DOE/RL-2001-49

0059074

Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit

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CONCURRENCE PAGE

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Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit

March 2003

Prepared for
the U.S. Department of Energy
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by Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

This document describes groundwater sampling and analysis requirements for the 200-BP-5 Operable Unit under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) program. The document also presents a revised monitoring network and sampling program needed to adequately define the major groundwater plumes that are associated with B Plant past practice operations as they currently exist. The wells associated with the 200-BP-5 Operable Unit network will be sampled annually to triennially for constituents including technetium-99, tritium, uranium, iodine-129, strontium-90, cesium-137, plutonium-239/240, cobalt-60, cyanide, and nitrate. Additional data are also available from surveillance (*Atomic Energy Act of 1954* [AEA]) and *Resource Conservation and Recovery Act* (RCRA) monitoring activities that will be used to supplement the CERCLA monitoring activities as defined in this document.

A list of 72 monitoring wells comprising the 200-BP-5 monitoring network, including specific contaminants to be analyzed and sampling frequency, is presented in this document. The monitoring network for Tc-99 is based on a combination of geostatistical modeling and hydrogeological considerations. The text provides a comparison of the revisions made in the monitoring network for the 200-BP-5 Operable Unit relative to that defined in a previous Federal Facility Agreement and Consent Order Change Control Form (Change Number M-15-96-04; April 29, 1996). In addition, drilling a new well and deepening of an existing well are proposed in order to better define the distribution of technetium-99 in the area between the 200 East Area and Gable Mountain Gap. Also included in this document are sampling and analysis protocol, waste handling requirements, quality assurance and quality control requirements, groundwater level monitoring, and data management requirements associated with groundwater monitoring of the 200-BP-5 Operable Unit.

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1.0 Introduction

The purpose of this document is to identify groundwater sampling and analysis requirements for the 200-BP-5 Operable Unit. This sampling and analysis plan describes a revised monitoring well network, constituents analyzed, sampling protocol and waste management requirements, groundwater level measurement, and reporting and quality assurance requirements associated with this activity.

Data are necessary to define plume detection and movement in the 200-BP-5 Operable Unit to meet the requirements for remediation performance monitoring (i.e., *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* [CERCLA] monitoring) and site-wide surveillance monitoring (*Atomic Energy Act of 1954* [AEA]) activities as directed in U.S. Department of Energy (DOE) orders. This sampling and analysis plan was prepared in response to the U.S. Environmental Protection Agency (EPA) 5-year review of groundwater remedial actions of the Hanford Site and supports Action Item 200-8 (EPA 2001).

Groundwater remediation is not currently being performed in the 200-BP-5 Operable Unit. This is because some of the contaminants associated with the plumes are not considered to pose a risk to the public at current concentrations and areal distributions, or are at too low a concentration to warrant a remediation response at this time. Others cannot be effectively remediated using current known technologies. However, monitoring groundwater contamination in the operable unit is necessary to determine if contaminant levels are attenuating with time and to ensure that no new or previously unidentified groundwater contamination goes undetected. A record of decision (ROD) is not yet in place for the 200-BP-5 Operable Unit. The sampling and analysis plan for this operable unit will be modified if a ROD is developed in the future.

This section provides background information about the 200-BP-5 Operable Unit, a list of the contaminants of concern (COCs), and a summary of the data quality objectives (DQOs) for groundwater monitoring in the unit as defined in PNNL-14049.

1.1 Background

Groundwater in the northern part of the 200 East Area and the 600 Area north of 200 East constitutes the 200-BP-5 Operable Unit (Figure 1.1). Tritium contamination extends north through the Gable Mountain Gap to the Columbia River (Figure 1.2), and the 2000 pCi/L tritium contour has been utilized in this plan to define the limits of the operable unit to the north of the 200 East Area (PNNL-14049). The Gable Mountain Pond is also associated with the 200-BP-5 Operable Unit.

The primary focus of this sampling and analysis plan is on the unconfined aquifer, which contains most of the contamination associated with this operable unit. Selected wells associated with this unit also monitor the upper basalt confined aquifer. Activities associated with B Plant past practice operations are the primary source of the contaminants found in the unconfined aquifer in the 200-BP-5 Operable Unit. The southeastern and eastern parts of 200 East are in the 200-PO-1 Operable Unit, where groundwater monitoring operations are directed toward contamination associated with the Plutonium-Uranium Extraction (PUREX) facility. B Plant and PUREX were used to process irradiated reactor fuel to extract plutonium between 1944 and 1990.

