchange also could promote the reversed exchange, or desorption, of Sr-90 from the zeolite's structure. Depending on the results of pre-design evaluation, potential methods to increase the potential longevity of the system include using zeolite minerals with greater CEC, increasing the volume of the PTW in those areas where greater capacity likely is needed, and designing a method to maintain a slightly higher pH within the PTW (for greater Sr partitioning) will be considered. Additional monitoring in specific portions of the PTW also may be appropriate although the monitoring will be tailored to the specific design of the PTW and physical hydrogeologic characteristics for which an effective monitoring program would be designed (e.g., see Warner, et al., 1998).

Construction would most likely be performed using a one-pass trencher system. The trencher is a track mounted vehicle that has a cutting boom resembling a large chain saw. The trenchers have interchangeable cutting booms and can cut a nominal 14, 20, 26, or 36-inch wide trench and average depths of 20 feet to 35 feet and up to 50 feet for slurry walls. A laser-guided system allows precise depth control during installation. As the trencher removes soil, treatment material is backfilled immediately from a hopper located on the trenching machine. Sheet piles are not needed for this process.

The trencher for installing the zeolite PTW would be operated to complete an approximately 2 to 3 foot wide trench along the majority of the proposed PTW alignment. Contractors that operate trenching systems (such as DeWind, Inc.) report that smearing along cut faces within the trench is not likely due to the action of the carbide teeth at each end of the trenching "saw." However, fines will be produced and may interact with the zeolitic material placed during the trenching operation as the native subsurface material is removed. Design studies that involve laboratory bench testing of the effective cation exchange capacity of the selected zeolite minerals under various levels of siltation should be performed. Note that an upgradient sand or gravel zone cannot be accommodated using the one-pass trenching system. However, based on initial review, such an upgradient coarse section would not be considered necessary considering the great length of the PTW (the full-scale system would not be as negatively impacted by a short length PTW as with the pilot test where an upgradient collection or development section was considered necessary).

Soil removed during the trenching would be stockpiled for soil management and disposal based on activity and chemical levels within the soil. Stockpiling and disposal present similar implementation issues as described in Section 5.3, above. No dewatering is anticipated to be applied during construction using the trencher. If unanticipated conditions occur, completion of the PTW using conventional excavation and backfill using backhoe-type equipment is feasible. However, as was the case during installation of the pilot PTW, sheet piles to hold open the PTW excavation may then be required for backfilling. The trencher is suitable for completing 3-foot thick (flow-through direction) trenches with some specialization of equipment. For those sections where a thicker section (e.g. approximately 4-feet) is necessary for additional treatment capacity, the supplemental PTW section may be offset downgradient by several feet to allow installation by the trenching system. This detail would be developed during design work.

The area for which the PTW would be installed – south of the CDDL access road – is relatively open for heavy equipment use. Utilities have apparently been mapped in the area (although specific evaluation of utilities would have to be field checked once a final alignment is selected).

The PTW would be installed to a depth no greater than approximately 25 feet below ground surface based on the current understanding of site conditions (additional subsurface detail along the proposed alignment would be proposed). The PTW would be keyed into the underlying till. Some additional characterization work to identify the specific depths across the proposed PTW alignment may be necessary.

The current applicable WVDP processes and procedures to address ALARA, contamination control, worker safety, and radioactive waste management would be employed to implement this alternative. A monitoring program would be designed specifically to evaluate performance by the PTW. The existing site monitoring program would be modified to best locate wells in areas where migration is greatest through the PTW and in areas where Sr-90 activity levels are high and transient over time. Using information specific to the plume geometry, hydraulic conditions of the ambient system and PTW, and other subsurface information, an effective monitoring program will be designed. Considerations used to develop successful monitoring programs for PTWs will be applied (e.g., see Warner, et al., 1998).

<u>Effectiveness in Attaining RAO</u>

The PTW in Alternative 6 will not treat groundwater downgradient of the PTW, however, the PTW will cut off the higher activity Sr-90 source from further affecting downgradient areas. This will reduce the concentration gradient of Sr-90 toward the north and downgradient areas. As with Alternatives 2 and 3, the effectiveness in attaining the RAO would depend in part on the natural attenuation of Sr-90 as it continues to migrate downgradient of the PTW. Once the plume migration is cut off at the PTW, Sr-90 concentrations in downgradient groundwater will decline. As indicated in Section 5.4, it is possible that the DCG could be temporarily exceeded in seeps located downgradient of the swamp ditch. However, unless there is an unknown source of Sr-90 located north of the PTW alignment, any exceedance of the DCG in downgradient seepage should be a relatively short lived phenomenon. As described in Section 5.4, planning for such an occurrence should be a component of the detailed design of Alternative 6, should it be implemented. In addition it may be appropriate to conduct some investigation activities to refine the extent of the Sr-90 plume downgradient of the PTW location in the vicinity of the CDDL based on a fewer number of sampling points when compared to other areas of the North Plateau.

The effectiveness of the PTW composed of the clinoptilolite is proven to be successful for Sr-90 affected groundwater based on pilot testing at the WVDP, and work by others (including Brookhaven National Laboratory [Fuhrman, et al., 1995] and Atomic Energy of Canada, Ltd (AECL) [Lee, et al., 1998]). The Brookhaven work did test two types of zeolite, clinoptilolite and mordenite and found that better removal of Sr-90 was afforded by the clinoptilolite. The AECL system used a semi-passive hydraulic system that allowed flow through the system to be managed directly.

The treatment would be designed to be sustainable for at least 15 years by evaluating Sr-90 migration rates, location specific hydrogeologic conditions, and the CEC of the zeolite. The pilot PTW performed such that moderate Sr-90 activity levels in groundwater were treated successfully for at least 5 years; increases in Sr-90 activity for samples from PTW wells only appeared after a very high activity groundwater front (<100,000 pCi/L) migrated to the PTW. Although these very high activity levels are not expected to migrate to the proposed placement of a full-scale PTW (activity levels of 10,000 pCi/L or less are anticipated), thicker treatment zones could be installed where additional capacity is needed. Sustainability also would require that the PTW is protected from being flushed with water (e.g.,. high sodium content water) that could cause a replacement of the Sr-90 within the mineral matrix (i.e., desorption of Sr-90 from the zeolitic treatment material back to the groundwater flow system). Such flushing by high ionic-content water, for example, is not anticipated, although there may be some competition from natural ionic conditions in the groundwater. A background (i.e.., upgradient) monitoring program intended to assess the potential for water of unintended quality to flush through the PTW system would be evaluated for implementation.

Installation of additional PTW sections downgradient and adjacent to the primary PTW may be considered as long-term maintenance alternatives if breakthrough or desorption is indicated. Although the activity of Sr-90 will continue to decrease naturally, complete closure of the PTW, which would only occur if complete cation-exchange capacity is exhausted, or ambient Sr-90 levels in groundwater were reduced to below target levels, likely would not occur for several decades. For those portions of a full-scale PTW where the treatment capacity is exhausted, the initial PTW likely would remain in place (i.e., would not be excavated) and a secondary downgradient PTW would be installed to provide additional treatment for the required number of years. The exhausted PTW may eventually become a source of Sr-90 if geochemical equilibrium conditions are inappropriate for retaining the Sr-90 in the zeolite structure. Design studies will evaluate this potential using geochemical numerical analysis. The downgradient secondary PTW would be designed to achieve treatment even with the nearby Sr-90 source from the upgradient PTW.

<u>Additional Data Requirements</u>

Ensuring the potential effectiveness of Alternative 6 (PTW component) will require the following design-level data to be collected and evaluated:

- Development of a hydrostratigraphic/hydrochemical cross-section along the alignment of the proposed PTW (some additional data collection, including site specific detail may be warranted to best assess the depth required for the PTW and the locations where additional treatment capacity would be beneficial).

- Bench-testing of one or more zeolite samples (including clinoptilolite, mordenite, chabazite, or others) to best select a zeolite with appropriate CEC, material competency, size, and cost value. Testing would also assess affects of siltation on zeolite CEC that could develop during PTW installation.

- Refinement of the groundwater flow/transport model to develop the appropriate orientation and thickness of the PTW.

- Assess existing pilot PTW to determine if its existence will have a negative impact on the performance of the selected alternative.

- Completion of cation-exchange modeling under local geochemical and flow conditions to assess desorption potential and to develop closure and post-closure criteria and maintenance for the PTW.

The pre-design/design work could be accomplished within a relatively short period of time if this alternative is selected. This work also would be proposed for completion of Alternatives 6A and 7. A potential schedule for completing this work over a period of approximately four to six months (note some activities would occur concurrently) would consist of:

  - Work Plan development and approval - 1 month

  - Field design detail collection (hydrostratigraphy along the proposed PTW alignment and collection/analysis of additional hydrochemistry data) – 3 to 4 weeks

  - Bench-scale testing of zeolite samples. Testing would also assess affects of siltation on zeolite CEC that could develop during PTW installation – 1 to 2 months

  - Hydraulic design assessment using existing site flow model – 1 month

  - Evaluation of data and reporting – 1 month

<u>Compatibility with Comprehensive Decommissioning Plan</u>

This alternative is considered to be compatible with the overall strategy of reducing and eliminating downgradient migration of Sr-90 affected groundwater toward the northern discharge areas. This alternative will not directly reduce the activity/concentration of Sr-90 in the core of the plume upgradient from the PTW, however, the PTW also is not anticipated to negatively impact potential core remedies. It is not anticipated to have a significant influence on the plume shape as is the case with the hydraulic barrier alternatives installed along the same alignment (Alternatives 2 and 3).

This alternative will not require aboveground equipment with the exception of access for performance monitoring activities (e.g., well heads and access to those well heads). Therefore, land use of the site should not be negatively affected by the PTW.

<u>Cost</u>

The representative costs for implementation of this alternative are presented in Table 6. For 5 years operation assuming a discount rate of 6%, the NPV for implementation of Alternative 6 is approximately $6.4 million.

Costs for installation of the PTW include:

- Construction of a level platform along the PTW alignment on which the one-pass trencher will rest.
- Purchase and delivery of zeolite (clinoptilolite).
- Excavation and simultaneous backfill of the 500 ft long trench and of the additional 250 feet of secondary trench (for additional treatment capacity in high flow rate – high activity areas) by the one-pass trencher.
- Soil disposal as a low level radioactive waste which includes an additional volume of soil (approximately 400 cubic yards) produced in those areas where additional flow through thickness of the PTW is required.
- Installation of monitoring wells.
- Site restoration.

Geomatrix anticipates that this alternative will perform successfully for at least 15 years with the appropriate level of monitoring to assure that no significant breakthrough occurs. Additional PTW sections may be required at this time (or in later years) in areas where higher flow rate and higher Sr-90 activity zones are present.

As discussed above, it could be appropriate to incorporate long term operation of Alternative 6 into the CDP. While this report is not intended to address the CDP, for information purposes the NPV for 30 years operation of Alternative 6 would be approximately $8.7 million. The 30 year NPV cost includes costs for wall mitigation (e.g., replacement) if unacceptable Sr-90 breakthrough occurred within 30 years. For cost analysis, we have assumed a replacement wall is constructed after 15 years of operation.

5.11 ALTERNATIVE 6A: SEEPAGE FACE PRB/IN-SITU PLUME TREATMENT WITH ACTIVE PTW

Alternative 6A relies on the PTW operating in a hydraulically active mode where gradient control (to promote hydraulic capture) is provided by a series of pumping wells constructed within the PTW system. The swamp ditch seepage face PRB used in Alternatives 2, 3, 6, 6A and 7 are evaluated in Section 5.4, however its cost is included in the cost evaluation for Alternative 6A below.

Implementability

This alternative has high potential implementability (see rationale under Alternative 6, previously). The primary difference in this alternative is the inclusion of active hydraulic control via pumping. The potential benefit and effectiveness in enhancing hydraulic capture, including capturing downgradient areas, was evaluated as part of the pilot PTW assessment studies conducted under the direction of WVNS. Geomatrix (2001) assessed potential pumping scenarios within the pilot PTW and concluded that additional capture was possible using a series of one or more low-rate pumping wells. Groundwater removed from the pumping wells should be treated for Sr-90 by the PTW, provided the residence time is sufficient to allow for adequate ion-exchange to occur. Including pumping wells within the PTW is conventional technology; routing discharge lines from the PTW to a discharge location (if no further treatment is necessary) also uses conventional technology. If a siphon-pumping system is used to provide hydraulic control; additional design work should be conducted to confirm implementability due to head loss and contingency discharge considerations.

The current applicable WVDP processes and procedures to address ALARA, contamination control, worker safety, and radioactive waste management would be employed to implement this alternative.

Effectiveness is Attaining RAOs

Plume control will occur at the location of the PTW and to some distance downgradient of the PTW due to the promotion of an enhanced capture zone from active pumping. The PTW in Alternative 6A will treat groundwater some distance downgradient of the PTW and will cut off the higher activity Sr-90 source from further affecting downgradient areas. This will reduce the concentration gradient of Sr-90 toward the north and downgradient areas. However, the downgradient capture zone is expected to extend only a short distance from the active PTW and, as with Alternatives 2, 3 and 6, the effectiveness in attaining the RAO would depend in part on the natural attenuation of Sr-90 as it continues to migrate downgradient of the PTW. Once the plume migration is cut off at the PTW, Sr-90 concentrations in downgradient groundwater will decline. As indicated in Section 5.4, it is possible that the DCG could be temporarily exceeded in seeps located downgradient of the swamp ditch. However, unless there is an unknown source of Sr-90 located north of the PTW alignment, any exceedance of the DCG in downgradient seepage should be a relatively short lived phenomenon. As described in Section 5.4, planning for such an occurrence should be a component of the detailed design of Alternative 6A, should it be implemented. In addition it should be verified that the CDDL is not a significant source of Sr-90 at levels above the DCG.

The effectiveness of the PTW composed of the zeolitic material is proven to be successful for Sr-90 affected groundwater as described under Alternative 6.

The treatment would be designed to be sustainable for at least 15 years by evaluating Sr-90 migration rates, location specific hydrogeologic conditions, and the CEC of the zeolite. Because pumping could increase the rate at which Sr-90 impacted groundwater flows into and through the PTW, additional design work would be recommended to appropriately place pumping wells and size (thickness and percent zeolite) the PTW system. The 15 year time is considered reasonable based on the following rationale:

- Laboratory testing has indicated that the ion exchange capacity is sustainable for at least 20 years (Rabideau, 1999).

- The pilot PTW has achieved treatment of Sr-90 affected groundwater for at least 5 years (at activity levels significantly higher than those levels anticipated along the proposed alignment of a full-scale PTW).

- Design work would focus on both a design and zeolite composition capable of achieving the 15 year lifetime.

Because pumping could increase the rate at which Sr-90 impacted groundwater flows into and through the PTW, additional design work would be recommended to appropriately place pumping wells and size the PTW system (thickness and percent zeolite) so that the 15 year lifetime is achievable.

<u>Additional Data Requirements</u>

The potential effectiveness of Alternative 6A (PTW component) will require the following design-level data to be collected and evaluated:

- Development of a hydrostratigraphic/hydrochemical cross-section along the alignment of the proposed PTW (some additional data collection, including site specific detail may be warranted to best assess the depth required for the PTW and the locations where additional treatment capacity would be beneficial).

- Limited bench-testing of one or more zeolite samples to best select a zeolite with appropriate CEC, material competency, size, and cost value. Testing would also assess affects of siltation on zeolite CEC that could develop during PTW installation.

- Refinement of the groundwater flow/transport model to develop the appropriate orientation and thickness of the PTW along the final alignment and to place gradient control/capture wells within the PTW.

- Assess existing pilot PTW to determine if its existence will have a negative impact on the performance of the selected alternative.

- Completion of cation-exchange modeling under local geochemical and flow conditions to assess desorption potential and to develop closure and post-closure criteria and maintenance for the PTW.

- Assessment of recovered groundwater treatment alternatives as a contingency if discharge limits are exceeded (for example, a siphon-control system treatment cell or treatment at LLW2).

The potential schedule for collecting and assessing the additional data is as described above for Alternative 6.

Compatibility with Comprehensive Decommissioning Plan

This alternative is considered to be compatible with an overall strategy of reducing and eliminating downgradient migration of Sr-90 affected groundwater toward the northern discharge areas. This alternative may provide some reduction of the activity/concentration of Sr-90 in the core of the plume upgradient from the PTW because non-Sr-90 impacted water would be reinjected into the core of the plume, however, the PTW also is not anticipated to negatively impact potential core remedies. If reinjection of discharge from the PTW pumping system occurs upgradient in the plume core area, an evaluation of the potential affects (positive or negative) will be required.

This alternative will require above ground equipment associated with pumping and reinjection systems. However, this potential impact is considered to be limited in area and the majority of the site should not be negatively affected by this PTW alternative.

Cost

The representative costs for implementation of this alternative using a mechanical driven pump system are presented in Table 7. For 5 years of operation assuming a discount rate of 6%, the NPV for implementation of Alternative 6A is approximately $6.6 million.

Costs for installation of the PTW include:

- Construction of a level platform along the PTW alignment on which the one-pass trencher will rest.
- Purchase and delivery of zeolite (clinoptilolite).
- Excavation and simultaneous backfill of the 500 ft long trench and of the additional 250 feet of secondary trench (for additional treatment capacity in high flow rate – high activity areas) by the one-pass trencher.
- Soil disposal.

- Installation of gradient-control/capture wells within the PTW and discharge piping.
- Installation of monitoring wells.
- Site restoration.

Geomatrix anticipates that this alternative will perform successfully for at least 15 years with the appropriate level of monitoring to assure that no significant breakthrough occurs. Additional PTW sections may be required in time to prevent potential breakthrough or desorption prior to final closure.

As discussed above, it could be appropriate to incorporate long term operation of Alternative 6A into the CDP. While this report is not intended to address the CDP, for information purposes the NPV for 30 years operation of Alternative 6A would be approximately $14.4 million. The comparatively higher cost is based on the assumption that groundwater collected from the system requires additional treatment after 5 years. This cost could be substantially lower if treatment of collected groundwater is delayed beyond the 5 year time-frame. The 30 year NPV cost includes costs for wall mitigation (e.g., replacement) if unacceptable Sr-90 breakthrough occurred within 30 years. For cost analysis, we have assumed a replacement wall is constructed after 15 years of operation.

5.12 ALTERNATIVE 7: SEEPAGE FACE PRB/FAR DOWNGRADIENT IN-SITU PLUME TREATMENT WITH PASSIVE PERMEABLE TREATMENT WALL

This alternative involves a combination of reducing/eliminating groundwater discharge at the swamp ditch by placement of the swamp ditch seepage face PRB as described in Section 5.4 and promoting plume control through in-situ fixation of Sr-90 using a passive PTW that extends out to the swamp ditch and beyond the 100 pCi/L contour. The PTW also would be placed beyond the limits of the CDDL because of the inability to implement a PTW within the CDDL. This alternative also would include low permeability diversion walls in areas where treatment may not be necessary, but plume control or routing of the groundwater through the downgradient limits of the PTW is intended. The dimensions of this alternative include approximately 1000-feet of PTW at 2-foot width to the base of the Lavery Till, and approximately 700 feet of hydraulic diversion barriers composed of a soil-bentonite mixture. The proposed orientation of the PTW/barrier system is illustrated by Figure 14.