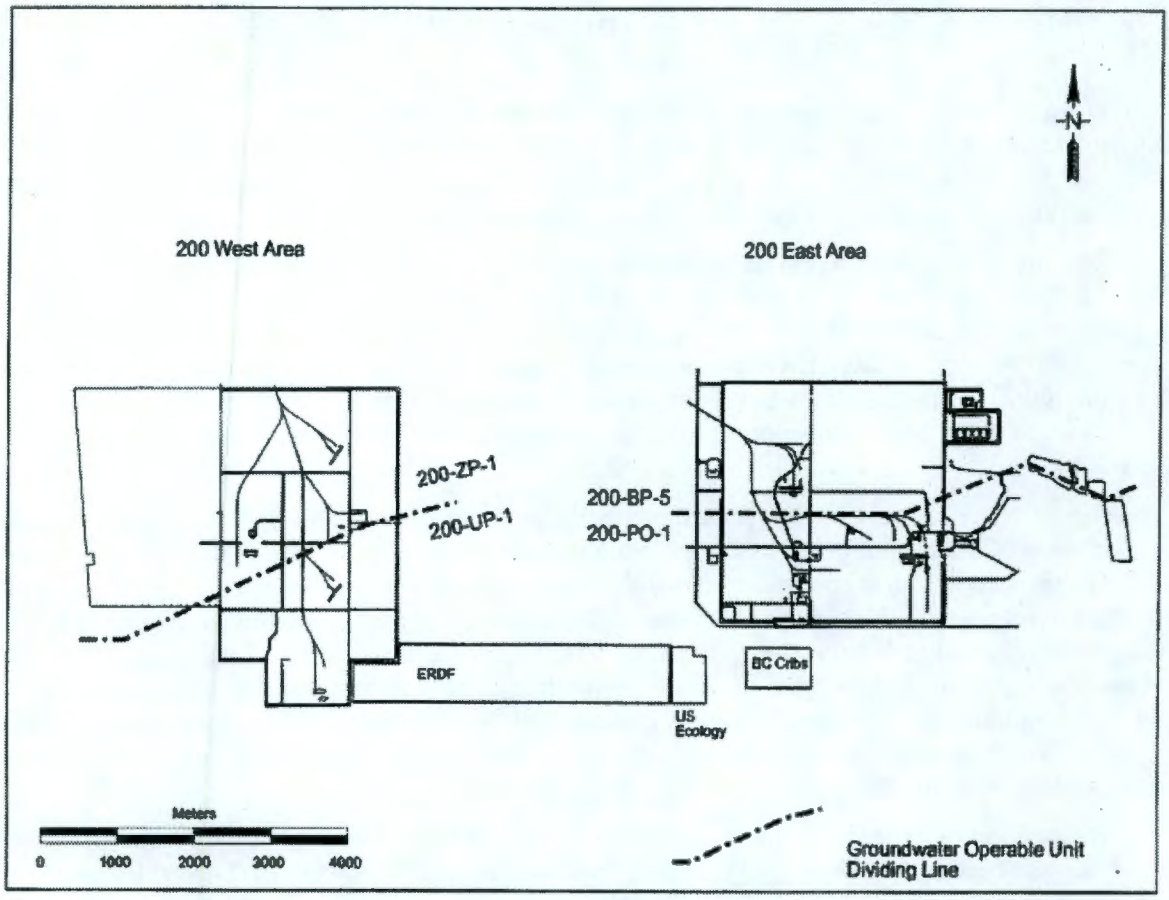

Figure 1.1. 200 Area Groundwater Operable Units

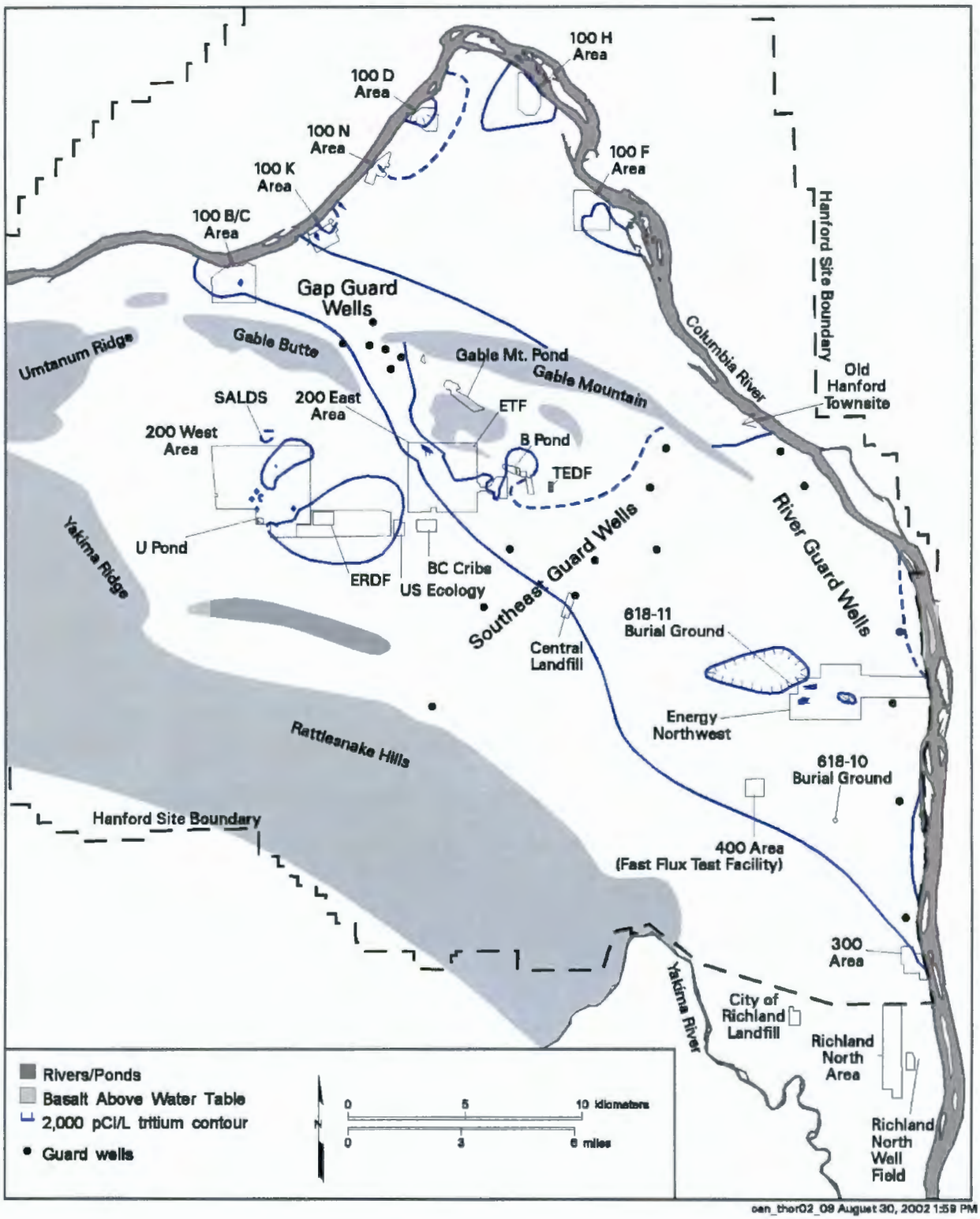

Figure 1.2. 2000 pCi/L Tritium Contour

The 200-BP-5 Operable Unit contaminant sources include the facilities surrounding B Plant plus waste storage and disposal facilities north of the plant. B Plant was used to recover plutonium from irradiated fuel using the bismuth phosphate process from 1945 to 1956 (PNNL-13788; PNNL-13080; DOE/RL-92-05). From 1968 to 1985, the plant was used to recover cesium-137 and strontium-90 from tank farm waste (DOE/RL-95-100). Contamination is primarily the result of waste disposal to the soil at various locations and includes effluent from process streams, cooling water, and condensate.

In 1954 and 1955, scavenged uranium recovery waste supernatant from U Plant operations was discharged to the BY Cribs (PNNL-13080). This waste contained large amounts of ferrocyanide and other chemical and radiological components. Disposal of this waste was discontinued because high levels of cobalt-60 were detected in the groundwater.

Significant waste sources for the 200-BP-5 Operable Unit are facilities associated with CERCLA and AEA monitoring activities and include the BY Cribs, the 216-B-5 Reverse Well, and Gable Mountain Pond. Associated *Resource Conservation and Recovery Act* (RCRA) facilities include low-level burial grounds Waste Management Areas 1 and 2, the 216-B-63 Ditch, the 216-B-3 Pond, and the tank farm facilities at Waste Management Areas B-BX-BY and C. The RCRA facilities are primarily monitored for non-radioactive contaminants under RCRA and for radioactive contaminants under CERCLA and AEA regulations. Current activities conducted in the 200 East Area include waste management, storage, and disposal (PNNL-13788 and PNNL-13080; DOE/RL-92-19).