The PTW would be oriented across the width of the plume as either a single treatment trench or a series of treatment gates depending on mass discharge and hydraulic control needs in certain areas. The PTW and diversion walls would be constructed to the base of the TBU or SWS so to be keyed into to the underlying low permeability Lavery Till. Alternative 7 relies solely on the PTW operating in a passive mode (without the use of pumping or other active hydraulic control).

The description of the PTW concept was provided under Alternative 6. The following paragraphs describe the feasibility of Alternative 7 for meeting the project RAO.

Implementability

This alternative has high potential implementability as described for Alternative 6.

Construction would likely be performed using a one-pass trencher system as described for Alternative 6. Soil removed during the trenching to construct the PTW would be stockpiled for soil management and disposal based on activity and chemical levels within the soil. Stockpiling and disposal present similar implementation concerns as described in Section 5.5, above. The diversion walls would be mixed in place with the one-pass trencher; soil would be mixed with bentonite and water slurry and excess soil (assumed to be 20% of the volume of the diversion wall) would be stockpiled for soil management and disposal based on activity and chemical levels within the soil. No dewatering is anticipated to be applied during construction using the trencher. If unanticipated conditions occur, completion of the PTW using conventional excavation and backfill using backhoe-type equipment is feasible. However, as was the case during installation of the pilot PTW, sheet piles to hold open the PTW excavation may then be required for backfilling. Consideration of potential affects on the ambient hydraulics due to potential “smearing” along fine grained hydrostratigraphic zones in the SWS, from the sheet pile installation and withdrawal within the subsurface would be important. Similarly, the diversion walls can be completed using conventional soil-bentonite slurry wall or sheet pile wall construction techniques if the one-pass trencher encounters unanticipated difficulties. The trencher is suitable for completing 2 to 3-foot thick (flow-through direction) trenches.

The area for which the PTW and diversion walls would be installed – including north of the CDDL – is relatively open for heavy equipment use. Utilities have apparently been mapped in the area (although specific evaluation of utilities would have to be field checked once a final alignment is selected).

The PTW and diversion walls would be keyed into the underlying till. Some additional characterization work to identify the specific depths across the proposed PTW alignment may be necessary.

The current applicable WVDP processes and procedures to address ALARA, contamination control, worker safety, and radioactive waste management would be employed to implement this alternative.

Effectiveness is Attaining RAOs

Plume control will occur at the location of the PTW. In this case, the PTW captures the entire plume area to the currently mapped 100 pCi/L contour but its treatment efficiency would be lower relative to Alternatives 6 and 6A because of the very low concentrations of Sr-90 in groundwater that would eventually interact with the PTW. The PTW in Alternative 7, while protective, is considered inefficient as a means to remove Sr-90 mass from the plume because of the PTW's location.

The effectiveness of the PTW composed of the zeolitic material is proven to be successful for Sr-90 affected groundwater based on pilot testing at the WVDP, and work by others (including Brookhaven National Laboratory and Atomic Energy of Canada, Ltd.).

The treatment would be designed to be sustainable for at least 15 years by evaluating Sr-90 migration rates, location specific hydrogeologic conditions, and the CEC of the zeolite. The PTW may be located far downgradient from the leading edge of the plume in some areas because of being north of the CDDL and the inability to implement the PTW within the CDDL. Due to this, the PTW would be inefficient in reducing Sr-90 concentrations from the plume significantly. Once within the PTW, the activity of Sr-90 will continue to decrease naturally, complete closure of the PTW likely would not occur for several decades.

Additional Data Requirements

The potential effectiveness of Alternative 7 will require the following design-level data to be collected and evaluated:

- Development of a hydrostratigraphic/hydrochemical cross-section along the alignment of the proposed PTW (some additional data collection, including site specific detail may be warranted to best assess the depth required for the PTW and the locations where additional treatment capacity would be beneficial).

- Bench-testing of one or more zeolite samples to best select a zeolite with appropriate CEC, material competency, size, and cost value and assess affects of siltation on zeolite CEC that could develop during PTW installation.

- Refinement of the groundwater flow/transport model to develop the appropriate orientation and thickness of the PTW along the final alignment.

- Assess existing pilot PTW to determine if its existence will have a negative impact on the performance of the selected alternative.

- Completion of cation-exchange modeling under local geochemical and flow conditions to assess desorption potential and to develop closure and post-closure criteria and maintenance for the PTW.

The potential schedule for collecting and assessing the additional data is as described above for Alternative 6. The greater length of PTW components would increase the duration for hydrostratigraphic/hydrochemical data collection by several weeks.

Compatibility with Comprehensive Decommissioning Plan

This alternative is considered to be compatible with the overall strategy of reducing and eliminating downgradient migration of Sr-90 affected groundwater toward the northern discharge areas. This alternative will not directly reduce the activity/concentration of Sr-90 in the core of the plume upgradient from the PTW nor will it cause plume distortion. However, as with Alternatives 4 and 5, the negative aspect is that the Sr-90 plume will continue to migrate to the far downgradient PTW location causing soils to become more contaminated along the way. This could increase the quantity of soil to be excavated or treated as part of the CDP. Alternative 7 would be compatible if it could be incorporated into the CDP in lieu of widespread excavation of impacted soils.

This alternative will not require above-ground equipment with the exception of access for performance monitoring activities (e.g., well heads and access to those well heads). Therefore, land use of the site should not be negatively affected by the PTW.

Cost

The representative costs for implementation of this alternative are presented in Table 8. For 5 years of operation assuming a discount rate of 6%, the net present value (NPV) for implementation of Alternative 7 is approximately $8.7 million.

Costs for installation of the PTW include:

- Construction of a level platform along the PTW alignment on which the one-pass trencher will rest.

- Purchase and delivery of zeolite (clinoptilolite).

- Excavation and simultaneous backfill of the 1000 ft long trench for the PTW and 700 ft long trenches for the low permeability diversion walls.

- Soil disposal. For a 2-feet-wide trench, approximately 17,000 cubic yards of soil requiring disposal will be generated.

- Installation of monitoring wells.

- Site restoration.

Geomatrix anticipates that this alternative will perform successfully for at least 15 years with the appropriate level of monitoring to assure that no significant break through occurs. However, because the majority of the PTW is located far from high-activity Sr-90-groundwater, aging of the PTW (through competitive ion-exchange) may occur in advance of any high-activity Sr-90 front reaching the PTW.

As discussed above, it could be appropriate to incorporate long term operation of Alternative 7 into the CDP. While this report is not intended to address the CDP, for information purposes the NPV for 30 years operation of Alternative 7 would be approximately $11.8 million. The 30 year NPV cost includes costs for wall mitigation (e.g., replacement) if unacceptable Sr-90 breakthrough occurred within 30 years. For cost analysis, we have assumed a replacement wall is constructed after 15 years of operation.

6.0 COMPARISON OF ALTERNATIVES

Alternative 1 (maintain current NPGRS) is the least effective alternative and would not meet the project RAO. The estimated cost (5-year NPV) of $2.4 million is the lowest of the evaluated alternatives.

The far downgradient hydraulic barriers as employed in Alternatives 4 and 5 are clearly the most effective in meeting RAO 1. The combined effect of dewatering in the vicinity of the swamp ditch and the swamp ditch controls will prevent the development of increased Sr-90 concentrations in seeps located downgradient of the swamp ditch. Plume distortion and consequent effect on the CDP for Alternatives 4 and 5 is minimized by the distance from the withdrawal points to the core of the plume, however some minor increase in the rate of Sr-90 migration to the extraction wells or trench drain should be expected. The high degree of effectiveness of these alternatives comes at a steep price however--$24.2 million 5-year NPV for Alternative 4 and $28.2 million 5-year NPV for Alternative 5. A second downside (in addition to the cost) is that the Sr-90 plume would continue to migrate to the far downgradient hydraulic barrier location causing more soil to become contaminated as it expands and thus not meeting RAO 2. Furthermore, these alternatives therefore may not be compatible with the CDP (RAO 3) if widespread excavation of soils below the water table is a remedy component.

The high costs of Alternatives 4 and 5 relative to all other alternatives evaluated is attributable entirely to the higher volume of groundwater requiring treatment. Geomatrix assumed ion exchange treatment as is currently being used at the Site. Alternative treatment methods may be available at a somewhat lower cost, though this is by no means certain. All treatment methods necessarily generate a low level waste stream which requires disposal (e.g., spent resin for ion exchange systems, highly concentrated reject streams for reverse-osmosis systems). Therefore, there may not be much opportunity for cost saving through use of alternative groundwater treatment technologies (though some evaluation of alternative technologies would be appropriate if a hydraulic barrier alternative is selected for implementation).

For Alternatives 2 and 3, both alternatives satisfy RAO 1 and the cost of maintaining the hydraulic barrier is reduced by locating the barrier farther upgradient, closer to the core of the plume. Since the plume is narrower at this location, the hydraulic barrier needs to be effective over a smaller width with a proportional decrease in required groundwater extraction rate. The estimated 5-year NPV costs for implementation of Alternatives 2 and 3 are $11.9 million and $16.5 million respectively. The cost reduction relative to the far downgradient hydraulic barriers is substantial. Alternatives 2 and 3 are also preferable to the far downgradient hydraulic barrier alternatives from a treatment efficiency perspective. Even in the most impacted groundwater, Sr-90 makes up a small component of the total cation content of the water. Therefore, when ion exchange methods are used, the cost of treating groundwater with high concentrations of Sr-90 is similar to the cost for treating groundwater with low levels. Alternatives 2 and 3 provide greater treatment efficiency in that more mass of Sr-90 is removed per dollar of treatment cost. The disadvantages of both Alternatives 2 and 3 is that there would be more uncertainty with respect to the temporary development of downgradient seeps exceeding the DCG and potentially more impact on plume distortion (less compatibility with the CDP unless the alternatives are incorporated into the CDP).

The passive PTW alternatives (Alternatives 6 and 7) are favorable from a cost perspective because no above-ground groundwater treatment is required. The estimated 5-year NPV costs for implementation of Alternatives 6 and 7 are \$6.4 million and \$8.7 million, respectively. Similarly, these alternatives are favorable from the perspective of compatibility with the CDP because no groundwater extraction would be performed and no plume distortion would be expected. For the PTW nearer the core of the plume (Alternative 6), the degree of uncertainty associated with potential temporary development of seepage exceeding the DCG at locations downgradient of the swamp ditch is slightly higher than for Alternatives 2 and 3 since there would be no drawdown associated with the PTW. The far downgradient PTW employed in Alternative 7 would provide an inefficient means to remove Sr-90 mass from the plume due to the low concentrations present in the far downgradient area. The far downgradient PTW would remove relatively more natural cations (e.g., calcium) and less Sr-90 than the PTW constructed closer to the core of the plume. In addition, the downgradient PTW would allow the Sr-90 plume to continue to migrate to the far downgradient PTW location causing more soil to become contaminated as it expands. This presents compatibility concerns with respect to any future widespread soil removal actions (if included in the CDP). The possible future need to add to the PTW represents an added uncertainty for all these alternatives (Alternatives 6, 6A and 7).

The effectiveness of the active PTW employed in Alternative 6A is slightly improved over Alternative 6 as pumping would create some minor drawdown, reducing the possibility of impacted groundwater flowing around the PTW with some capture of groundwater north of the PTW. However, even minor drawdown could result in some plume distortion. The disadvantage is in the cost of treating the pumped water (which Geomatrix has assumed would be required after approximately 5 years) and the effect of active pumping on reducing the effective life of the PTW. The 5-year NPV for implementation of Alternative 6A is estimated to be $6.6 million.

For any selected remedy, a series of contingency measures also would be designed, at least in concept, to afford continued treatment if an implemented remedy failed for any reason and was not salvageable. Contingent remedies likely would include the placement of additional treatment zones in areas downgradient, if feasible, of initial or exhausted treatment zones. Source treatment in upgradient hot spots (perhaps through injection of solutions intended to reduce Sr-90 activity and concentration through precipitation and sequestration) may occur as part of the overall decommissioning program for the site, but are not seen as relevant to this alternatives analysis for management of the downgradient plume.

Table 9 presents a matrix table summarizing the compatibility of the eight alternatives with potential components of the CDP. All alternatives, except Alternative 1, are compatible (and easily integrated with) a CDP which would include mitigation of the leading edge of the plume (though this depends on defining the leading edge as the location of plume control associated with each alternative). There are no other major incompatibility issues with any of the alternatives.

A summary of the comparison of alternatives is provided in Table 10 and a generalized summary follows:

Alternative	*Implementability*	*Effectiveness*	*Data Requirements*	*Compatibility with CDP*	*5-Year NPV Cost*	*30-Year NPV Cost*
1	High	Low	None	Moderate	$ 2.0 million	$ 6.6 million
2	Moderate	Moderate	Low	Moderate	$ 11.9 million	$ 30.9 million
3	High	Moderate	Low	Moderate	$ 16.5 million	$ 47.5 million
4	Moderate	High	Moderate	Moderate	$ 24.2 million	$ 68.7 million
5	High	High	Moderate	Moderate	$ 28.2 million	$ 86.0 million
6	Moderate	Moderate	High	High	$ 6.4 million	$ 8.7 million
6A	Moderate	Moderate	High	High	$ 6.6 million	$ 14.4 million
7	Moderate	Moderate	High	Moderate	$ 8.7 million	$ 11.8 million

7.0 ALTERNATIVE RECOMMENDATION

Alternative 6, swamp ditch seepage face PRB/in-situ plume treatment with passive PTW is recommended as the preferred alternative. Alternative 6 is far less costly compared to alternatives employing hydraulic barriers and ex-situ groundwater treatment and would provide a similar environmental benefit with respect to mitigating further expansion of the plume beyond its location. Alternative 6 may be somewhat less effective than the hydraulic barriers in the near term with respect to elimination of Sr-90 in seepage to surface water downgradient of the swamp ditch seepage face PRB; however, the alternative allows more flexibility should this situation arise. If seepage problems develop in new areas, one or more targeted PTWs could be constructed to treat this seepage. Alternatively, rather than target specific seepage points, a second PTW similar to that contemplated in Alternative 7 could be implemented to provide more widespread protection. A provision to increase monitoring frequency and assess the feasibility and design of additional PTWs in the event seepage at downgradient areas develops and persists should be included as contingency planning for Alternative 6.

Alternative 6 is also flexible in that the passive PTW can be converted in the future to an active PTW with little added construction cost. Water pumped from the active PTW with either mechanical or siphon-driven pumps may still require treatment. However, since the purpose of the pumping would be to draw more water into the PTW rather than to create a complete hydraulic barrier, pumping rates and associated treatment costs would be far lower than the hydraulic barrier alternatives.

Passive PTW technology at the WVDP has been demonstrated and pre-design data requirements could be satisfied within a rather short timeframe (approximately six months). The passive PTW is not expected to adversely impact the CDP for the North Plateau area.

Given the expected performance, relatively low cost, and flexibility to be upgraded to improve performance if needed, Alternative 6 is recommended as the most feasible alternative to meet the RAOs.

8.0 REFERENCES

Berkey, E., 2000, Review of Preliminary Operational Assessment Report for the Pilot Permeable Treatment Wall (Draft), West Valley Demonstration Project, May 5.

Dames & Moore, 1996. Pumping Test Analyses, September 1996 – Progressive Rate Pumping Test on North Plateau Groundwater Recovery Well System Well RW-03 and Pumping Tests on North Plateau Groundwater Recovery Well System Wells RW-01, RW-02, and RW-03.

Fuhrman, M., D. Aloysius, and H. Zhou, 1995, Permeable, subsurface sorbant barrier for 90Sr: Laboratory studies of natural and synthetic materials. *Waste Management*, Volume 15, No. 7, pp. 485-493.

Geomatrix, 2001. Pilot Permeable Treatment Wall Modifications Options Report, prepared for West Valley Nuclear Services, LLC, April 2001.

Geochemistry: WVDPEIS009, p. 99.

Gilham, R. W., and S. F. O'Hannesin. 1994. Enhanced degradation of halogenated aliphatics by zero-valent iron. Groundwater Volume 32, pp 958–967.

Lee, D. R., Smyth, D. J.A., Shikaze, S. G., Jowett, R., Harwig, D. S., and C. Milloy, 1998. Wall-and-curtain for passive collection/treatment of contaminant plumes, in Designing and Applying Treatment Technologies: Remediation of Chlorinated and Recalcitrant Compounds, Battelle Press, Columbus, OH., pp. 77-84.

Lee, D.R., S. Shikaze, D. Smyth, R. Jowett, and C. Milloy, 1998, Wall and Curtain for Passive Collection/Treatment of Contaminant Plumes, First International Conference, Remediation of Chlorinated and Recalcitrant Compounds, May 18-21, Monterey, California *in* G.B Wickramanayake and R.E. Hinchee, Designing and Applying Treatment Technologies, Battelle, Press, 1998.

Puls, R. W., Blowes, D. W., Bennett, T. A., Gillham, R. W., Paul, C. J., Hanton-Fong, C. J., Clark, P. J., Ptacek, C. J., 1997. Permeable reactive barrier for in situ treatment of Cr(VI) and chlorinated solvent compounds in groundwater: the USCG demonstrations near Elizabeth City, North Carolina, in Field Testing of Innovative Subsurface Remediation Technologies, American Chemical Society Book Publication, Rabideau, A.J., I. Jankovic, and V. Raghaven, 2001, Flow Modeling of the WVDP Treatment Wall: Preliminary Results DRAFT, Department of Civil, Structural, and Environmental Engineering, State University of New York at Buffalo.

Rabideau, A.J., J. Van Benschoten, C. Huang, and A. Patel, 1999, Bench Testing of Zeolite Barrier Materials, State University of New York at Buffalo.

URS, July 1993, editorially revised in December 2006. Evaluation of Estimated Doses to Humans and Biota Potentially Affected by the Strontium-90 Groundwater Plume on the North Plateau of the West Valley Demonstration Project.

Van Benschoten, A.J., Rabideau, K. Bandilla, A. Chang, and A. Patel. 2001, Application of a Competitive Cation Exchange Model for Simulating Removal of Strontium in a Zeolite Permeable Reactive Barrier, 2001, State University of New York at Buffalo.

Warner, S.D. and D. Sorel, 2003. Ten Years of Permeable Reactive Barriers: Lessons Learned and Future Expectations, in, Chlorinated Solvent and DNAPL Remediation: Innovative Strategies for Subsurface Cleanup, Henry, S.M., and S. D. Warner, *eds.*, American Chemical Society Symposium Series 837, Oxford University Press, pp. 36-50.

West Valley Nuclear Services Co., Inc., 1993. Environmental Information Document, Volume I: Geology, Part 1, Regional Geology: WVDPEIS004, p. 24.

West Valley Nuclear Services Co., Inc., 1993. Environmental Information Document, Volume III: Hydrology, Part 4 and 5 Groundwater Hydrology and Geochemistry

West Valley Nuclear Services Co., Inc., 1995. WVDP-220, Subsurface Probing Investigation on the North Plateau at the West Valley Demonstration Project.

West Valley Nuclear Services Co., Inc., 1998. WVDP-298, 1997 Geoprobe Investigation on the North Plateau.

West Valley Nuclear Services Co., Inc., 1999. WVDP-346, 1998 Geoprobe Investigation in the Core Area of the North Plateau Groundwater Plume.

West Valley Nuclear Services Co., Inc., 2002. Supplemental Hydrogeologic Investigation of the North Plateau Pilot Permeable Treatment Wall: Performance Assessment and Evaluation of

Potential Enhancements.

West Valley Nuclear Services Co., Inc., 2006. Annual Summary for the North Plateau Strontium-90 Groundwater Plume: October 1, 2005 – September, 2006.

Warner, S.D., Longino, B.S., Zhang, M., Bennett, P., Szerdy, F. S. and L. A. Hamilton, 2005. The first commercial permeable reactive barrier composed of granular iron: Hydraulic and chemical performance at 10 years of operation, Permeable Reactive Barriers (Proceedings of the International Symposium held at Belfast, Northern Ireland, March 2004) IAHS Publ. 298, pp. 32-42.

Warner, S.D., Yamane, C. L., Gallinatti, J.D., and D. H. Hankins, 1998. Considerations for monitoring permeable ground-water treatment walls, Journal of Environmental Engineering, Vol. 124, No. 6, pp. 524 – 529.

TABLES

Table 1

West Valley Demonstration Project - North Plateau
Alternative 1 - Maintain Current Approach

Item	Quantity	Units	Unit Cost	Total Cost
Annual NPGRS Treatment Operations (2006)	3,600,000	gallons	$ 0.133	$ 478,800
Cost includes:				
-- T-42 Resin				
-- Waste Disposal (resin, filters)				
-- Labor				
-- Monitoring (influent/effluent)				
Total:				**$ 478,800**
Number of years (n):				5
Interest rate (I):				6%
p/A value:				4.2124
5 year Operation, Maintenance and Monitoring (OM&M) Present Worth (PW):				**$ 2,016,897**
Number of years (n):				30
Interest rate (I):				6%
p/A value:				13.7648
30 year OM&M Present Worth (PW):				**$ 6,590,586**

Total Present Worth (PW 5 year): ***Capital Cost + OM&M PW***	**$ 2,016,897**
Total Present Worth (PW 30 year): ***Capital Cost + OM&M PW***	**$ 6,590,586**

Table 2

West Valley Demonstration Project - North Plateau
Alternative 2 - Surface Water Controls/Interceptor Trench Drain

Item	Quantity	Units	Unit Cost	Total Cost
Pre-Design Analysis/Investigation	1	Lump Sum	$ 110,000.00	$ 110,000
Contractor Mobilization/Demobilization	1	Lump Sum	$ 120,000.00	$ 120,000
Site Preparation	1	Lump Sum	$ 150,000.00	$ 150,000
Subtotal:				**$ 380,000**
Swamp Ditch Permeable Reactive Barrier (PRB):				
Regrade west end of ditch and berm construction	1	Lump Sum	$ 15,000.00	$ 15,000
Excavation of ditch and seep area	1,083	Cubic Yards	$ 30.00	$ 32,500
Construction dewatering	1	Lump Sum	$ 30,000.00	$ 30,000
Puchase/Install Washed Gabion Stone (6-inch D50)	2,000	Tons	$ 20.00	$ 40,000
Zeolite	379	Cubic Yard	$ 350.00	$ 132,708
Soil Disposal	29,250	Cubic Feet	$ 13.56	$ 396,630
Install woven monofilament geotextile filtration fabric	9,750	Square Feet	$ .25	$ 2,438
Washed Crushed Stone #2	361	Cubic Yards	$ 30.00	$ 10,833
Survey/Temporary Siltation & Erosion Control	1	Lump Sum	$ 2,000.00	$ 2,000
Subtotal:				**$ 662,109**
Trench Drain Construction:				
Trench Drain Excavation (Bench 4ft/excavation 12 ft)	650	Cubic Yards	$ 100.00	$ 65,000
Dewatering with Suction Lift Wellpoints	1	Lump Sum	$ 50,000.00	$ 50,000
Temporary HDPE Ground Cover	1	Lump Sum	$ 5,000.00	$ 5,000
Washed Stone Collection Pipe Bedding	400	Cubic Yards	$ 30.00	$ 12,000
Low Permeability Shallow Soil Backfill	250	Cubic Yards	$ 30.00	$ 7,500
Perforated PVC Drain Pipe Installed	275	Linear Feet	$ 20.00	$ 5,500
Manhole Cleanouts	2	Each	$ 2,500.00	$ 5,000
Packaged fiberglass re-enforced plastic (FRP) Lift Station	2	Each	$ 35,000.00	$ 70,000
Soil Disposal	17,600	Cubic Yards	$ 13.56	$ 238,656
Electrical Service	2	Each	$ 2,500.00	$ 5,000
Subtotal:				**$ 463,656**
SWS Recovery Well:				
Drilling/Well Installation/Development	1	Lump Sum	$ 25,000.00	$ 25,000
Pump/Level Controls/Electrical	1	Lump Sum	$ 5,000.00	$ 5,000
Subtotal:				**$ 30,000**
Treatment/Groundwater Management:				
Forcemain Trench Excavation	50	Cubic Yards	$ 25.00	$ 1,250
Double-wall Forcemain to LLWT2	300	Linear Feet	$ 80.00	$ 24,000
Forcemain Backfill/Surface Completion	1	Lump Sum	$ 5,000.00	$ 5,000
Addition Ion Exchange Skid (25 gpm)	1	Lump Sum	$ 300,000.00	$ 300,000
Plumbing - Controls for Existing Skid B	1	Lump Sum	$ 50,000.00	$ 50,000
Lagoon Bypass Pipe Trench Excavation	82	Cubic Yards	$ 25.00	$ 2,050
Lagoon Bypass Piping	550	Linear Feet	$ 20.00	$ 11,000
Outfall Construction	1	Lump Sum	$ 10,000.00	$ 10,000
SPDES Permit Application	1	Lump Sum	$ 10,000.00	$ 10,000
Subtotal:				**$ 413,300**
Subtotal Capital Cost				$ 1,949,065
Engineering (20%)				$ 389,813
Health and Safety/Monitoring (20%)				$ 389,813
Contingency (20%)				$ 389,813
Total Capital Cost				**$ 3,118,504**
Annual Operation Maintenance & Monitoring (OM&M):				
Treatment @ 27 gpm	14,191,200	Gallons	$ .133	$ 1,887,430
Pump Stations Maintenance, Power	12	Month	$ 250.00	$ 3,000
Performance monitoring (hydraulic/water quality)	1	Lump Sum	$ 100,000.00	$ 100,000
Total Annual OM&M Cost				**$ 1,990,430**
Number of years (n):				5
Interest rate (I):				6%
p/A value:				4.2124
5 year OM&M Present Worth (PW):				**$ 8,384,486**
Number of years (n):				30
Interest rate (I):				6%
p/A value:				13.7648
30 year OM&M Present Worth (PW):				**$ 27,397,865**
Swamp Ditch PRB Removal after 5 years:				
Engineering/Contractor/Health & Safety	1	Lump Sum	$ 75,000.00	$ 75,000
Excavation of PRB materials	1,083	Cubic Yards	$ 30.00	$ 32,500
Disposal of PRB materials	29,250	Cubic Feet	$ 13.56	$ 396,630
Area restoration	1	Lump Sum	$ 15,000.00	$ 15,000
Subtotal One-Time PRB Removal Cost				$ **519,130**
5 year PRB Removal PW *(6% interest rate)*				$ **387,950**
Total Present Worth (PW 5 year): ***Capital Cost + OM&M PW + PRB Removal PW***				**$ 11,890,940**
Total Present Worth (PW 30 year): ***Capital Cost + OM&M PW + PRB Removal PW***				**$ 30,904,320**

Table 3

West Valley Demonstration Project - North Plateau
Alternative 3 - Surface Water Controls/Groundwater Extraction Wells

Item	Quantity	Units	Unit Cost	Total Cost
Pre-Design Analysis/Investigation	1	Lump Sum	$ 95,000.00	$ 95,000
Contractor Mobilization/Demobilization	1	Lump Sum	$ 100,000.00	$ 100,000
Site Preparation	1	Lump Sum	$ 100,000.00	$ 100,000
Subtotal:				**$ 295,000**
Swamp Ditch Permeable Reactive Barrier (PRB):				
Regrade west end of ditch and berm construction	1	Lump Sum	$ 15,000.00	$ 15,000
Excavation of ditch and seep area	1,083	Cubic Yards	$ 30.00	$ 32,500
Construction dewatering	1	Lump Sum	$ 30,000.00	$ 30,000
Puchase/Install Washed Gabion Stone (6-inch D50)	2,000	Tons	$ 20.00	$ 40,000
Zeolite	379	Cubic Yard	$ 350.00	$ 132,708
Soil Disposal	29,250	Cubic Feet	$ 13.56	$ 396,630
Install woven monofilament geotextile filtration fabric	9,750	Square Feet	$ .25	$ 2,438
Washed Crushed Stone #2	361	Cubic Yards	$ 30.00	$ 10,833
Survey/Temporary Siltation & Erosion Control	1	Lump Sum	$ 2,000.00	$ 2,000
Subtotal:				**$ 662,109**
Recovery Well System:				
Drilling/Well Installation/Development	9	Each	$ 12,000.00	$ 108,000
Pump/Level Controls/Electrical	9	Each	$ 3,000.00	$ 27,000
Wellhead Vault/Metering Pit	9	Each	$ 4,000.00	$ 36,000
Soil Disposal	50	Cubic Feet	$ 13.56	$ 678
Subtotal:				**$ 171,678**
Treatment/Groundwater Management:				
Forcemain Excavation	50	Cubic Yards	$ 25.00	$ 1,250
Double-wall Forcemain to LLWT2	600	Linear Feet	$ 80.00	$ 48,000
Forcemain Backfill/Surface Completion	1	Lump Sum	$ 5,000.00	$ 5,000
Additional Ion Exchange Skid (25 gpm)	1	Lump Sum	$ 300,000.00	$ 300,000
Plumbing - Controls for Existing Skid B	1	Lump Sum	$ 50,000.00	$ 50,000
Lagoon Bypass Pipe Trench Excavation	82	Cubic Yards	$ 25.00	$ 2,050
Lagoon Bypass Piping	550	Linear Feet	$ 20.00	$ 11,000
Outfall Construction	1	Lump Sum	$ 10,000.00	$ 10,000
SPDES Permit Application	1	Lump Sum	$ 10,000.00	$ 10,000
Subtotal:				**$ 437,300**
Subtotal Capital Cost				$ 1,566,087
Engineering (20%)				$ 313,217
Health and Safety/Monitoring (20%)				$ 313,217
Contingency (20%)				$ 313,217
Total Capital Cost				**$ 2,505,739**
Annual Operation Maintenance & Monitoring (OM&M):				
Treatment @ 45 gpm	23,600,000	Gallons	$ .133	$ 3,138,800
Wellhead Maintenance, Power	12	Month	$ 300.00	$ 3,600
Performance monitoring (hydraulic/water quality)	1	Lump Sum	$ 100,000.00	$ 100,000
Total Annual OM&M Cost				**$ 3,242,400**
Number of years (n):				5
Interest rate (I):				6%
p/A value:				4.2124
5 year OM&M Present Worth (PW):				**$ 13,658,286**
Number of years (n):				30
Interest rate (I):				6%
p/A value:				13.7648
30 year OM&M Present Worth (PW):				**$ 44,630,988**
Swamp Ditch PRB Removal after 5 years:				
Engineering/Contractor/Health & Safety	1	Lump Sum	$ 75,000.00	$ 75,000
Excavation of PRB materials	1,083	Cubic Yards	$ 30.00	$ 32,500
Disposal of PRB materials	29,250	Cubic Feet	$ 13.56	$ 396,630
Area restoration	1	Lump Sum	$ 15,000.00	$ 15,000
Subtotal One-Time PRB Removal Cost				$ **519,130**
5 year PRB Removal PW *(6% interest rate)*				$ **387,950**
Total Present Worth (PW 5 year): ***Capital Cost + OM&M PW + PRB Removal PW***				**$ 16,551,975**
Total Present Worth (PW 30 year): ***Capital Cost + OM&M PW + PRB Removal PW***				**$ 47,524,677**

Table 4

West Valley Demonstration Project - North Plateau
Alternative 4 - Surface Water Controls/Far Downgradient Interceptor Trench Drain

Item	Quantity	Units	Unit Cost	Total Cost
Pre-Design Analysis/Investigation	1	Lump Sum	$ 170,000.00	$ 170,000
Contractor Mobilization/Demobilization	1	Lump Sum	$ 120,000.00	$ 120,000
Site Preparation	1	Lump Sum	$ 150,000.00	$ 150,000
Subtotal:				**$ 440,000**
Swamp Ditch Control:				
Regrade west end of ditch/seep area and berm construction	1	Lump Sum	$ 15,000.00	$ 15,000
Install geomembrane liner	9,750	Square Feet	$ 1.00	$ 9,750
Rip Rap and bedding stone	361	Cubic Yards	$ 25.00	$ 9,028
Survey/Temporary Siltation & Erosion Control	1	Lump Sum	$ 2,000.00	$ 2,000
Subtotal:				**$ 35,778**
Trench Drain Construction:				
Trench Drain Excavation (Bench 4ft/excavation 12 ft)	2400	Cubic Yards	$ 100.00	$ 240,000
Dewatering with Suction Lift Wellpoints	1	Lump Sum	$ 150,000.00	$ 150,000
Temporary HDPE Ground Cover	1	Lump Sum	$ 10,000.00	$ 10,000
Washed Stone Collection Pipe Bedding	1600	Cubic Yards	$ 30.00	$ 48,000
Low Permeability Soil Backfill	1000	Cubic Yards	$ 30.00	$ 30,000
Perforated PVC Drain Pipe Installed	1000	Linear Feet	$ 20.00	$ 20,000
Manhole Cleanouts	6	Each	$ 2,500.00	$ 15,000
Packaged fiberglass re-enforced plastic (FRP) Lift Station	4	Each	$ 35,000.00	$ 140,000
Soil Disposal	64,800	Cubic Feet	$ 13.56	$ 878,688
Electrical Service	4	Each	$ 3,000.00	$ 12,000
Subtotal:				**$ 1,543,688**
Treatment/Groundwater Management:				
Forcemain Trench Excavation	180	Cubic Yards	$ 25.00	$ 4,500
Double-wall Forcemain to LLWT2	1000	Linear Feet	$ 80.00	$ 80,000
Forcemain Backfill/Surface Completion	1	Lump Sum	$ 10,000.00	$ 10,000
Addition Ion Exchange Skid (35 gpm)	2	Lump Sum	$ 350,000.00	$ 700,000
Plumbing - Controls for Existing Skid B	1	Lump Sum	$ 75,000.00	$ 75,000
Lagoon Bypass Pipe Trench Excavation	82	Cubic Yards	$ 25.00	$ 2,050
Lagoon Bypass Piping	550	Linear Feet	$ 20.00	$ 11,000
Outfall Construction	1	Lump Sum	$ 10,000.00	$ 10,000
SPDES Permit Application	1	Lump Sum	$ 10,000.00	$ 10,000
Subtotal:				**$ 902,550**
Subtotal Capital Cost				$ 2,922,016
Engineering (20%)				$ 584,403
Health and Safety/Monitoring (20%)				$ 584,403
Contingency (20%)				$ 584,403
Total Capital Cost				**$ 4,675,225**
Annual Operation Maintenance & Monitoring (OM&M):				
Treatment @ 65 gpm (lower end of 65 to 75 gpm range based on anticipated lower permeability at edge of plateau based on existing data)	34,164,000	Gallons	$ .133	$ 4,543,812
Pump Stations Maintenance, Power	12	Month	$ 600.00	$ 7,200
Performance monitoring (hydraulic/water quality)	1	Lump Sum	$ 100,000.00	$ 100,000
Total Annual OM&M Cost				**$ 4,651,012**
Number of years (n):				5
Interest rate (I):				6%
p/A value:				4.2124
5 year OM&M Present Worth (PW):				**$ 19,591,923**
Number of years (n):				30
Interest rate (I):				6%
p/A value:				13.7648
30 year OM&M Present Worth (PW):				**$ 64,020,250**
Total Present Worth (PW 5 year): *Capital Cost + OM&M PW*				**$ 24,267,148**
Total Present Worth (PW 30 year): *Capital Cost + OM&M PW*				**$ 68,695,475**

Table 5

West Valley Demonstration Project - North Plateau
Alternative 5 - Surface Water Controls/Far Downgradient Groundwater Extraction Wells

Item	Quantity	Units	Unit Cost	Total Cost
Pre-Design Analysis/Investigation	1	Lump Sum	$ 170,000.00	$ 170,000
Contractor Mobilization/Demobilization	1	Lump Sum	$ 100,000.00	$ 100,000
Site Preparation	1	Lump Sum	$ 100,000.00	$ 100,000
Subtotal:				**$ 370,000**
Swamp Ditch Control:				
Regrade west end of ditch/seep area and berm construction	1	Lump Sum	$ 15,000.00	$ 15,000
Install geomembrane liner	9,750	Square Feet	$ 1.00	$ 9,750
Rip Rap and bedding stone	361	Cubic Yards	$ 25.00	$ 9,028
Survey/Temporary Siltation & Erosion Control	1	Lump Sum	$ 2,000.00	$ 2,000
Subtotal:				**$ 35,778**
Recovery Well System:				
Drilling/Well Installation/Development	17	Each	$ 12,000.00	$ 204,000
Pump/Level Controls/Electrical	17	Each	$ 3,000.00	$ 51,000
Wellhead Vault/Metering Pit	17	Each	$ 4,000.00	$ 68,000
Soil Disposal	130	Cubic Feet	$ 13.56	$ 1,763
Subtotal:				**$ 324,763**
Treatment/Groundwater Management:				
Forcemain Excavation	300	Cubic Yards	$ 25.00	$ 7,500
Double-wall Forcemain to LLWT2	1800	Linear Feet	$ 80.00	$ 144,000
Forcemain Backfill/Surface Completion	1	Lump Sum	$ 10,000.00	$ 10,000
Additional Ion Exchange Skid (35 gpm)	2	Lump Sum	$ 350,000.00	$ 700,000
Plumbing - Controls for Existing Skid B	1	Lump Sum	$ 75,000.00	$ 75,000
Lagoon Bypass Pipe Trench Excavation	82	Cubic Yards	$ 25.00	$ 2,050
Lagoon Bypass Piping	550	Linear Feet	$ 20.00	$ 11,000
Outfall Construction	1	Lump Sum	$ 10,000.00	$ 10,000
SPDES Permit Application	1	Lump Sum	$ 10,000.00	$ 10,000
Subtotal:				**$ 969,550**
Subtotal Capital Cost				$ 1,700,091
Engineering (20%)				$ 340,018
Health and Safety/Monitoring (20%)				$ 340,018
Contingency (20%)				$ 340,018
Total Capital Cost				**$ 2,720,145**
Annual Operation Maintenance & Monitoring (OM&M):				
Treatment @ 85 gpm	44,676,000	Gallons	$ .133	$ 5,941,908
Wellhead Maintenance, Power	12	Month	$ 750.00	$ 9,000
Performance monitoring (hydraulic/water quality)	1	Lump Sum	$ 100,000.00	$ 100,000
Total Annual OM&M Cost				**$ 6,050,908**
Number of years (n):				5
Interest rate (I):				6%
p/A value:				4.2124
5 year OM&M Present Worth (PW):				**$ 25,488,845**
Number of years (n):				30
Interest rate (I):				6%
p/A value:				13.7648
30 year OM&M Present Worth (PW):				**$ 83,289,538**
Total Present Worth (PW 5 year): *Capital Cost + OM&M PW*				**$ 28,208,990**
Total Present Worth (PW 30 year): *Capital Cost + OM&M PW*				**$ 86,009,683**