Major groundwater contaminant constituents associated with the 200-BP-5 Operable Unit include tritium, iodine-129, technetium-99, uranium, nitrate, cyanide, cobalt-60, strontium-90, cesium-137, and plutonium. Tritium, iodine-129, and nitrate contamination is widespread in the 200 East Area and is associated with both B Plant and PUREX operations (Figure 1.2). Groundwater plumes of these contaminants within the 200-BP-5 Operable Unit extend to the northwest into the 600 Area toward the Gable Mountain/Gable Butte gap and southeast toward the PUREX Plant. The BY Cribs were important sources of technetium-99, cyanide, cobalt-60, and nitrate contamination associated with early releases and were a main contributor for plumes that moved to the northwest. Waste Management Area B-BX-BY appears to have contributed nitrate, technetium-99, and uranium to groundwater through remobilization of vadose zone contamination (PNNL-11826). Groundwater monitoring at the 216-B-62 Crib, located west of B Plant, also indicates that this crib is a contributor of uranium locally. Monitoring wells associated with the 216-B-5 Reverse Well have had detectable concentrations of strontium-90, cesium-137, plutonium-239 and -240, and uranium in groundwater samples. Localized plumes of strontium-90 and nitrate in the vicinity of Gable Mountain Pond are also being monitored.

Groundwater remediation in the 200-BP-5 Operable Unit is dictated by CERCLA regulations. Two groundwater extraction treatability tests were performed in the 200-BP-5 Operable Unit (DOE/RL-95-59) during the period from August 29, 1994, to May 29, 1995. The location of one test was near the 216-B-5 Reverse Well; the second was located just north of the northwestern corner of the 200 East Area in an area of contamination probably originating in the BY Cribs. Treatability testing results indicated that groundwater remediation by current pump and treat technology would not be practical in this area (DOE/RL-94-95). However, technetium-99, cobalt-60, cyanide, and nitrate groundwater contamination believed to be sourced in the BY Cribs will naturally dissipate within a relatively short period of time. Because of high sorption coefficients and inclusion in relatively insoluble solid phases, plutonium, strontium-90, and cesium-137 in the 216-B-5 Reverse Well plume are not considered to pose a threat outside of the 200 East Area. Strontium-90 associated with the Gable Mountain Pond plume, though further to the north, is expected to decay to acceptable levels before the plume migrates a significant distance.

1.2 Contaminants of Concern

A list of the contaminants of concern for the 200-BP-5 and 200-PO-1 operable units was generated by initially listing all of the contaminants of potential concern (COPCs) based on historical process operations (PNNL-14049). Certain COPCs identified below are in other plans (i.e., RCRA treatment, storage, or disposal (TSD) monitoring plans), but were included in the final list of COCs to prevent missing them during monitoring.

Table 1.1 identifies ten COPCs identified to apply to groundwater within the 200-BP-5 Operable Unit. A number of the COPCs for the 200-BP-5 Operable Unit are associated with the BY cribs, the B-5 reverse well, and Gable Mountain Pond, as indicated in Table 1.1. Tritium, iodine-129, and nitrate are associated with various sites in 200-BP-5, but have also entered the operable unit from 200-PO-1. Uranium is monitored for surveillance in conjunction with assessment monitoring at Waste Management Area (WMA) B-BX-BY (PNNL-13022), and will receive additional monitoring under the CERCLA program at 200-BP-5 to ensure that adequate data is available to track its movement. This sampling and analysis plan defines the monitoring activities conducted in support of CERCLA and also indicates supplemental data available from monitoring associated with RCRA TSD facilities located within the operable unit.

Table 1.1. List of all Contaminants of Potential Concern (COPCs) for Each Media Type

Media	Known or Suspected Source of Contamination	Type of Contamination (General)	COPCs (Specific)
200-BP-5 Operable Unit			
Groundwater	BY cribs; WMA B-BX-BY	Radionuclide Radionuclide Anion Radionuclide/toxic metal Anion	Tc-99 Co-60 Cyanide Uranium Nitrate
	B-5 reverse well; B Plant	Radionuclide Radionuclide Radionuclide	Cs-137 Sr-90 Pu-239/240
	Gable Mountain Pond	Radionuclide	Sr-90 Nitrate
	Various sites associated with discharges or waste from B Plant operations; facilities associated with the PUREX Plant in the 200-PO-1 OU	Radionuclide Radionuclide Radionuclide Anion	Tritium I-129 Uranium Nitrate

It was decided that no COPCs would be eliminated from the final list of COCs. It is recognized that certain nonradioactive constituents are currently monitored at RCRA TSD facilities, but inclusion of these contaminants in the final list of COCs will ensure that they are not overlooked. Sampling of these constituents will be evaluated annually and the sampling and analysis plan prepared for the operable unit will define the monitoring activities conducted in support of CERCLA and will indicate supplemental data available from monitoring associated with RCRA facilities located within the operable unit.

Table 1.2 identifies the best understanding of how each of the COCs arrived at the site and the fate and transport mechanisms (e.g., groundwater) that may have impacted their distribution. Dense non-aqueous phase liquids (chlorinated solvents) are not present in the 200-BP-5 Operable Unit; thus no contaminant is identified as distributed in a heterogeneous manner. Several contaminants are largely dissolved in groundwater (e.g., nitrate and tritium) and are thus homogeneously distributed, while others are dissolved in groundwater and sorbed onto aquifer sediments (e.g., strontium-90) and are semi-homogeneously distributed.

Table 1.2. Distribution of Contaminants of Concern

Media	Contaminant	How COC Arrived at Site	Fate and Transport Mechanisms	Expected Subsurface Distribution (Heterogeneous/ Homogeneous)
200-BP-5 Operable Unit				
Groundwater	Technetium-99	Ferrocyanide waste liquids released to BY Cribs from U Plant process operations	Groundwater and soil moisture	Semi-homogeneous[a]
	Cobalt-60	Ferrocyanide waste liquids released to BY Cribs from U Plant process operations	Groundwater and soil moisture	Semi-homogeneous[b]
	Cyanide	Ferrocyanide waste liquids released to BY Cribs from U Plant process operations	Groundwater and soil moisture	Semi-homogeneous[a]
	Uranium	Injection of waste liquids into the B-5 reverse well; monitored in wells near the WMA B-BX-BY tank farms (source uncertain)	Groundwater and soil moisture	Semi-homogeneous[b]
	Nitrate	Various sites in the operable unit	Groundwater and soil moisture	Semi-homogeneous[a]
	Cesium-137	Injection of waste liquids into the B-5 reverse well	Groundwater and soil moisture	Semi-homogeneous[b]
	Strontium-90	Injection of waste liquids into the B-5 reverse well; Gable Mountain Pond	Groundwater and soil moisture	Semi-homogeneous[b]
	Iodine-129	Associated with various sites in the operable unit	Groundwater and soil moisture	Semi-homogeneous[a]
	Tritium	Associated with various sites in the operable unit	Groundwater and soil moisture	Semi-homogeneous[a]
	Plutonium-239/240	Injection of waste liquids into the B-5 reverse well.	Groundwater and soil moisture	Semi-homogeneous[b]

(a) Dissolved in groundwater.
(b) Dissolved in groundwater and sorbed on aquifer sediment.

1.3 Data Quality Objectives

The U.S. Environmental Protection Agency's (EPA) DQO procedure (EPA 1994) was used to develop this sampling and analysis plan. The DQO process is a strategic planning approach for defining the criteria that a data collection design should satisfy. Using the DQO process ensures that the type, quantity, and quality of environmental data used in decision-making will be appropriate for the intended application.

This section presents only a summary of the key outputs resulting from the DQO process. For additional details, refer to Data Quality Objectives Summary Report – Designing a Groundwater Monitoring Network for the 200-BP-5 and 200-PO-1 Operable Units (PNNL-14049).

1.3.1 Statement of the Problem

The shape and concentration of the COC plumes within the 200-BP-5 Operable Unit have changed over time as a result of natural groundwater flow, source term variability, and natural attenuation. Therefore, the network of wells used to monitor known COCs in groundwater and the associated sampling frequency and analytical methods need to be reassessed to determine if the requirements of the CERCLA and AEA monitoring programs are being met. The current design of the 200-BP-5 Operable Unit network is based primarily on expert judgment and to a limited extent on geostatistical modeling results. Groundwater flow direction is difficult to assess in the 200 East Area because of a low hydraulic gradient and, thus, an accurate definition of the water table elevation is needed. In addition, a number of wells are anticipated to go dry as water levels drop locally and their replacements, if possible, need to be planned.

1.3.2 Decision Rules

The decision rules for each decision statement identified in the DQO summary report (PNNL-14049) are summarized in Table 1.3. These "IF…THEN…" statements describe what action will be taken based on the results of the data collected. The inputs used to develop the decision rules and the defined final action levels are presented in Table 1.4.

1.3.3 Error Tolerance and Decision Consequences

Because a new groundwater monitoring well costs approximately $200,000 to drill and install at the Hanford Site, traditional statistical sampling designs are not feasible for groundwater investigations since a large number of new sampling locations cannot readily be added. Furthermore, traditional statistics do not apply to the spatial aspects of designing a groundwater monitoring network. Thus, tables defining the null hypothesis, alpha and beta error, and width of the gray region were excluded from the DQO process (PNNL-14049). It was concluded that nonstatistical (expert judgment) methods will be used primarily as the basis for sampling design; however, geostatistical modeling will be employed where appropriate. Geostatistical modeling potentially could be used to reduce the number of wells sampled, for example, if a major change in the monitor network design results from the application of expert judgment.

Table 1.3. Decision Rules

DS #	DR #	Decision Rule
200-BP-5 Operable Unit		
1	1	IF the results from the evaluation of the current monitoring networks indicate that they adequately define the extent of the COC groundwater plumes THEN no action is required; otherwise, select new monitoring well networks from existing wells based on expert judgment and/or drill and install new monitoring wells to supplement the existing or new monitoring well networks.
2	2	IF the results from the evaluation of the current monitoring networks indicate that they define water table elevations and groundwater flow direction THEN no action is required; otherwise, select a new monitoring well network from existing wells and/or drill and install new monitoring wells to supplement the existing or new monitoring well network, and/or apply another method to define groundwater flow direction.
3	3	IF the current frequencies permit tracking of plume movement, THEN no action is required; otherwise, select a new frequency that will permit tracking of plume.

Table 1.4. Inputs Needed to Develop Decision Rules and Final Action Levels

DS #	Parameters of Interest	Units of Measurement	Scale of Decision Making	Final Action Level (MCL)	Alternative Actions
1	Tc-99	pCi/L	Concentration of COC in groundwater within the perimeter of the 200-BP-5 compliance boundary over the next year.	900 pCi/L	1) No action. 2) Select a new monitoring well network from existing wells to better define plume extent. 3) Drill and install new monitoring wells to supplement existing or new monitoring well network.
	Co-60	pCi/L		100 pCi/L	
	Cs-137	pCi/L		200 pCi/L	
	Cyanide	µg/L		200 µg/L	
	Sr-90	pCi/L		8 pCi/L	
	Pu 239/240	pCi/L		1.2 pCi/L	
	Uranium	µg/L		30 µg/L	
	Tritium	pCi/L		20,000 pCi/L	
	I-129	pCi/L		1 pCi/L	
	Nitrate	µg/L		45,000 µg/L as NO_3	
2	Water level	m or ft	Groundwater level within the perimeter of the 200-BP-5 compliance boundary over the next year.	No prescribed action level	1) No action. 2) Select a new monitoring well network from existing wells to better define water table elevations. 3) Drill and install new monitoring wells to supplement existing or new monitoring well network. 4) Use other methods to define flow directions.
3	Sampling frequency	Samples/year	Number of groundwater samples for wells within the perimeter of the 200-BP-5 compliance boundary over the next year.	No prescribed action level	1) No action (maintain current sampling frequencies) 2) Revise sample frequencies in some or all wells to better define plume movement.

1.4 Summary of the Network Design Approach

The DQO summary report (PNNL-14049) indicated a non-statistical design approach will be implemented during development of the 200-BP-5 Operable Unit monitoring network for the reasons discussed above. However, geostatistical modeling can also be employed if appropriate. Geostatistical methods have been used previously, for example, to reduce the number of wells resulting from a non-statistical (expert judgment) approach, resulting in significant cost savings.

Per the conclusions presented in the DQO summary report, a well list has been developed for the 200-BP-5 Operable Unit based on hydrogeologic expertise and by considering the goals of the CERCLA, RCRA, and AEA site-wide surveillance monitoring activities. The method used in the sampling design process primarily involved review of current and past COC contaminant plume maps, trend plots of COC concentration versus time for individual wells, and water-table maps. Wells that are not currently being sampled but could be used have also been identified in this sampling and analysis plan. A summary of the approach used to develop the monitoring network as is described below. The specific wells selected for the network, the contaminants to be analyzed for samples from each well, and the sampling frequency are presented in Section 3.