Table 6

West Valley Demonstration Project - North Plateau
Alternative 6 -Surface Water Controls/InSitu Treatment with Passive Permeable Treatment Wall

Item	Quantity	Units	Unit Cost	Total Cost
Pre-Design Analysis/Investigation	1	Lump Sum	$ 320,000.00	$ 320,000
Contractor Mobilization/Demobilization	1	Lump Sum	$ 140,000.00	$ 140,000
Site Preparation	1	Lump Sum	$ 150,000.00	$ 150,000
Subtotal:				**$ 610,000**
Swamp Ditch Permeable Reactive Barrier (PRB):				
Regrade west end of ditch and berm construction	1	Lump Sum	$ 15,000.00	$ 15,000
Excavation of ditch and seep area	1,083	Cubic Yards	$ 30.00	$ 32,500
Construction dewatering	1	Lump Sum	$ 30,000.00	$ 30,000
Puchase/Install Washed Gabion Stone (6-inch D50)	2,000	Tons	$ 20.00	$ 40,000
Zeolite	379	Cubic Yard	350.00	$ 132,708
Soil Disposal	29,250	Cubic Feet	$ 13.56	$ 396,630
Install woven monofilament geotextile filtration fabric	9,750	Square Feet	$ .25	$ 2,438
Washed Crushed Stone #2	361	Cubic Yards	$ 30.00	$ 10,833
Survey/Temporary Siltation & Erosion Control	1	Lump Sum	$ 2,000.00	$ 2,000
Subtotal:				**$ 662,109**
Permeable Treatment Wall:				
Prepare working platform	2	Days	4,000.00	8,000
25 ft trencher with 3 foot wide hopper	20000	Square Feet	$ 20.00	$ 400,000
Loader and operator	3	Week	$ 8,000.00	$ 24,000
Excavator and operator	3	Week	$ 8,000.00	$ 24,000
Laborers	5	Week	$ 2,200.00	$ 11,000
Zeolite	2200	Cubic Yard	350.00	770,000
Soil Disposal	59,400	Cubic Feet	$ 13.56	$ 805,464
Site restoration	1	Lump Sum	50,000.00	50,000
Monitoring well system	1	Lump Sum	100,000.00	100,000
Subtotal:				**$ 2,192,464**
Subtotal Capital Cost				$ 3,464,573
Engineering (20%)				$ 692,915
Health and Safety/Monitoring (20%)				$ 692,915
Contingency (20%)				$ 692,915
Total Capital Cost				**$ 5,543,317**
Annual Operation Maintenance & Monitoring (OM&M):				
Performance monitoring (hydraulic/water quality)	1	Lump Sum	$ 100,000.00	$ 100,000
Total Annual OM&M Cost				**$ 100,000**
Number of years (n):				5
Interest rate (I):				6%
p/A value:				4.2124
5 year OM&M Present Worth (PW):				**$ 421,240**
Number of years (n):				30
Interest rate (I):				6%
p/A value:				13.7648
30 year OM&M Present Worth (PW):				**$ 1,376,480**
Swamp Ditch PRB Removal after 5 years:				
Engineering/Contractor/Health & Safety	1	Lump Sum	$ 75,000.00	$ 75,000
Excavation of PRB materials	1,083	Cubic Yards	$ 30.00	$ 32,500
Disposal of PRB materials	29,250	Cubic Feet	$ 13.56	$ 396,630
Area restoration	1	Lump Sum	$ 15,000.00	$ 15,000
Subtotal One-Time PRB Removal Cost				$ **519,130**
5 year PRB Removal PW *(6% interest rate)*				$ **387,950**
One-Time PTW Replacement after 15 years:				
Engineering/Contractor/Health & Safety	1	Lump Sum	$ 1,000,000.00	$ 1,000,000
PTW Replacement + Mobilization	1	Lump Sum	$ 2,332,464.00	$ 2,332,464
Subtotal One-Time PTW Replacement Cost				$ **3,332,464**
15 year PTW Replacement PW *(6% interest)*				$ **1,390,631**

Total Present Worth (PW 5 year): ***Capital Cost + OM&M PW + PRB Removal PW***	**$ 6,352,507**
Total Present Worth (PW 30 year): ***Capital Cost + OM&M PW+PTW Replacement PW***	**$ 8,698,378**

Table 7

West Valley Demonstration Project - North Plateau
Alternative 6a Surface Water Controls/InSitu Treatment with Active Permeable Treatment Wall

Item	Quantity	Units	Unit Cost	Total Cost
Pre-Design Analysis/Investigation	1	Lump Sum	$ 370,000.00	$ 370,000
Contractor Mobilization/Demobilization	1	Lump Sum	$ 140,000.00	$ 140,000
Site Preparation	1	Lump Sum	$ 150,000.00	$ 150,000
Subtotal:				**$ 660,000**
Swamp Ditch Permeable Reactive Barrier (PRB):				
Regrade west end of ditch and berm construction	1	Lump Sum	$ 15,000.00	$ 15,000
Excavation of ditch and seep area	1,083	Cubic Yards	$ 30.00	$ 32,500
Construction dewatering	1	Lump Sum	$ 30,000.00	$ 30,000
Puchase/Install Washed Gabion Stone (6-inch D50)	2,000	Tons	$ 20.00	$ 40,000
Zeolite	379	Cubic Yard	350.00	$ 132,708
Soil Disposal	29,250	Cubic Feet	$ 13.56	$ 396,630
Install woven monofilament geotextile filtration fabric	9,750	Square Feet	$ .25	$ 2,438
Washed Crushed Stone #2	361	Cubic Yards	$ 30.00	$ 10,833
Survey/Temporary Siltation & Erosion Control	1	Lump Sum	$ 2,000.00	$ 2,000
Subtotal:				**$ 662,109**
Permeable Treatment Wall:				
Prepare working platform	2	Day	4,000.00	8,000
25 ft trencher	20000	Square Feet	$ 20.00	$ 400,000
Loader and operator	3	Week	$ 8,000.00	$ 24,000
Excavator and operator	3	Week	$ 8,000.00	$ 24,000
Laborer	5	Week	$ 2,200.00	$ 11,000
Zeolite	2200	Cubic Yards	350.00	$ 770,000
Soil Disposal	59,400	Cubic Feet	$ 13.56	$ 805,464
Site restoration	1	Lump Sum	50,000.00	$ 50,000
Monitoring well system	1	Lump Sum	100,000.00	$ 100,000
Subtotal:				**$ 2,192,464**
Extraction wells				
Install 4 wells, including pumps, well boxes, etc	4	Each	12,000.00	48,000
Forcemain Excavation	50	Cubic Yards	$ 25.00	$ 1,250
Double-wall Forcemain to LLWT2	600	Linear Feet	$ 80.00	$ 48,000
Forcemain Backfill/Surface Completion	1	Lump Sum	$ 5,000.00	$ 5,000
Subtotal:				**$ 102,250**
Subtotal Capital Cost				$ 3,616,823
Engineering (20%)				$ 723,365
Health and Safety/Monitoring (20%)				$ 723,365
Contingency (20%)				$ 723,365
Total Capital Cost				**$ 5,786,917**
Annual Operation Maintenance & Monitoring (OM&M):				
Treatment @ 4 gpm (assume treatment is required after the 5th year of operation as Sr-90 concentrations increase in the PTW to levels that would not allow direct discharge of collected water)	2,102,400	Gallons	$ .133	$ 279,619
Wellhead Maintenance, Power	12	Months	$ 300.00	$ 3,600
Performance monitoring (hydraulic/water quality)	1	Lump Sum	$ 100,000.00	$ 100,000
Total Annual OM&M Cost (OM&M for years 1 - 5)				**$ 103,600**
Total Annual OM&M Cost (OM&M for years 6 - 30)				**$ 383,219**
Number of years (n):				5
Interest rate (I):				6%
p/A value:				4.2124
5 year OM&M Present Worth (PW):				**$ 436,405**
Number of years (n):				30
Interest rate (I):				6%
p/A value:				13.7648
30 year OM&M Present Worth (PW):				**$ 6,700,969**
Swamp Ditch PRB Removal after 5 years:				
Engineering/Contractor/Health & Safety	1	Lump Sum	$ 75,000.00	$ 75,000
Excavation of PRB materials	1,083	Cubic Yards	$ 30.00	$ 32,500
Disposal of PRB materials	29,250	Cubic Feet	$ 13.56	$ 396,630
Area restoration	1	Lump Sum	$ 15,000.00	$ 15,000
Subtotal One-Time PRB Removal Cost				**$ 519,130**
5 year PRB Removal PW *(6% interest rate)*				**$ 387,950**
One-Time PTW Replacement after 15 years:				
Engineering/Contractor/Health & Safety	1	Lump Sum	$ 1,000,000.00	$ 1,000,000
PTW Replacement + Contractor Mobilization	1	Lump Sum	$ 2,584,714.00	$ 2,584,714
Subtotal One-Time PTW Replacement Cost				**$ 3,584,714**
15 year PTW Replacement PW *(6% interest)*				**$ 1,495,894**

Total Present Worth (PW 5 year): *Capital Cost + OM&M PW + PRB Removal PW*	**$ 6,611,272**
Total Present Worth (PW 30 year): *Capital Cost + OM&M PW+PTW Replacement PW*	**$ 14,371,730**

Table 8

West Valley Demonstration Project - North Plateau
Alternative 7 - Surface Water Controls/Far Downgradient Passive Permeable Treatment Walls

Item	Quantity	Units	Unit Cost	Total Cost
Pre-Design Analysis/Investigation	1	Lump Sum	$ 470,000.00	$ 470,000
Contractor Mobilization/Demobilization	1	Lump Sum	$ 140,000.00	$ 140,000
Site Preparation	1	Lump Sum	$ 200,000.00	$ 200,000
Subtotal:				**$ 810,000**
<u>Swamp Ditch Permeable Reactive Barrier (PRB):</u>				
Regrade west end of ditch and berm construction	1	Lump Sum	$ 15,000.00	$ 15,000
Excavation of ditch and seep area	1,083	Cubic Yards	$ 30.00	$ 32,500
Construction dewatering	1	Lump Sum	$ 30,000.00	$ 30,000
Puchase/Install Washed Gabion Stone (6-inch D50)	2,000	Tons	$ 20.00	$ 40,000
Zeolite	379	Cubic Yard	350.00	$ 132,708
Soil Disposal	29,250	Cubic Feet	$ 13.56	$ 396,630
Install woven monofilament geotextile filtration fabric	9,750	Square Feet	$ .25	$ 2,438
Washed Crushed Stone #2	361	Cubic Yards	$ 30.00	$ 10,833
Survey/Temporary Siltation & Erosion Control	1	Lump Sum	$ 2,000.00	$ 2,000
Subtotal:				**$ 662,109**
<u>Permeable Treatment Wall:</u>				
Prepare working platform	8	Day	4,000.00	32,000
25 ft trencher	24000	Square Feet	$ 20.00	$ 480,000
Loader and operator	2	Week	$ 8,000.00	$ 16,000
Excavator and operator	2	Week	$ 8,000.00	$ 16,000
Laborer	4	Week	$ 2,200.00	$ 8,800
Zeolite	2667	Cubic Yards	350.00	933,450
Soil Disposal	82,800	Cubic Feet	$ 13.56	$ 1,122,768
Site restoration	1	Lump Sum	100,000.00	100,000
Monitoring well system	1	Lump Sum	100,000.00	100,000
Subtotal:				**$ 2,809,018**
<u>Diversion Walls:</u>				
Prepare working platform	6	Day	4,000.00	24,000
25 ft trencher	17500	Square Feet	$ 20.00	$ 350,000
Loader and operator	2	Week	$ 8,000.00	$ 16,000
Excavator and operator	2	Week	$ 8,000.00	$ 16,000
Laborer	4	Week	$ 2,200.00	$ 8,800
Bentonite	8102	Pounds	.50	$ 4,051
Soil Disposal	10,500	Cubic Feet	$ 13.56	$ 142,380
Site restoration	1	Lump Sum	100,000.00	$ 100,000
Subtotal:				**$ 661,231**
Subtotal Capital Cost				$ 4,942,358
Engineering (20%)				$ 988,472
Health and Safety/Monitoring (20%)				$ 988,472
Contingency (20%)				$ 988,472
Total Capital Cost				**$ 7,907,773**
<u>Annual Operation Maintenance & Monitoring (OM&M):</u>				
Performance monitoring (hydraulic/water quality)	1	Lump Sum	$ 100,000.00	$ 100,000
Total Annual OM&M Cost				**$ 100,000**
Number of years (n):				5
Interest rate (I):				6%
p/A value:				4.2124
5 year OM&M Present Worth (PW):				**$ 421,240**
Number of years (n):				30
Interest rate (I):				6%
p/A value:				13.7648
30 year OM&M Present Worth (PW):				**$ 1,376,480**
<u>Swamp Ditch PRB Removal after 5 years:</u>				
Engineering/Contractor/Health & Safety	1	Lump Sum	$ 75,000.00	$ 75,000
Excavation of PRB materials	1,083	Cubic Yards	$ 30.00	$ 32,500
Disposal of PRB materials	29,250	Cubic Feet	$ 13.56	$ 396,630
Area restoration	1	Lump Sum	$ 15,000.00	$ 15,000
Subtotal One-Time PRB Removal Cost				$ **519,130**
5 year PRB Removal PW *(6% interest)*				$ **387,950**
<u>One-Time PTW Replacement after 15 years:</u>				
Engineering/Contractor/Health & Safety	1	Lump Sum	$ 1,500,000.00	$ 1,500,000
PTW Replacement + Contractor Mobilization	1	Lump Sum	$ 3,610,249.00	$ 3,610,249
Subtotal One-Time PTW Replacement Cost				$ **5,110,249**
15 year PTW Replacement PW *(6% interest)*				$ **2,132,497**

Total Present Worth (PW 5 year): ***Capital Cost + OM&M PW + PRB Removal PW***	**$ 8,716,963**
Total Present Worth (PW 30 year): ***Capital Cost + OM&M PW+PTW Replacement PW***	**$ 11,804,700**

TABLE 9
Compatibility Matrix for Long Term and Interim North Plateau Plume Management Options
West Valley Demonstration Project - North Plateau Strontium-90 Groundwater Plume

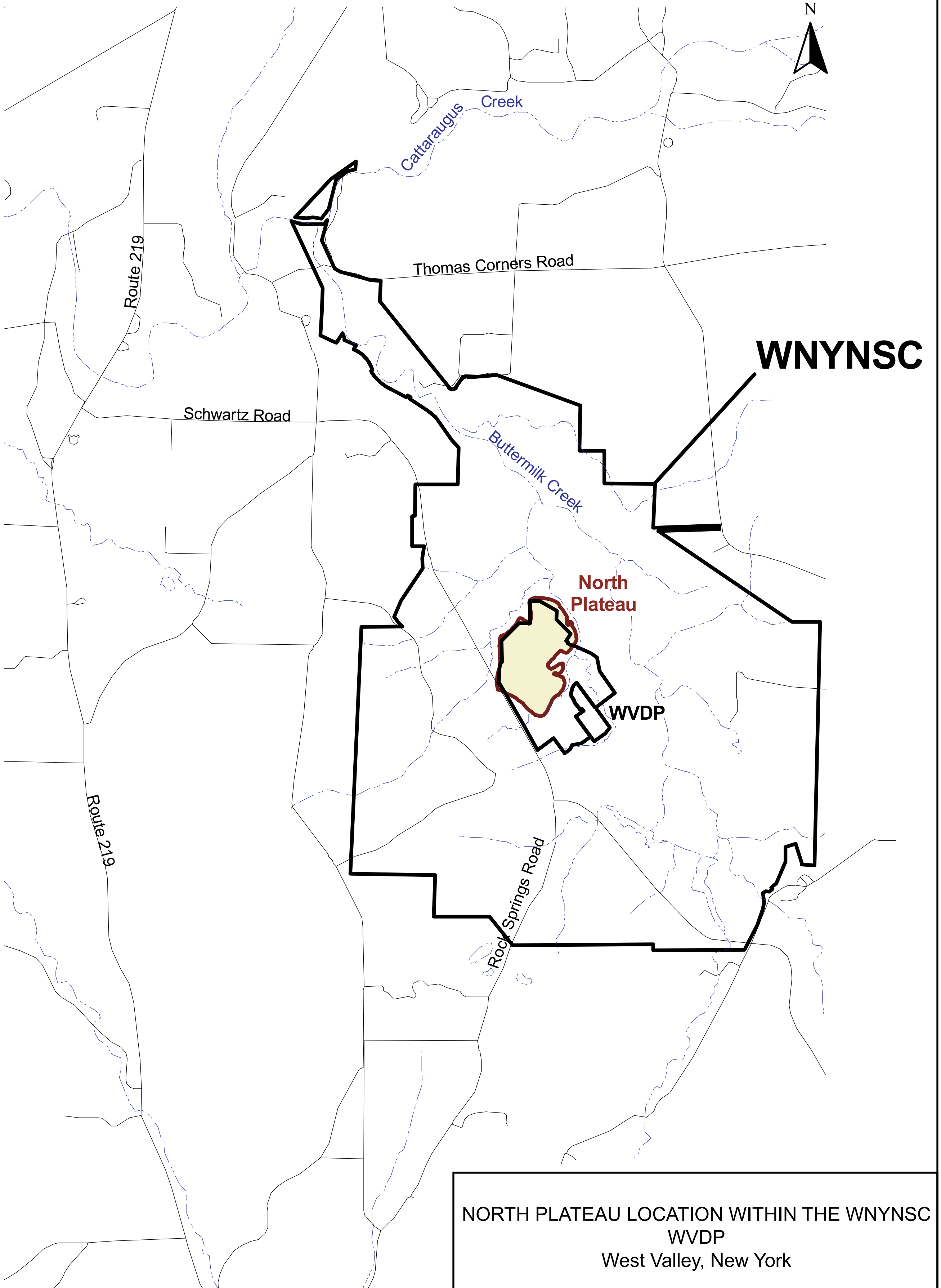
Potential Long Term EIS Control Actions	Interim Alternatives for Plume Management						
	Maintain Current Approach	Surface Water Controls/Interceptor Drain	Surface Water Controls/Groundwater Extraction Wells	Surface Water Controls/Far Downgradient Interceptor Drain	Surface Water Controls/Far Downgradient Groundwater Extraction Wells	Surface Water Controls/Permeable Treatment Wall	Surface Water Controls/Far Downgradient Permeable Treatment Wall
Excavate Plume Source Area with Process Building	O	O	O	O	O	O	O
Excavate Entire Plume	O	-	-	-	-	-	-
Isolate Source Area with Barrier and Cap	O	O	O	O	O	O	O
Divert Upgradient Groundwater	O	O	O	O	O	O	O
Identify and focus remediation to treat "Hot Spots"	O	O	O	O	O	O	O
Remediation of Plume exceeding concentration above 100,000 pCi/L	O	+	+	O	O	+	+
Contaminant Flushing	O	O	O	O	O	O	O
Permeable Reactive Barrier	O	O	O	O	O	+	+
Monitored Natural Attenuation	O	O	O	O	O	O	O
Long-Term Leading Edge Control	O	+	+	+	+	+	+

Key:
+ - Favorable Compatibility
O - Neutral Compatibility
- - Incompatible

TABLE 10
Comparison of Alternatives
West Valley Demonstration Project - North Plateau Strontium-90 Groundwater Plume

Alternatives	Comparative Summary						
	Implementability	Attainment of RAO (effectiveness)	Additional Data Requirements (Predesign Data)	Compatibility with WVDP Comprehensive Decommissioning Plan	Alternative Cost (5 yr NPV)	Alternative Cost (30 yr NPV)	Alternative Advantages/Disadvantages
Alternative 1 - Maintain Current Approach	No new construction.	Surface water discharge and plume expansion would not be mitigated.	None	Current approach could supplement WVDP facility decommissioning.	$2.0 million	$6.6 million	
Alternative 2 -Swamp Ditch Surface Water Controls/Interceptor Trench Drain	• Implementable. • Generates large soil volumes and groundwater requiring treatment. • Worker exposure issues need to be addressed.	• Effective in immediately intercepting the plume and preventing discharge to surface water. • Relies on MNA.	Limited predesign data required for construction. *Duration:* 3 to 4 mos. *Cost:* $110K.	Compatible if integrated into facility decommissioning.	$11.9 million	$30.9 million	Achieves RAO but relies on MNA for Sr-90 north of hydraulic area of control.
Alternative 3-Swamp Ditch Surface Water Controls/Groundwater Extraction Wells	Less difficult to implement than Alternative 2.	Similar to Alternative 2.	Similar to Alternative 2. *Duration:* 3 to 4 mos. *Cost:* $95K.	Similar to Alternative 2.	$16.5 million	$47.5 million	• Less difficult to implement than Alternative 2. • More costly than Alternative 2.
Alternative 4 -Swamp Ditch Surface Water Controls/Far Downgradient Interceptor Trench Drain	Similar issues as Alternative 2 but fewer worker exposure issues.	Highly effective in achieving RAO.	Similar to Alternative 2. *Duration:* 4 to 5 mos. *Cost:* $170K.	• Would not affect facility decommissioning. • Possibly incompatible if decommissioning plan required impacted soil removal and higher Sr-90 concentrations advance in soil.	$24.2 million	$68.7 million	• Mitigates migration of Sr-90 on north plateau. • Very high cost. • May have compatibility issues.
Alternative 5 -Swamp Ditch Surface Water Controls/Far Downgradient Groundwater extraction Wells	Less difficult to implement than Alternative 4.	Similar to Alternative 4.	Similar to Alternative 2. *Duration:* 4 to 5 mos. *Cost:* $170K.	Similar to Alternative 4.	$28.2 million	$86.0 million	• Mitigates migration of Sr-90 on North Plateau. • Highest cost alternative. • May have compatability issues.
Alternative 6 -Swamp Ditch Surface Water Controls/InSitu Plume Treatment with Passive Permeable Treatment Wall	• Previously demonstrated to be implementable. • Use of trencher would facilitate construction. • Worker exposure issues need to be addressed.	Similar to Alternative 2 and 3.	Design data needs: • Geologic/Chemical data • Zeolite benchscale testing • Modeling (groundwater flow & geochemical) *Duration:* 6 to 7 mos. *Cost:* $320K.	Compatible with the overall strategy of reducing and eliminating downgradient migration of Sr-90 affected groundwater toward the northern discharge areas if integrated into decommissioning.	$6.4 million	$8.7 million	Lowest cost alternative to achieve RAO but relies on MNA for Sr-90 north of PTW.
Alternative 6a -Swamp Ditch Surface Water Controls/InSitu Plume Treatment with Active PermeableTreatment Wall	Similar to Alternative 6.	Similar to Alternative 6.	Similar to Alternative 6.	Similar to Alternative 6.	$6.6 million	$14.4 million	Costs are similar to Alternative 6 but could be higher if groundwater treatment is required.
Alternative 7 -Swamp Ditch Surface Water Controls/Far Downgradient InSitu Plume Treatment with Passive PermeableTreatment Wall	Similar to Alternative 6, fewer worker exposure issues.	Similar to Alternative 3 and 4.	Similar to Alternative 6. *Duration:* 6 to 7 mos. *Cost:* $470K.	Similar to Alternative 4.	$8.7 million	$11.8 million	Similar advantages and disadvantages as Alternative 4 and 5, but at much lower cost.

FIGURES



NORTH PLATEAU LOCATION WITHIN THE WNYNSC
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 1

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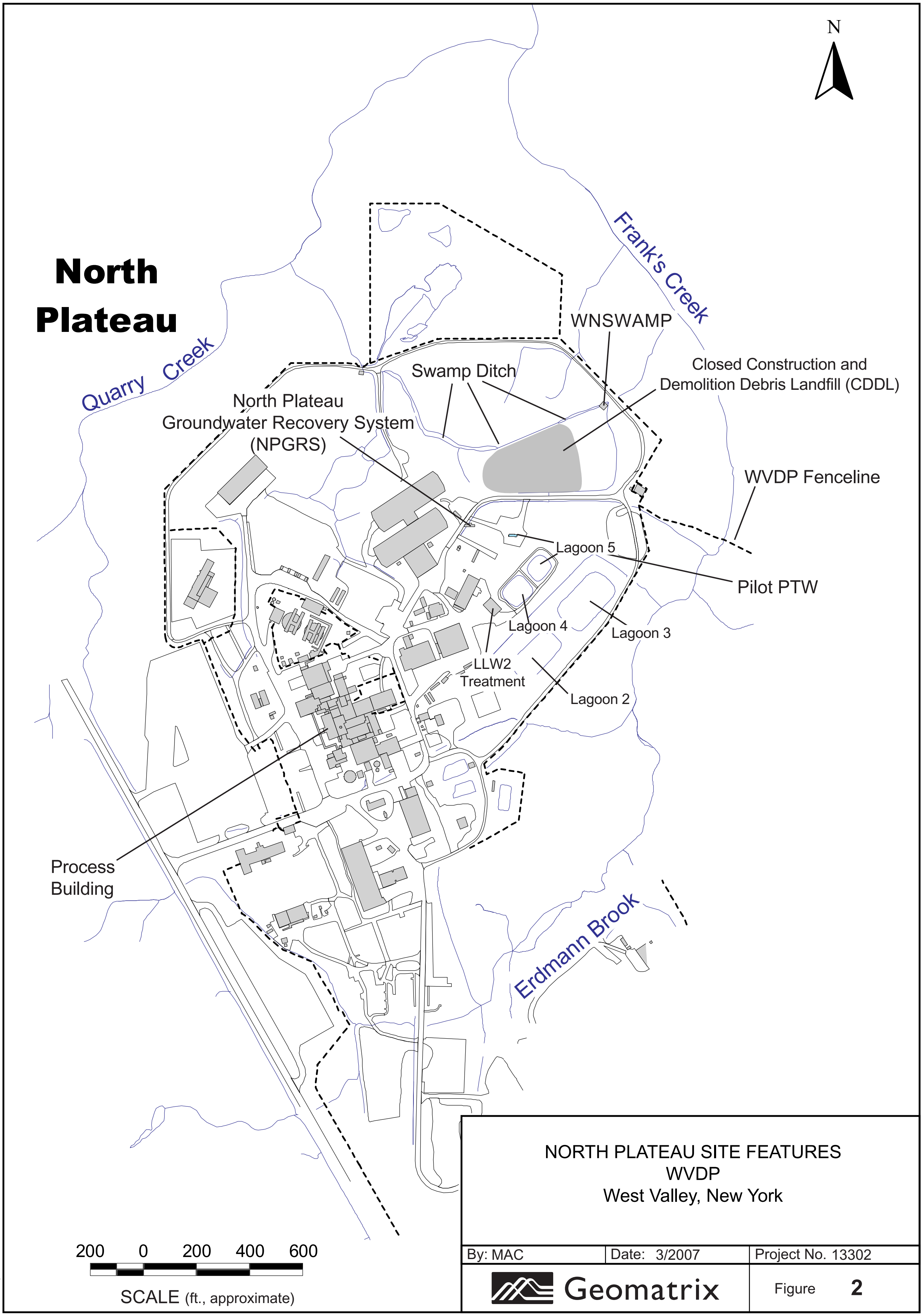
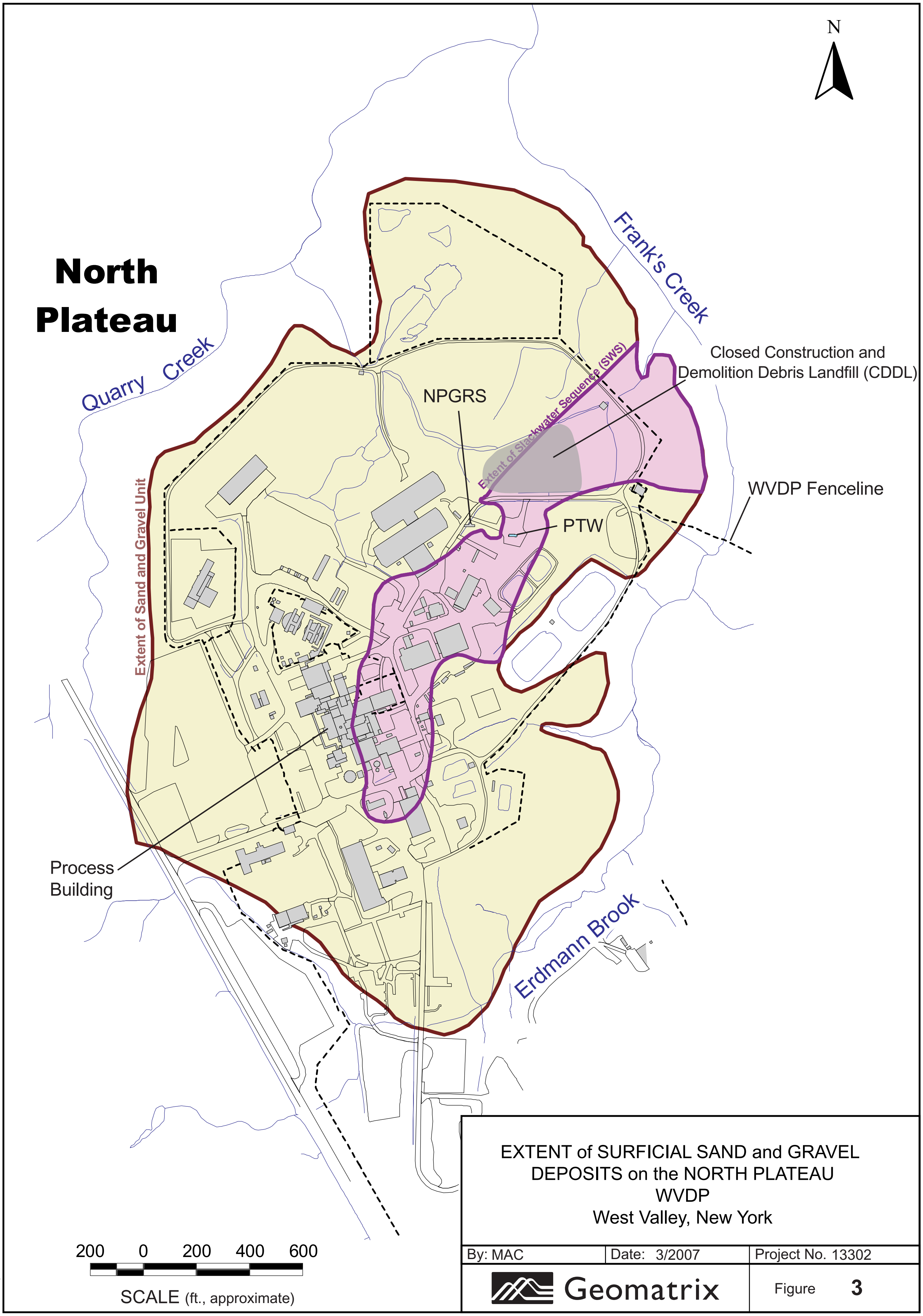


NORTH PLATEAU SITE FEATURES
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302

Geomatrix

Figure 2



EXTENT of SURFICIAL SAND and GRAVEL DEPOSITS on the NORTH PLATEAU
WVDP
West Valley, New York

By: MAC | Date: 3/2007 | Project No. 13302

Geomatrix

Figure 3

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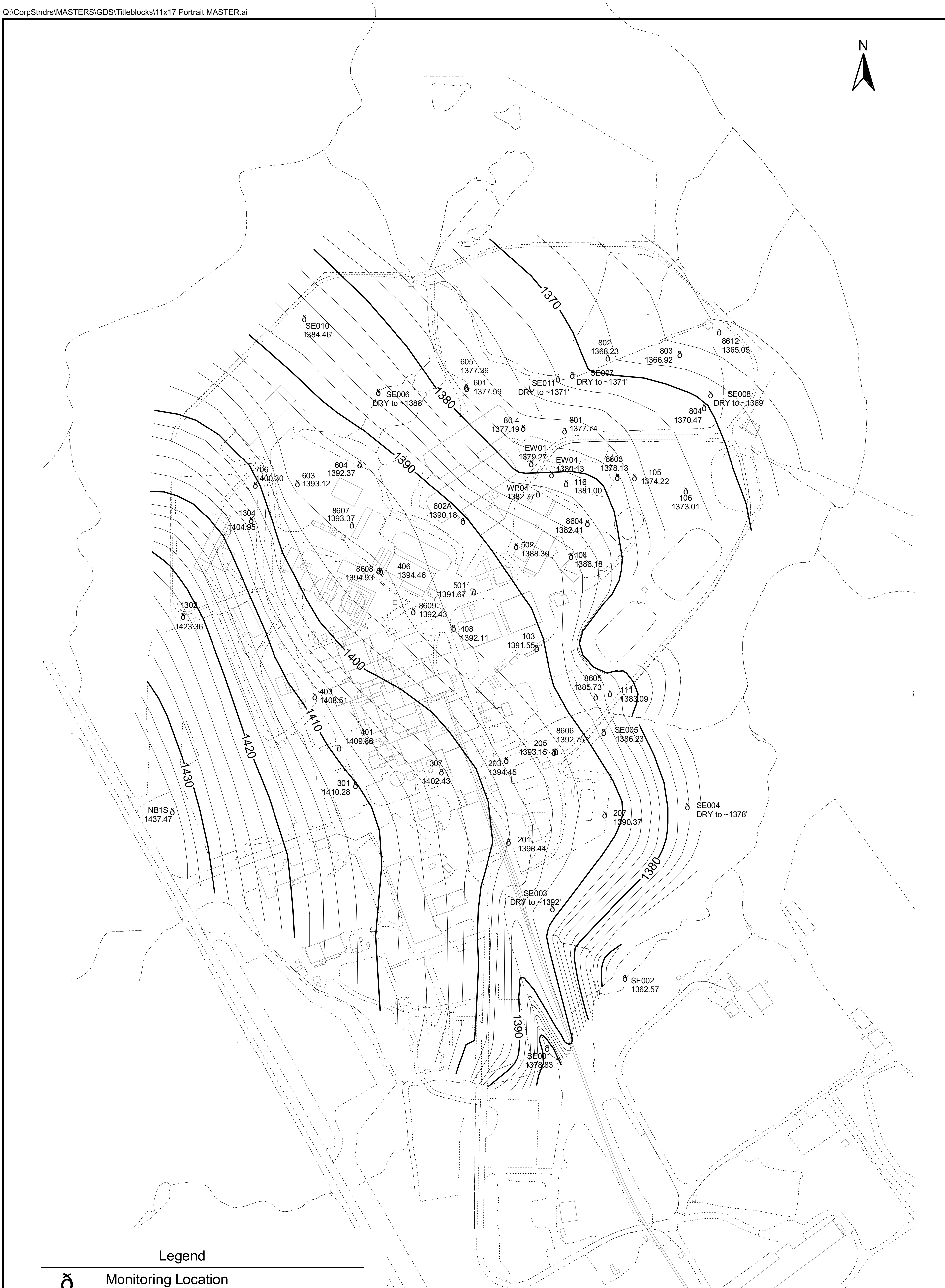


Legend

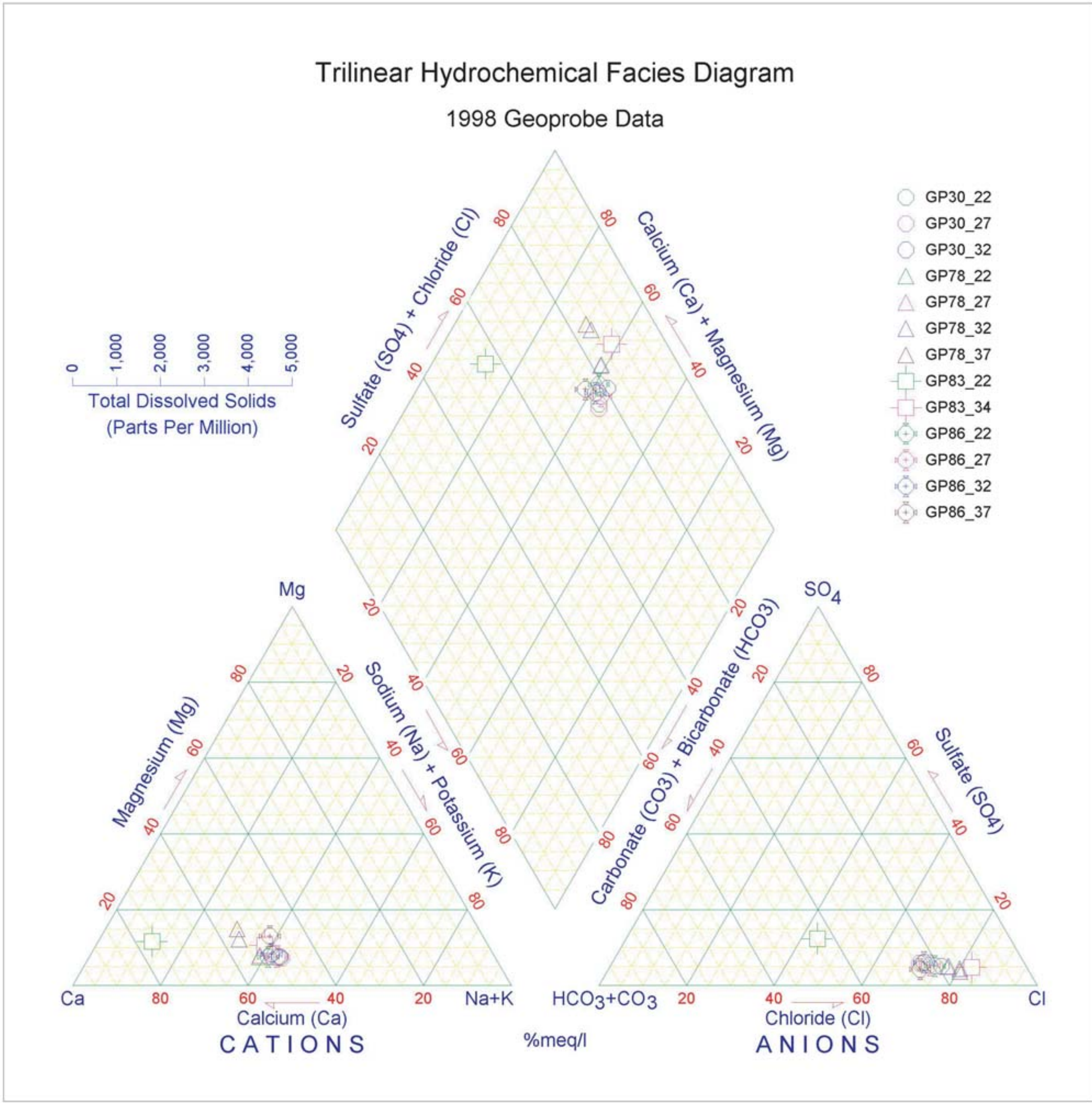
ð	Monitoring Location
– – – -	Approximate Extent of Sand & Gravel Unit
1435.53	Groundwater Elevation
	Inferred Zones of Seepage
NA	Measuring Point was Frozen at Grade

100 0 100 200 300 400 Feet

Contour Interval: 2 feet
Map Based on 1996 Fly-Over Survey
Water Levels Were Measured on August 21-31, 2006
Water Elevations in Feet Above Mean Sea Level (M.S.L.)