Development of the monitoring well networks defining COC distributions involved a review of the annual or latest quarter plume map for each COC. These plume maps identified the locations of the monitoring wells used and the COC value associated with each well. COC maps from previous years (e.g., 5 and 10 years ago) and trend plots also were examined to define recent plume movement and develop a conceptual model of potential movement over the next several years. The primary objective of this activity was to define the location of the contour associated with the action level of each COC (i.e., the maximum contaminant level (MCL) contour plus selected contours within this boundary) and determine if this location was adequately known from the current well network design. The basic approach involved selection of wells around the periphery of the plume that were above and below the MCL for each contaminant of concern. In general a well spacing was also selected that corresponds roughly to the width of each COC plume, which should ensure that no plume slips unnoticed between two adjacent monitoring wells. This approach is based primarily on expert judgment, however a geostatistical evaluation of technetium-99 distribution in a critical area north of the 200 East Area was performed to test the approach (Section 2.2).

If the previous network was determined to not be adequate, the network was redesigned using existing wells and/or new wells were added (see Section 2.3). Consideration of well quality was included, because some wells will go dry in the near future and should, if possible, be replaced with existing or new wells. Decisions were also made regarding the appropriate sampling frequency for each monitoring well and associated COCs.

Groundwater elevation maps of the 200 East Area were examined and an assessment made of the adequacy of the current water-table elevation monitoring networks and the methods used to acquire, resolve, and interpret data (Section 2.4). A primary objective of this activity was to determine if the current networks in the 200-BP-5 Operable Unit will be adequate to construct water table elevation maps over the next several years that are of sufficient accuracy to define water-table elevations and flow directions. Another objective was to evaluate, reduce, and/or correct to the extent possible all potential sources of uncertainty associated with water-level measurements. If needed, the network was redesigned using existing wells, and/or new wells recommended to be added. Consideration of well quality was undertaken, since some wells will go dry in the near future and should, if possible, be replaced with existing or new wells. Alternative approaches were suggested to measure water levels and flow direction

if it was determined that the above approaches cannot be utilized to design acceptable water-table elevation monitoring networks.

Several potential needs were recognized during the DQO process regarding new wells that should be considered. It was suggested, for example, that a sufficient number of wells may not be present in the area north of the Gable Mountain Gap to the Columbia River to adequately define the northern extent of contamination in the 200-BP-5 Operable Unit. These potential new well needs have been considered during the development of this sampling and analysis plan (Section 2.3).

The sampling and analysis plan for the 200-BP-5 Operable Unit will be updated in the future, if needed, on an annual basis after reviewing the current adequacy of the monitoring well network design based on the past year's data

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2.0 Revised Monitoring Network

A large number of groundwater wells are currently being sampled in the 200 East Area and the 600 Area north of 200 East in support of several monitoring objectives, including surveillance to meet the requirements of the *Atomic Energy Act* (AEA), monitoring networks associated with various RCRA units, and wells associated with several CERCLA sites. All wells currently being sampled in support of these objectives are identified in the Integrated Monitoring Plan (PNNL-14111), which also indicates the constituents being analyzed and the sampling schedule for each well. Sampling activities conducted at many of these wells help meet several objectives. Thus the monitoring requirements associated with the 200-BP-5 Operable Unit can be accommodated to a certain degree by co-sampling wells that are currently being sampled in support of surveillance or RCRA in addition to those wells associated with the CERCLA sites. A set of these wells is designated below for co-sampling in support of CERCLA monitoring at the 200-BP-5 Operable Unit. The primary objective of establishing a CERCLA network is to ensure that sufficient monitoring data is collected that will adequately define contaminant distribution. The data quality objectives and general approach to designing the revised CERCLA network is presented in Section 1 and PNNL-14049, and specific criteria are discussed below and the revised monitoring network design presented (Section 2.2). Wells that are not co-sampled in support of CERCLA will generally continue to be sampled to support other objectives, but will generate information that will be designated as supplemental data. New wells may also be proposed for the 200-BP-5 Operable Unit monitoring network in this and future sampling and analysis plans as older wells are decommissioned or new locations are identified.

2.1 Previous Monitoring Network

The specific monitoring wells and constituent/schedule information for the 200-BP-5 Operable Unit has been previously identified in a Federal Facility Agreement and Consent Order Change Control Form (Change Number M-15-96-04; April 29, 1996). As indicated in that form, limited groundwater monitoring should be performed to detect contamination and to define the geometry and direction of contaminant plume migration associated with CERCLA monitoring at 200-BP-5. Monitoring information needs specified by M-15-96-04 are reproduced in Table 2.1 and the locations of the 30 monitoring wells identified in that document are presented in Figure 2.1. This previous monitoring network focused on sources in the northwest portion of the 200 East Area because they are responsible for the most widespread groundwater contaminant plumes in the operable unit.

The monitoring network for 200-BP-5 needs to be reviewed and, if necessary, revised periodically owing to changes in plume geometry and the current status of well networks in the 200 East Area. This is particularly true for the northwestern part of 200 East and adjacent 600 Area, where a low hydraulic gradient exists and groundwater flow direction is somewhat uncertain and appears to be changing (PNNL-13404). In addition, many wells cannot be sampled because groundwater levels have declined below the well screen (i.e., gone dry) owing to decreased effluent releases in the 200 East Area. Additional wells are expected to become unsuitable for sampling purposes in the near future as groundwater levels continue to drop. Alternative wells will be used, if available, or new wells may be proposed, when possible, to address this problem and to increase monitoring coverage where required.

Table 2.1. Sampling and Analysis Schedule for the Previous 200-BP-5 Monitoring Network

Site	Well Name	Contaminants	Sample Frequency
216-B-5 Reverse Well	299-E28-2 299-E28-7 299-E28-23 299-E28-25	Sr-90 Cs-137 Pu-239/240	Annual
	299-E28-10	Sr-90	Annual
216-BY Cribs	299-E33-7	Tc-99 Cyanide	Annual
	299-E33-12 299-E33-13 299-E33-26 299-E33-38	Tc-99	Annual
	699-49-55A	Tc-99 Cyanide	Annual
	699-49-57A	Tc-99	Annual
	699-49-57B	Co-60	Annual
	699-50-53A	Co-60 Tc-99 Cyanide Nitrate	Annual
	699-52-54	Co-60 Tc-99 Cyanide Nitrate	Annual
	699-52-57	Tc-99 Nitrate	Annual
	699-53-55A 699-53-55B 699-53-55C	Tc-99	Annual
	699-55-57	Co-60 Tc-99 Cyanide Nitrate	Annual
	699-59-58	Tc-99	Annual
Gable Mountain Pond	699-53-47A 699-53-47B	Sr-90 Nitrate	Annual
	699-53-48A	Sr-90 Nitrate	Annual
	699-53-48B	Sr-90	Annual
	699-54-45A 699-54-45B	Nitrate	Annual
	699-54-48 699-54-49	Sr-90	Annual
	699-55-50C	Sr-90	Annual