GROUNDWATER ELEVATION CONTOURS
4th Quarter 2006
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 4



NORTH PLATEAU GROUNDWATER CHEMISTRY
TRILINEAR DIAGRAM
WVDP
West Valley, New York

By: MAC	Date: 5/2007	Project No. 13302
Geomatrix		Figure 5

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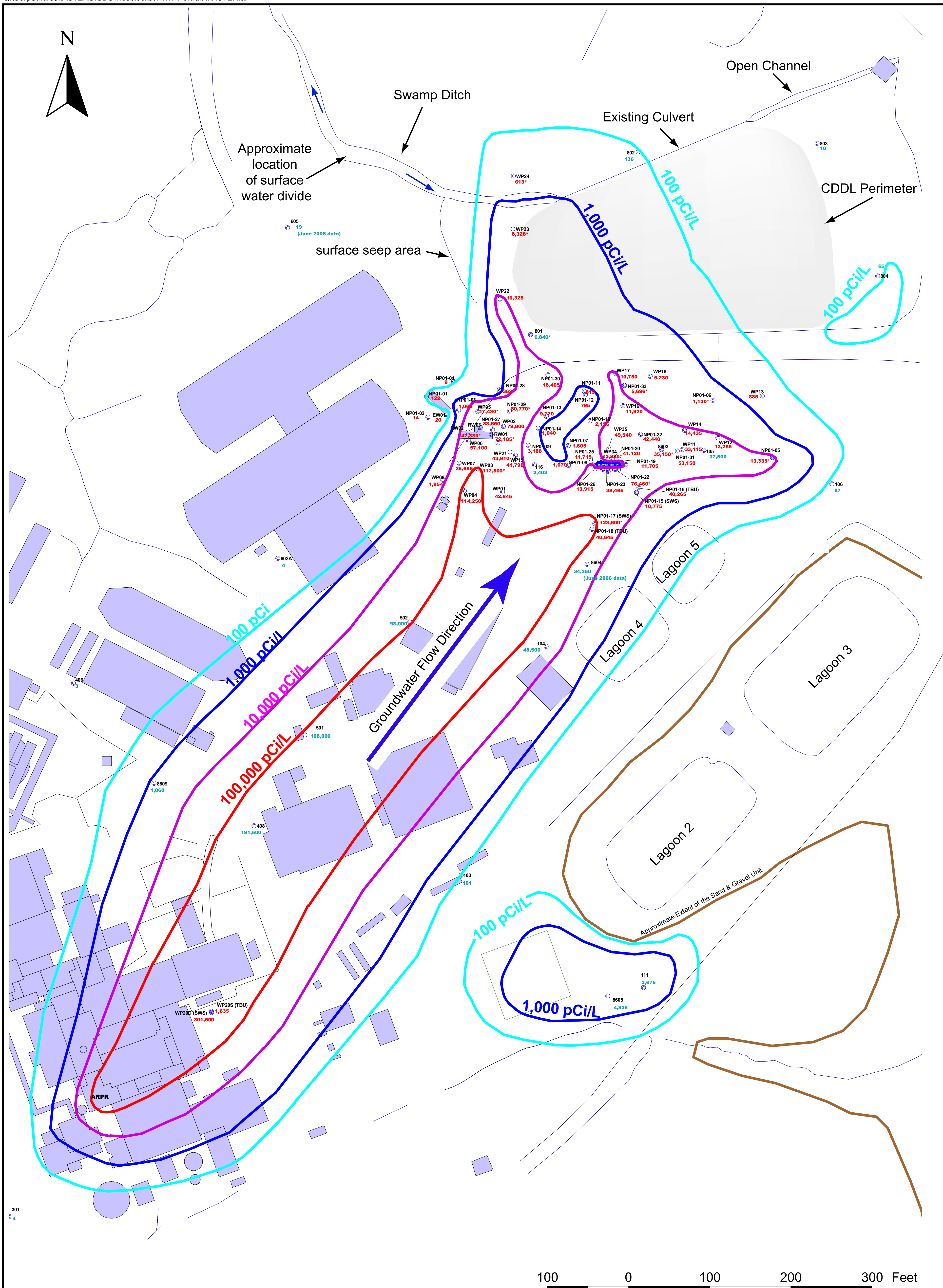

Sr-90 Concentration Isopleths (pCi/L)

100
1,000
10,000
100,000

WP36 © Monitoring Well

15,100 North Plateau Data (pCi/L) 09/25/06

15,100 GMP Data (pCi/L) 9/5 - 9/14/06

* = Samples analyzed for Sr-90. All other results are 50% of the Gross Beta concentration.

Sr-90 Plume Extent
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 6

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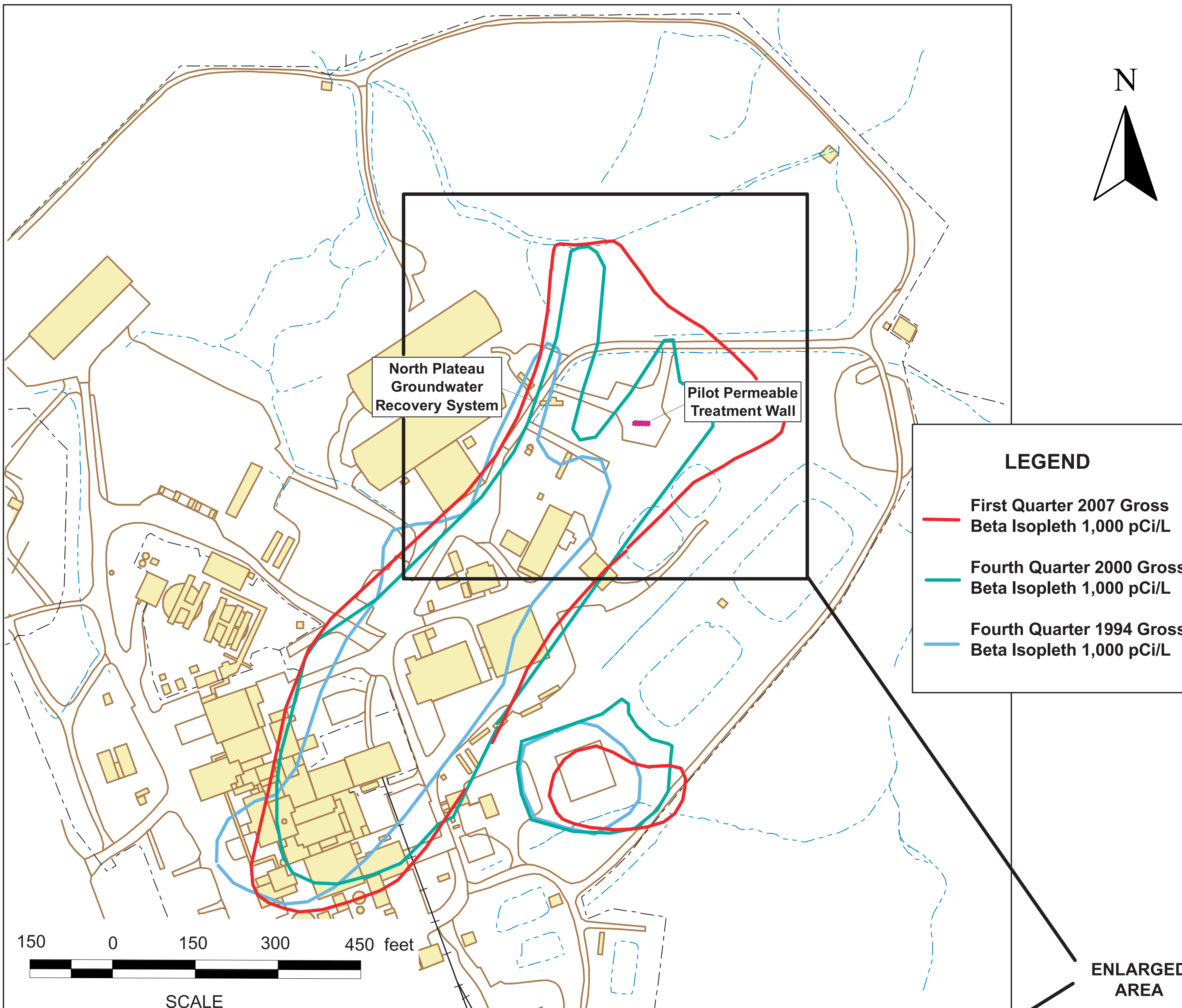

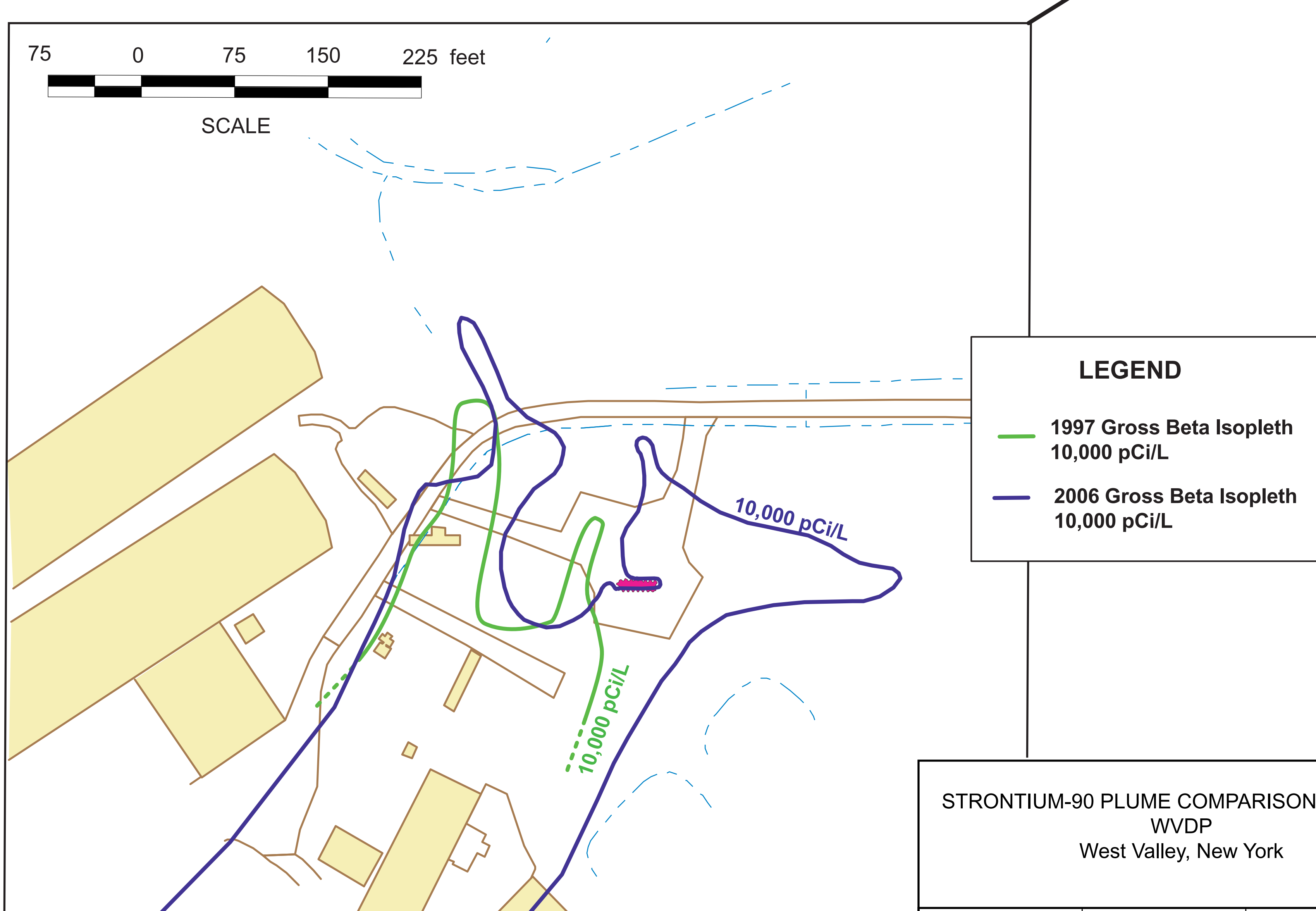

STRONTIUM-90 PLUME COMPARISON 1994-2007
WVDP
West Valley, New York

By: MAC	Date: 5/2007	Project No. 13302
Geomatrix		Figure 7

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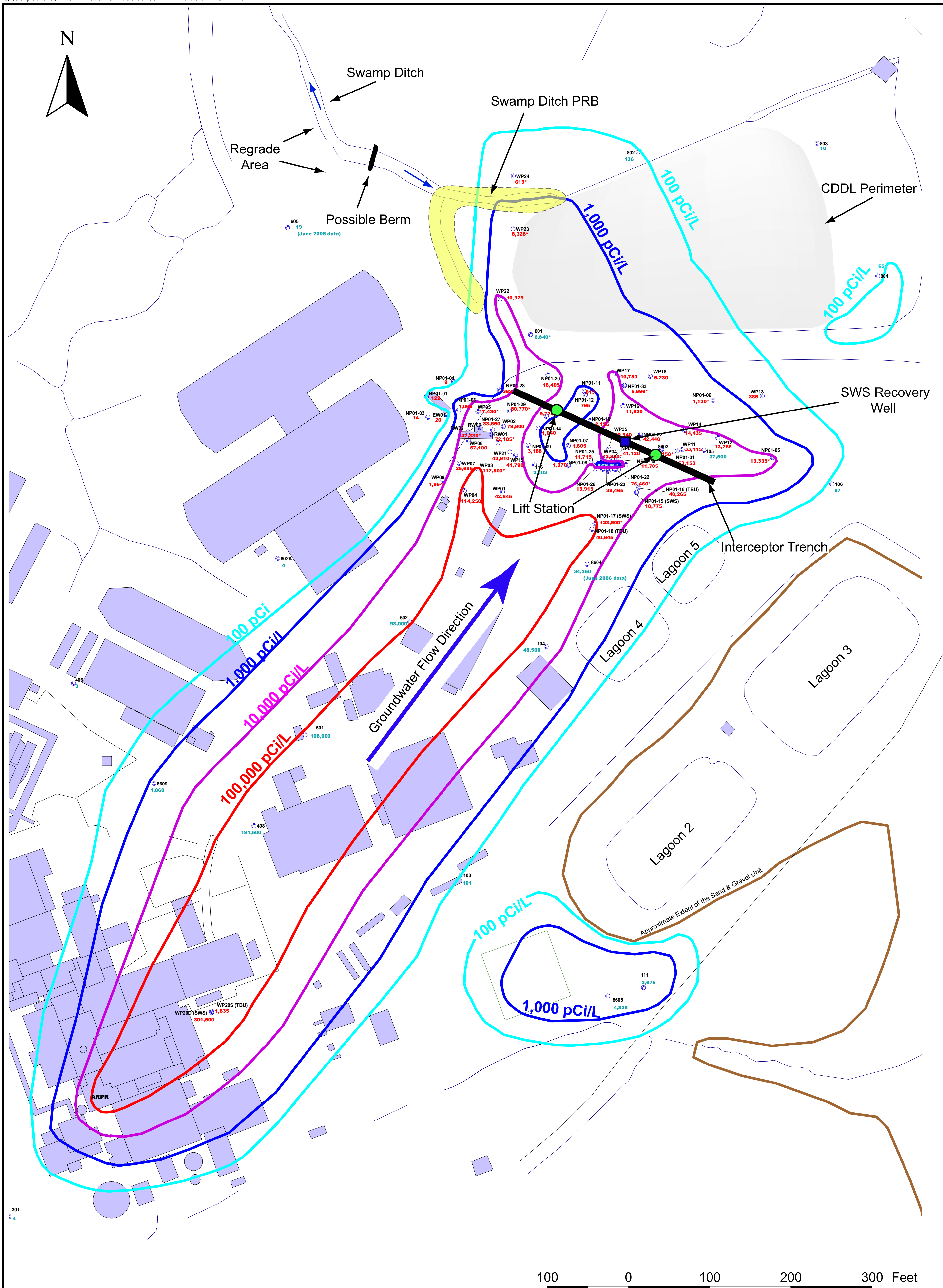

Sr-90 Concentration Isopleths (pCi/L)

- 100
- 1,000
- 10,000
- 100,000

WP36 ◎ Monitoring Well

15,100 North Plateau Data (pCi/L) 09/25/06

15,100 GMP Data (pCi/L) 9/5 - 9/14/06

* = Samples analyzed for Sr-90. All other results are 50% of the Gross Beta concentration.