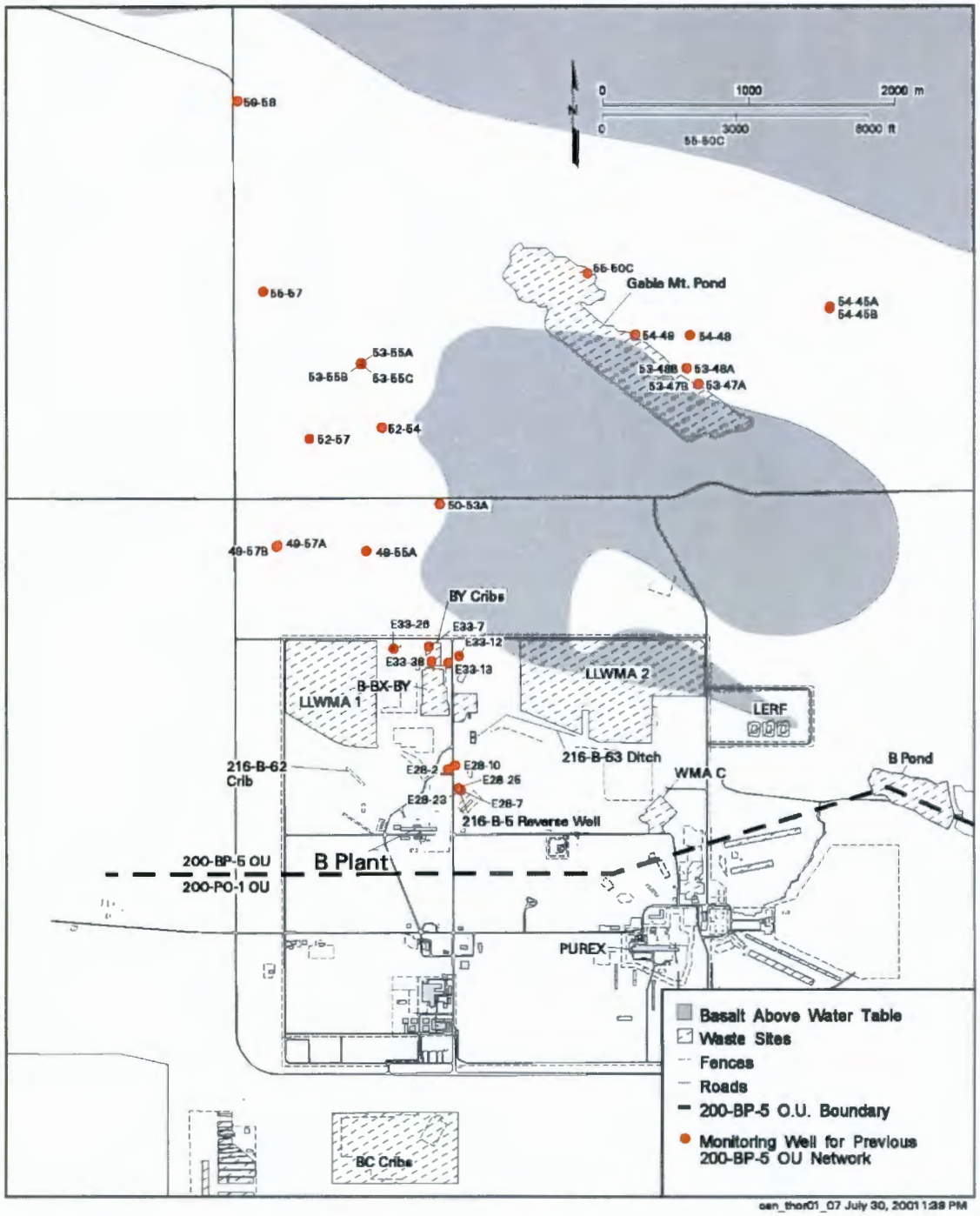

Figure 2.1. Previous 200-BP-5 Groundwater Monitoring Network

2.2 Revised Monitoring Network

A review of available wells has been undertaken in order to define a revised CERCLA monitoring network for the 200-BP-5 Operable Unit. The boundaries of the 200-BP-5 Operable Unit were extended to the northeastern portion of the 200 East Area and also to the north through Gable Mountain Gap to the Columbia River (Figure 1.2). This review included the definition of requirements identified in the DQO process (PNNL-14049) and development of a network based on a review of hydrogeological information. Geostatistical modeling was also undertaken to support the development of a monitoring network to better define the distribution of technetium-99 in the 200-BP-5 Operable Unit in the area between the northwestern part of 200 East up to the Gable Mountain Gap (Appendix A).

Ten contaminants of concern were identified during the DQO process, as indicated in Section 1.2. Hydrogeological information considered in developing a revised network to monitor these COCs included preparation of a set of maps showing the present distribution of these contaminants (Appendix C). A general consideration of groundwater flow directions was also included based on a groundwater level measurements obtained in March 2001 (see water table map in Appendix C).

Development of the revised network to monitor COCs was based primarily on expert judgment (i.e., hydrogeological considerations). This approach involved development of the set of figures and plates provided in Appendix C, where the geometry of the contaminant plumes are presented. The criteria for selection of wells to monitor in support of CERCLA involved identifying wells that served to delineate the location of the MCL concentration (action level) contour line associated with each COC. This required identifying at least one well on each side of the contour line for each side of each contaminant plume. A well spacing was also selected that corresponds roughly to the width of each COC plume, which should ensure that no plume slips unnoticed between two adjacent monitoring wells. In general there are a sufficient number of wells in the 200-BP-5 Operable Unit to satisfy these criteria, as can be seen by examining the plume maps in Appendix C. In addition, a set of AEA guard wells are included in the network design to determine if specific contaminants are moving through the Gable Mountain Gap. Examination of the maps presented in Appendix C indicates that the only COC currently above the action level in the area north of the gap is tritium.

The geostatistical model developed by PNNL was used to further support development of the revised monitoring network for Tc-99 in the area north of 200 East and south of the gap between Gable Mountain and Gable Butte (Appendix A). Technetium-99 was selected as the COC for geostatistical analysis because it is the COC of greatest concern at 200-BP-5. This model uses variogram analysis in combination with stochastic simulation to reduce the number of groundwater wells to be monitored without significantly decreasing the quality of the information provided. An initial list of 59 wells was prepared based on technetium-99 sampling activities conducted during the last 3 years. It was determined that this list could be reduced to 34 wells through sequential elimination of the least valuable wells and still be acceptable based on the variogram analysis. This final geostatistical list was found to agree fairly well with the list of recommended wells selected on the basis of hydrogeological considerations. A combined list of 35 wells was selected for monitoring of technetium-99 in the area selected for study.

The complete set of wells and associated analytes and sampling schedule associated with the modified network are presented in Table 2.2. This revised network consists of 72 wells, which includes wells also co-sampled to meet AEA and RCRA objectives. This list includes the wells identified for technetium-99 monitoring south of the gap plus several wells located in the area north of the gap to the Columbia River and several wells at WMA C. Additional wells are also presented in Table 2.2 that are needed for monitoring of the other COC plumes. The locations of these wells are presented in Figures 2.2

and 2.3. The plates and figures presented in Appendix C show the locations of the monitoring wells chosen for each COC relative to the extent of contamination defined by FY 2001 groundwater monitoring activities.

The level of variability in technetium-99 and other contaminant concentrations in the 200-BP-5 Operable Unit indicates that annual sampling is adequate to define regional trends. Wells should be sampled in the same quarter, if possible, to minimize variability. In some cases, wells are scheduled for sampling on a 3-year basis if a long history is available indicating little variability in contaminant concentrations.

The overall change in the revised monitoring network relative to the previous network can be seen by comparing Figure 2.1 with Figures 2.2 and 2.3. In particular, note that the monitoring network for 200-BP-5 has been extended north of the Gable Mountain Gap to the Columbia River to focus on contaminant movement in that area and also to the northeastern portion of the 200 East Area. Specific information and justification for changing wells designated for monitoring of the 200-BP-5 Operable Unit are discussed below.

Several changes in the monitoring network for the 216-B-5 Reverse Well have been identified, as reflected in Table 2.2 and the plates in Appendix C. Well 299-E28-7 has been removed from the monitoring network and replaced by 299-E28-24. This change has occurred because 299-E28-7 has been used as an injection well for the disposal of groundwater from a pump and treat system and may not produce samples representative of aquifer conditions. Well 299-E28-10 has also gone dry and hence has been eliminated from the 216-B-5 Reverse Well monitoring network. Wells 299-E28-5, 299-E28-6, 299-E28-27, and 299-E28-8 have been added to better define the limit of contamination in this area associated with the reverse well. Well 299-E28-17 has also been added to monitor the reverse well and to monitor B Plant. All of these wells will be monitored on an annual basis, as indicated in Table 2.2.

A number of changes have also been made in the 216-BY Cribs monitoring network. Wells 699-52-54 and 699-52-57 have gone dry and hence have been removed from the network. A number of wells have been added to the 216-BY Cribs monitoring network, primarily to define the extent of the technetium-99 groundwater plume and to replace the dry wells. Wells added in the 200 East Area include 299-E28-26, 299-E32-10, 299-E33-34, 299-E33-16, 299-32-9, 299-E33-35, 299-E33-41, 299-E33-338, 299-E32-4, 299-E33-39, 299-E32-6, 299-E33-15, 299-E33-28, 299-E33-30, 299-E33-18, 299-E33-42, and 299-E33-44. Wells added in the 600 Area north of the 200 East Area include 699-55-60A, six guard wells (699-57-59, 699-59-58, 699-60-60, 699-61-62, 699-61-66, and 699-64-62), and a set of wells north of the Gable Mountain Gap (699-65-50, 699-72-73, 699-66-58, 699-66-64, 699-70-68, 699-65-72, and 699-73-61). Wells 299-E33-12 and 699-49-57B are basalt-confined aquifer wells that will also be sampled to assess the extent of contamination passing from the unconfined to the upper basalt-confined aquifer. The frequency of sampling wells in the 216-BY Cribs network for the contaminants of concern is indicated in Table 2.2.

Wells 299-E28-18 and 299-E28-21, which are associated with the 216-B-62 Crib, have been added as monitoring wells. These wells will be sampled on an annual basis in 200-BP-5 to monitor total uranium in the vicinity of this facility.

Several wells have been identified for monitoring in the vicinity of WMA C (Table 2.2). Wells 299-E27-14, 299-E27-15, and 299-E27-7 will be sampled on an annual basis. Contaminants of concern are technetium-99 and nitrate.

Wells 699-43-40 and 699-45-42 near the 216-B-3 Pond will be sampled on a 3-year basis for tritium and iodine-129.

Table 2.2. Sampling and Analysis Schedule for the Revised 200 BP-5 Monitoring Network

Site	Well Name	Contaminants	Sample Frequency
216-B-5 Reverse Well and B Plant	299-E28-23 299-E28-24 299-E28-25 299-E28-5 288-E28-6	Sr-90 Cs-137 Pu-239/240 Uranium	Annual
	299-E28-2	Tc-99 Tritium I-129 Sr-90 Cs-137 Pu-239/240	Annual
	299-E28-17	Sr-90 Cs-137 Pu-239/240 Nitrate Uranium	Annual
	299-E28-27	Sr-90 Cs-137 Pu-239/240 Tc-99 Nitrate I-129 Uranium	Annual
	299-E28-8	Sr-90 Cs-137 Pu-239/240 Tc-99 Uranium	Annual
216-BY Cribs and WMA B-BX-BY	299-E28-26 299-E33-46	Tc-99 Nitrate Uranium	Annual
	299-E33-7 299-E33-38	Tc-99 Nitrate I-129 Cyanide Co-60 Uranium	Annual
	299-E33-26 299-E32-10	Tc-99 Cyanide Co-60 Uranium	Annual

Table 2.2 (contd). Sampling and Analysis Schedule for the Revised 200 BP-5 Monitoring Network

Site	Well Name	Contaminants	Sample Frequency
216-BY Cribs and WMA B-BX-BY (contd)	299-E33-13	Tc-99 Cyanide Uranium	Annual
	299-E33-34	Tc-99 Tritium Nitrate I-129 Cyanide Co-60 Uranium	Annual
	299-E33-16	Tc-99 Nitrate I-129 Uranium	Annual
	299-E32-9	Tc-99 Nitrate I-129	Annual
	299-E33-35	Tc-99 Nitrate Cyanide Uranium	Annual
	299-E33-12 (basalt confined)	Tc-99	3-Year
	299-E33-41 299-E33-338	Tc-99 Uranium	Annual
	299-E32-4 299-E33-39	Tc-99 Tritium Nitrate I-129	Annual
	299-E32-6 299-E33-15 299-E33-28 299-E33-30	Tc-99 Nitrate	Annual
	299-E33-18 299-E33-42 299-E33-43	Tc-99 I-129 Uranium	Annual
	299-E33-44	Tc-99 Co-60 Uranium	Annual