ALTERNATIVE 2- SURFACE WATER CONTROLS/
INTERCEPTOR TRENCH DRAIN
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 8

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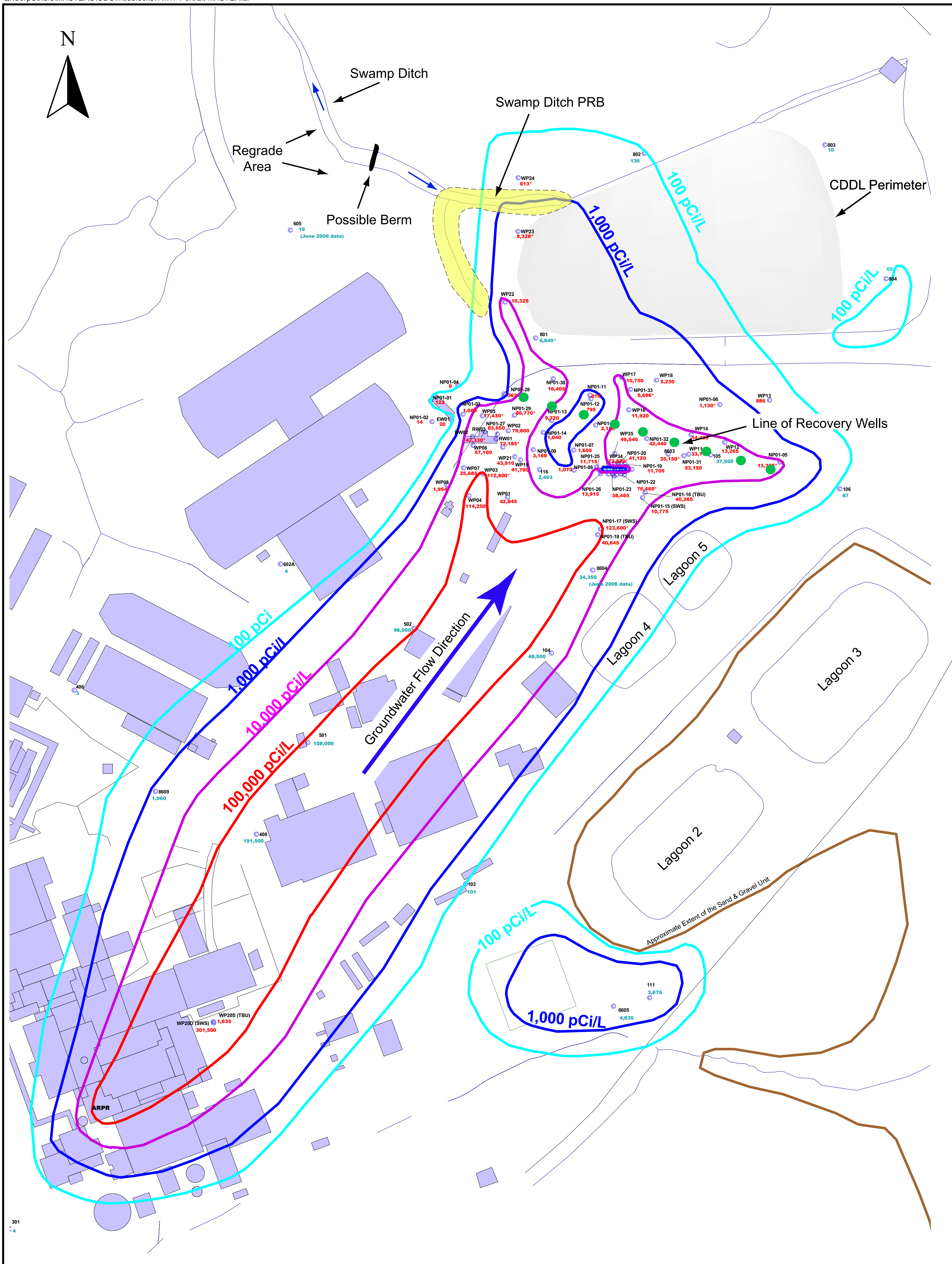

100 0 100 200 300 Feet

Sr-90 Concentration Isopleths (pCi/L)

100
1,000
10,000
100,000

WP36 Monitoring Well

15,100 North Plateau Data (pCi/L) 09/25/06

15,100 GMP Data (pCi/L) 9/5 - 9/14/06

* = Samples analyzed for Sr-90. All other results are 50% of the Gross Beta concentration.

ALTERNATIVE 3- SURFACE WATER CONTROLS/ GROUNDWATER RECOVERY WELLS
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 9

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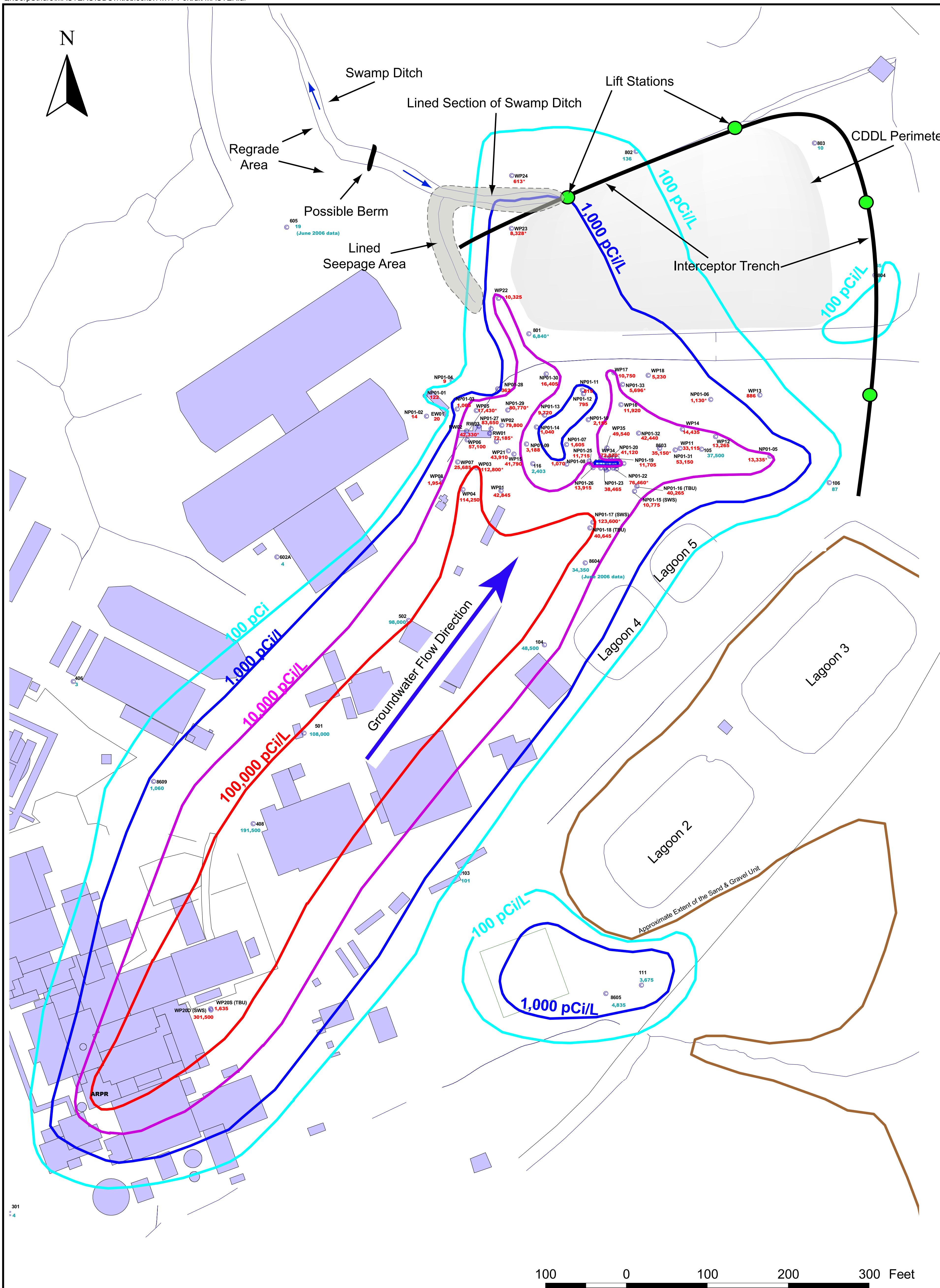

Sr-90 Concentration Isopleths (pCi/L)

- 100
- 1,000
- 10,000
- 100,000

WP36 Monitoring Well

15,100 North Plateau Data (pCi/L) 09/25/06

15,100 GMP Data (pCi/L) 9/5 - 9/14/06

* = Samples analyzed for Sr-90. All other results are 50% of the Gross Beta concentration.

ALTERNATIVE 4- SURFACE WATER CONTROLS/
FAR DOWNGRADIENT INTERCEPTOR
TRENCH DRAIN
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 10

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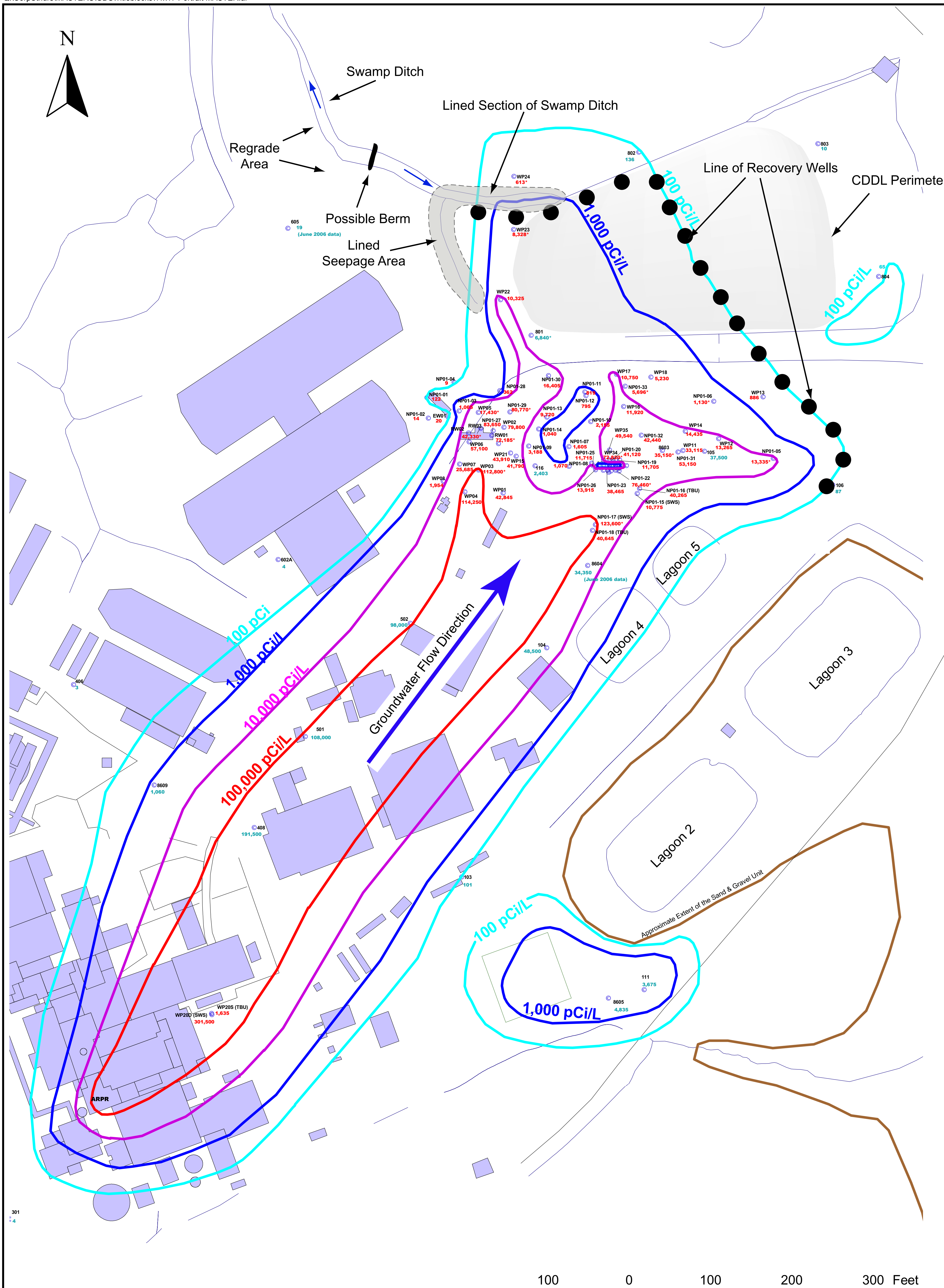

Sr-90 Concentration Isopleths (pCi/L)

- 100
- 1,000
- 10,000
- 100,000

WP36 ◎ Monitoring Well

15,100 North Plateau Data (pCi/L) 09/25/06

15,100 GMP Data (pCi/L) 9/5 - 9/14/06

* = Samples analyzed for Sr-90. All other results are 50% of the Gross Beta concentration.

ALTERNATIVE 5- SURFACE WATER CONTROLS/
FAR DOWNGRADIENT GROUNDWATER
RECOVERY WELLS
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 11

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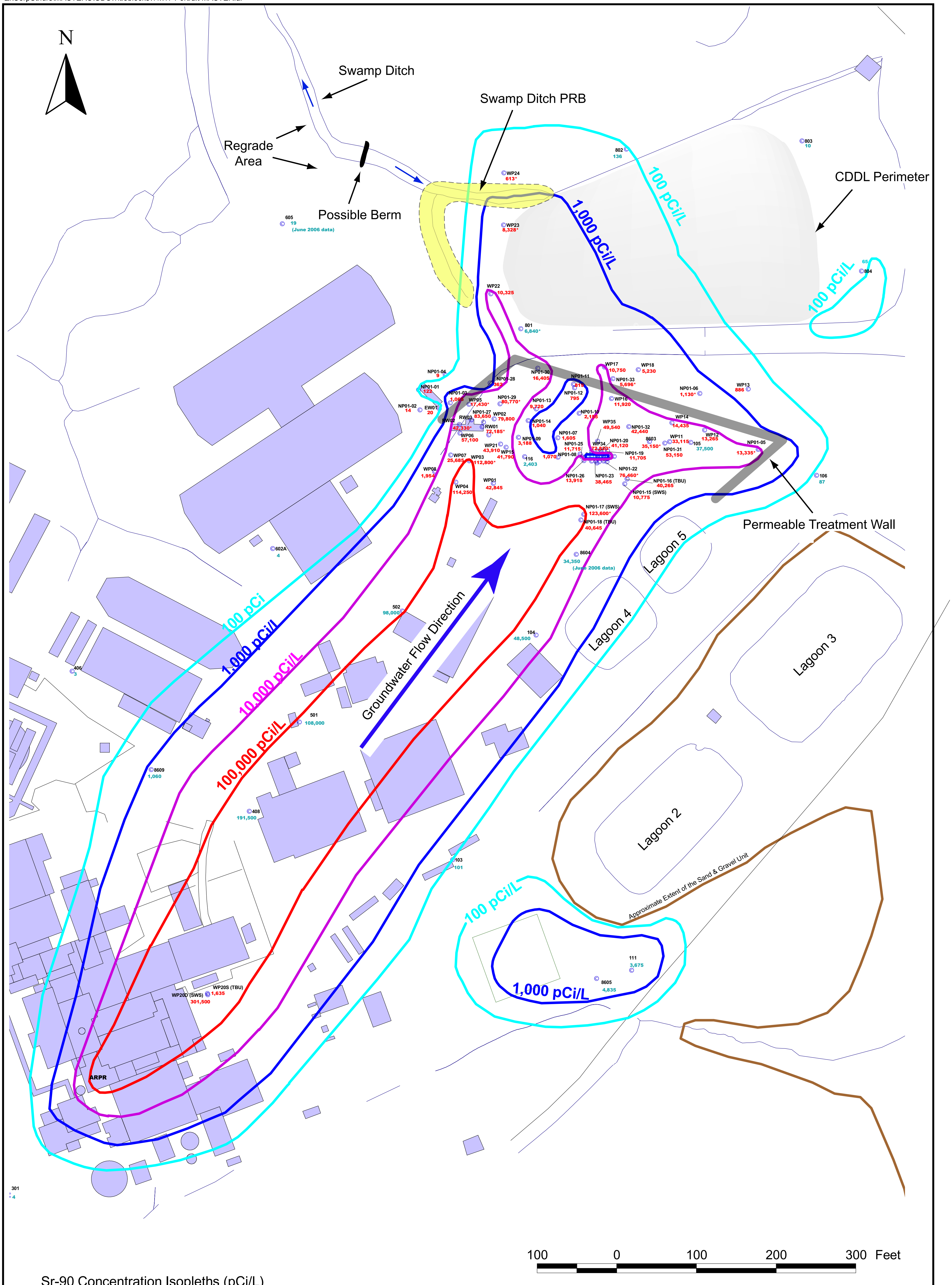

Sr-90 Concentration Isopleths (pCi/L)

100
1,000
10,000
100,000

WP36 Monitoring Well

15,100 North Plateau Data (pCi/L) 09/25/06

15,100 GMP Data (pCi/L) 9/5 - 9/14/06

* = Samples analyzed for Sr-90. All other results are 50% of the Gross Beta concentration.

ALTERNATIVE 6- SURFACE WATER CONTROLS/
IN-SITU PASSIVE PLUME TREATMENT WITH
PERMEABLE TREATMENT WALL
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 12

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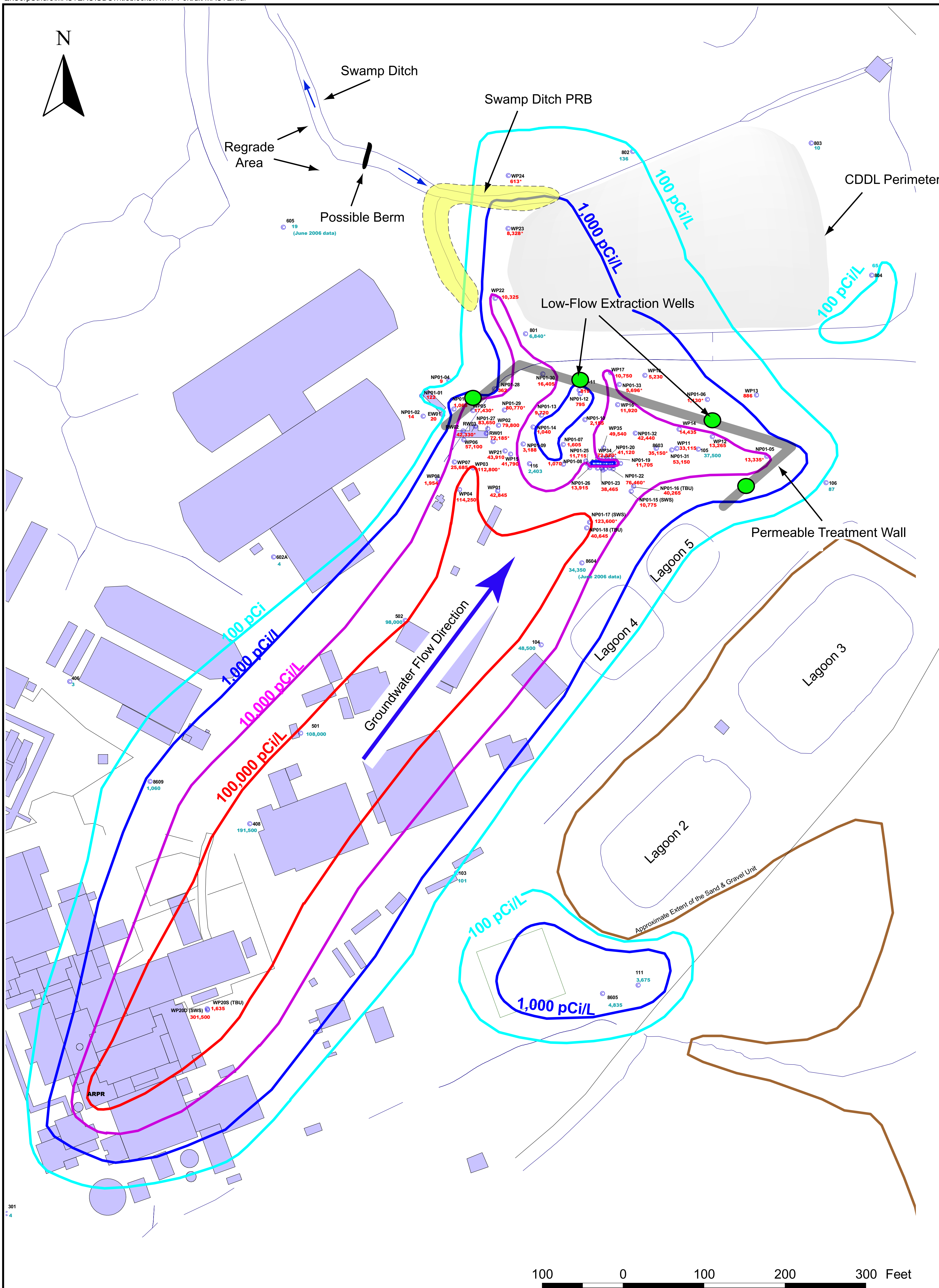

Sr-90 Concentration Isopleths (pCi/L)

100
1,000
10,000
100,000

WP36 Monitoring Well
15,100 North Plateau Data (pCi/L) 09/25/06
15,100 GMP Data (pCi/L) 9/5 - 9/14/06

* = Samples analyzed for Sr-90. All other results are 50% of the Gross Beta concentration.

ALTERNATIVE 6A- SURFACE WATER CONTROLS/ IN SITU ACTIVE PLUME TREATMENT WITH PERMEABLE TREATMENT WALL
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 13

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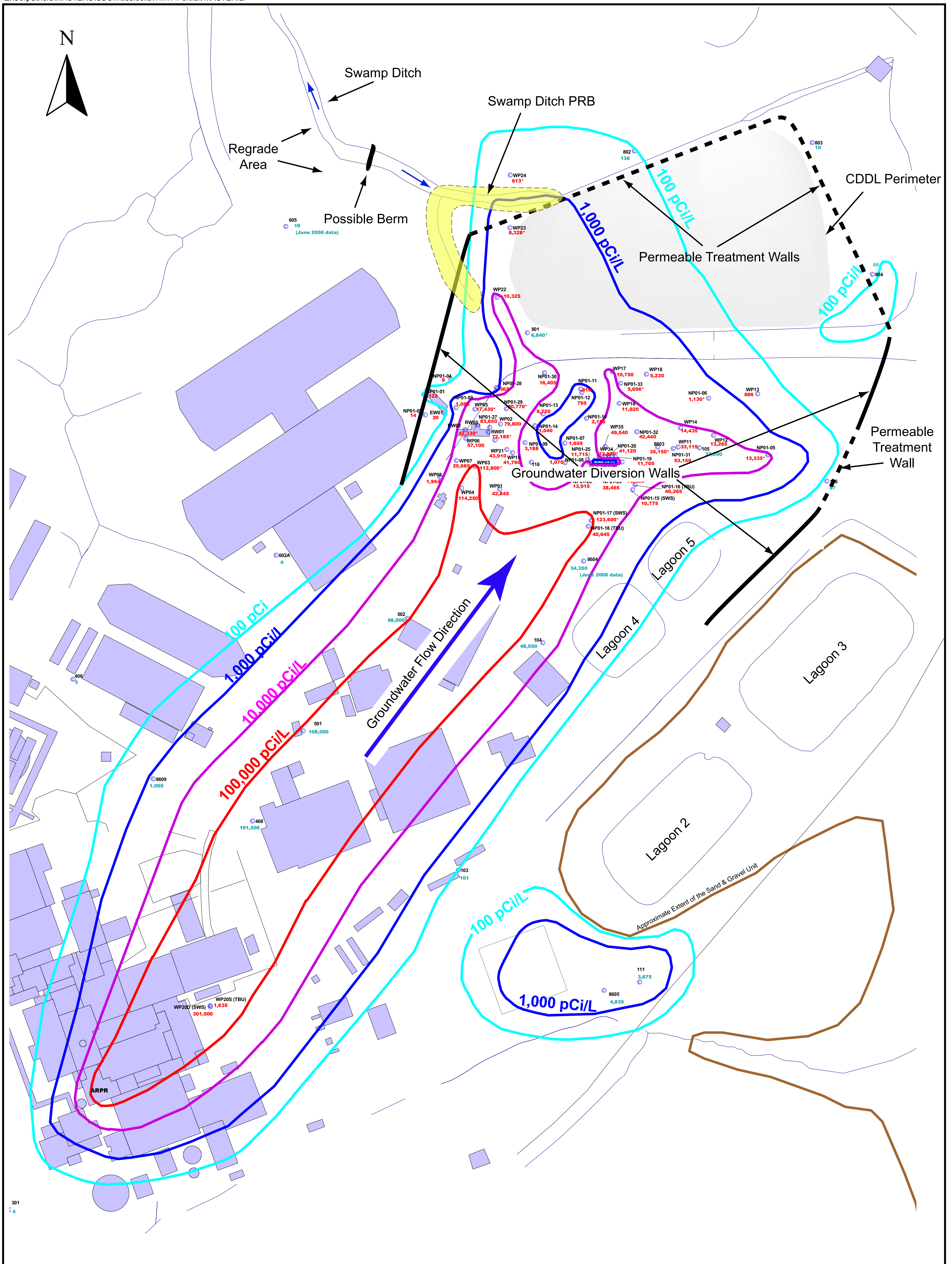


Sr-90 Concentration Isopleths (pCi/L)

- 100
- 1,000
- 10,000
- 100,000

WP36 Monitoring Well

15,100 North Plateau Data (pCi/L) 09/25/06

15,100 GMP Data (pCi/L) 9/5 - 9/14/06

* = Samples analyzed for Sr-90. All other results are 50% of the Gross Beta concentration.

ALTERNATIVE 7- SURFACE WATER CONTROLS/ FAR DOWNGRADIENT IN SITU PLUME TREATMENT WITH PERMEABLE TREATMENT WALL
WVDP
West Valley, New York

By: MAC	Date: 3/2007	Project No. 13302
Geomatrix		Figure 14

APPENDIX A

Hydraulic Control Flow Rate Estimation

Subject WVDP North Plateau FS Flow Estimation | Project No. 013302
By RHF | Checked By MM | Task No. 3
Date 3-25-07 | Date 3/30/07 | File No. CALC
Sheet 1 of 3

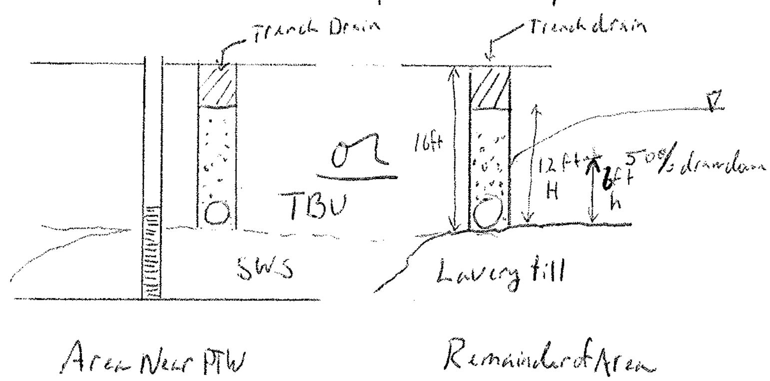
Estimation of Flow Rates for Hydraulic Control Alternatives

Analytical Solution -
Flow to a drainage trench: Equation 6.12 Construction Dewatering New Methods and Applications 2nd Ed POWERS, 1992

$$Q = \frac{\pi K (H^2 - h^2)}{\ln R_o / r_s} + 2\left[\frac{x K (H^2 - h^2)}{2L}\right]$$

Q - total system flow
K - hydraulic Conductivity
H - Saturated Thickness
h - height of water in trench
X - trench length
L - dist. of linear hydraulic influence
r_s - equivalent Well diameter
R_o trench end radius of influence

North Plateau Conceptual Capture:



North Plateau Hydraulic Conductivity:

WVNSCO, 1993 - $K = 1.9 \times 10^{-3}$ cm/s - Ave North Plateau

WVNSCO, 2002 - $K = 4.0 \times 10^{-3}$ cm/s - K from PTW Pumping Tests

Dames & Moore, 1996 - $K = \sim 3.0 \times 10^{-2}$ cm/s - K from 60 minute Pump test @ NPGRS (Assume too low)

Reasonable Average K for Estimation 4.1×10^{-3} cm/s

or

$K = 87$ gpd/ft^2

Subject WVDP North Plateau - FS Flow Estimation | Project No. 013302
Task No. 3
By RHF | Checked By MAL | File No. CALC
Date 3-25-07 | Date 3/30/07 | Sheet 2 of 3

H = Saturated thickness - 12 ft

h = height of drawdown in trench - 6 ft - 50% drawdown say 7ft at end of trench

x = trench length - 275 ft across 10,000 pCi/L

L = Dist. of hydraulic influence - 100 ft - Pumping of PTW produced 0.5 ft drawdown 100 ft away

r_s = Equivalent system well diameter - 1.5 ft

R_o = radius of influence on trench ends 100 ft

$$Q = \frac{\pi k (H^2 - h^2)}{\ln R_o / r_s} + 2\left[\frac{xK(H^2-h^2)}{2L}\right]$$

End of trench flow | Centerline trench flow

$$\frac{\pi \times 87\ gpd/ft^2 \times (12ft^2 - 7ft^2)}{\ln 100ft / 1.5ft} + 2\left[\frac{275ft \times 87 gpd/ft^2 \ (12ft^2 - 6ft^2)}{2(100ft)}\right]$$

$$= \frac{25952\ gpd}{3.07} + 2\times\left(\frac{2583900\ gpd}{200}\right)$$

8450 gpd ≈ 5.8 gpm + 25,839 gpd 17.9 gpm

Q = 23.7 gpm

+ Q from Slackwater sequence pumping well = 3 gpm (estimate)

Total Estimated flow = 26.7 gpm say 27 gpm

Subject: WVDP North Plateau - Flow Rate Estimation

Project No. 013304

Task No. 3

File No. CALC

By: RHK

Checked By: MAL

Date: 5/18/07

Date: 5/22/07

Hydraulic control with individual groundwater recovery wells:

Flow rate estimates applicable to Alternatives 3 and 5.

Individual recovery well estimates of steady state flow are based on the Pumping Test Analyses Report (Dames & Moore, 1996) and 2005 operational data for the North Plateau Groundwater Recovery System (NPGRS) presented in the 2006 Annual Report.

- Pumping test data report a radius of hydraulic influence exceeding 30 ft from RW-3 at a pumping rate of 4 gpm after 60 minutes of pumping. Figure 1 is a hand contoured sketch of drawdown from the 1 hr test.

- Actual flow rates from the NPGRS (2005) were:

  Total Flow = 4,105,084 gallons in 2005 or 7.8 gpm average
  Operating wells RW-1 + RW-2

  Therefore, individual well pumping rates are approximately 3.9 gpm

- Since some bypass is occurring, a higher flow rate of 5 gpm (25% higher) is assumed to be necessary to improve hydraulic containment using individual pumping wells.

Conservatively assuming a well spacing of 50 feet (overlapping area of hydraulic influence radii of 25 feet), 9 wells would be expected to capture flow across the leading plume edge @ 10,000 pCi/L (see Figure 9)

Alternative 3 flow rate estimate: 9 wells x 5 gpm each = 45 gpm

Baseline pumping rates could be lower based on cummulative drawdown effect, but sustained high water table conditions exist seasonally and higher flow rates may be required to maintain hydraulic control.

Alternative 5 flow rate estimate. Little to no hydraulic data in vicinity of CDDL. Saturated thickness is less near Northern end of N Plateau. Assuming 4 gpm flow rate for individual pumping wells and radii of influence of approximately 30 to 40 feet, 17 pumping wells would be necessary to achieve hydraulic control.

17 wells x 4 gpm each = 68 gpm   Say flow rate estimate of 65 to 75 gpm

GEOMATRIX CONSULTANTS

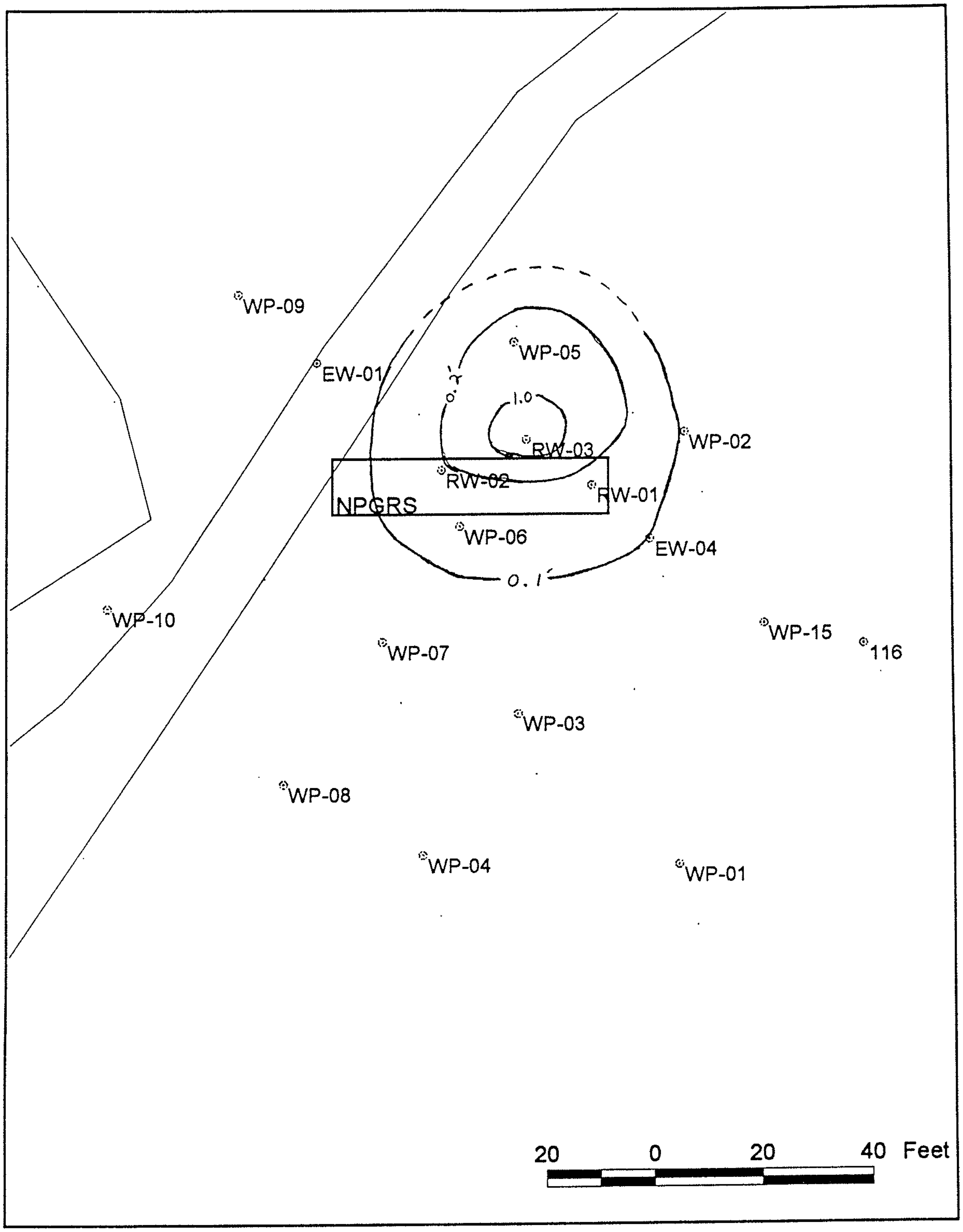
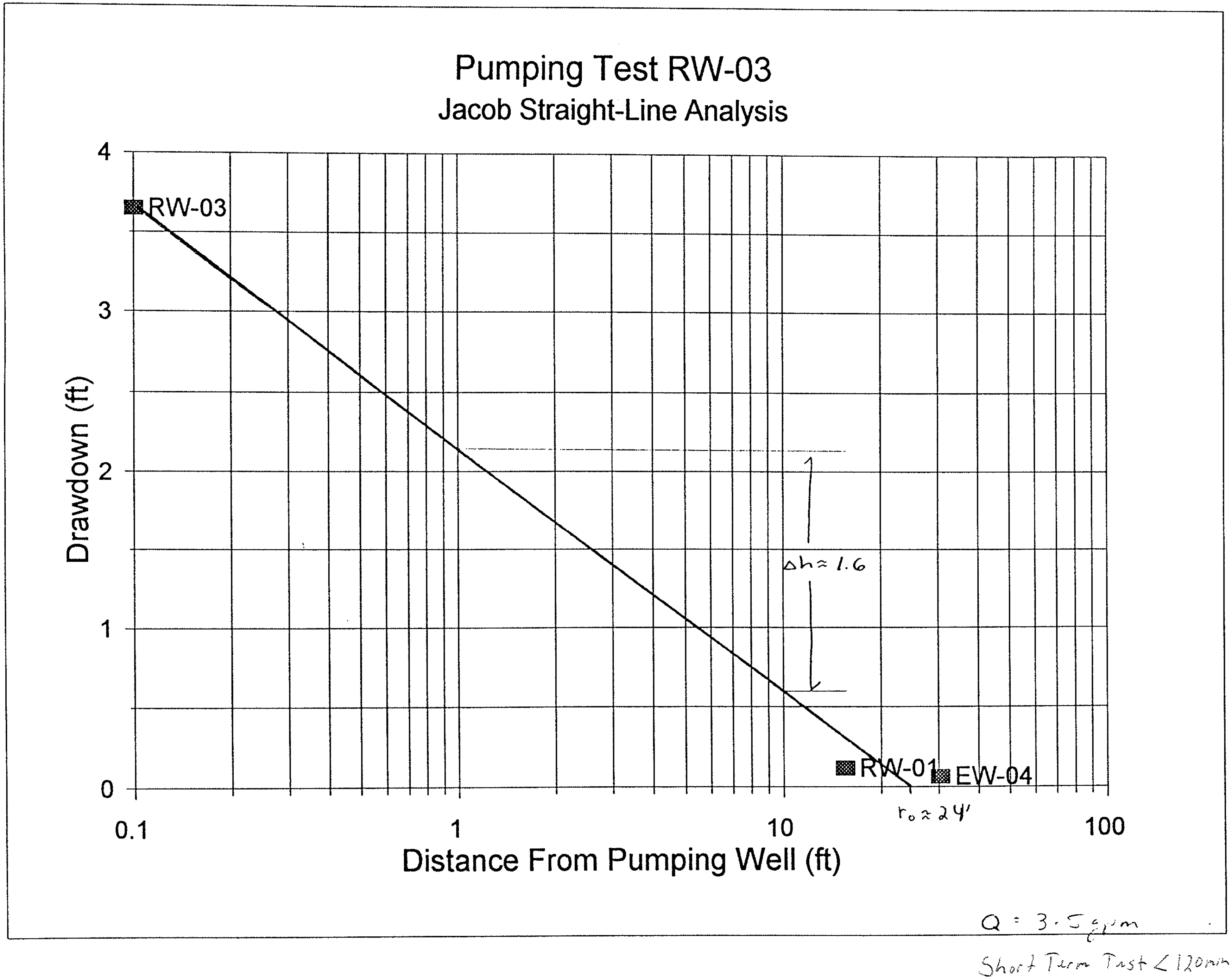


Figure 1. NPGRS Pumping Wells and Observation Wells With Approximate Zone of Influence For RW-03 Step Test


Pumping Test RW-03
Jacob Straight-Line Analysis
Drawdown (ft)
4
3
2
1
0
0.1
1
10
100
Distance From Pumping Well (ft)
RW-03
RW-01
EW-04
Δh ≈ 1.6
r₀ ≈ 24'
Q = 3.5 gpm
Short Term Test < 120 min.