Table 2.2 (contd). Sampling and Analysis Schedule for the Revised 200 BP-5 Monitoring Network

Site	Well Name	Contaminants	Sample Frequency
216-BY Cribs and WMA B-BX-BY (contd)	699-49-55A 699-53-55C 699-55-60A	Tc-99 Tritium Nitrate I-129 Cyanide Co-60	Annual
	699-49-57A	Tc-99 Tritium Nitrate I-129 Cyanide Co-60 Uranium	Annual
	699-49-57B (basalt confined)	Tc-99 Co-60	3-Year
	699-50-53A 699-55-57	Tc-99 Nitrate I-129 Cyanide Co-60	Annual
	699-53-55A 699-53-55B 699-65-50	Tc-99	3-Year
	699-47-60 699-57-59 (guard well) 699-59-58 (guard well)	Tc-99 Tritium Nitrate I-129	Annual
	699-60-60 (guard well) 699-61-66 (guard well)	Tc-99 Tritium Nitrate I-129	3-Year
	699-64-62 (guard well) 699-72-73	Tc-99 Tritium Nitrate	3-Year
	699-61-62 (guard well)	Tc-99 Tritium Nitrate I-129 Sr-90	3-Year
	699-66-58 699-66-64 699-70-68	Tritium Tc-99	3-Year
	699-65-72 699-73-61	Tritium	3-Year

Table 2.2 (contd). Sampling and Analysis Schedule for the Revised 200-BP-5 Monitoring Network

Site	Well Name	Contaminants	Sample Frequency
216-B-62 CRIB	299-E28-18	Uranium I-129	Annual
	299-E28-21	Uranium	Annual
WMA C	299-E27-14 299-E27-15 299-E27-7	Tc-99 Nitrate	Annual
216-B-3 Pond	699-43-40 699-45-42	Tritium I-129	3-Year
Gable Mountain Pond	699-53-47A	Sr-90 Nitrate	Annual
	699-53-47B	Sr-90 Nitrate	3-Year
	699-53-48A	Sr-90 Nitrate	3-Year
	699-53-48B	Sr-90	3-Year
	699-54-45A 699-54-45B	Nitrate	3-Year
	699-54-48	Sr-90	3-Year
	699-54-49	Sr-90 Nitrate	3-Year
	699-55-50C	Tc-99 Tritium Nitrate I-129 Sr-90	Annual
Note: All completions are in the top of the unconfined aquifer, except for those indicated as being basalt confined.			

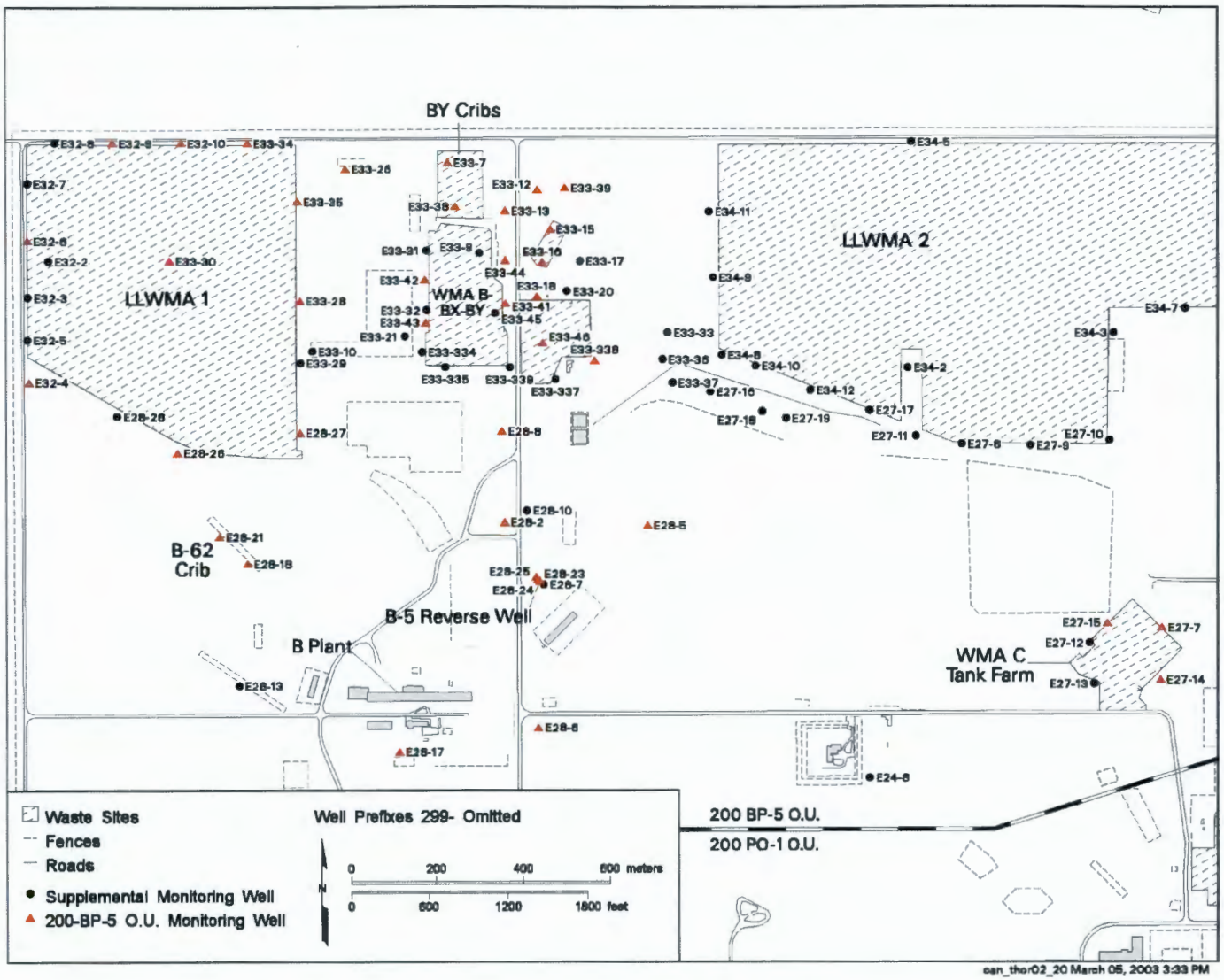

Figure 2.2. Revised 200-BP-5 Groundwater Monitoring Network (200 East Area)

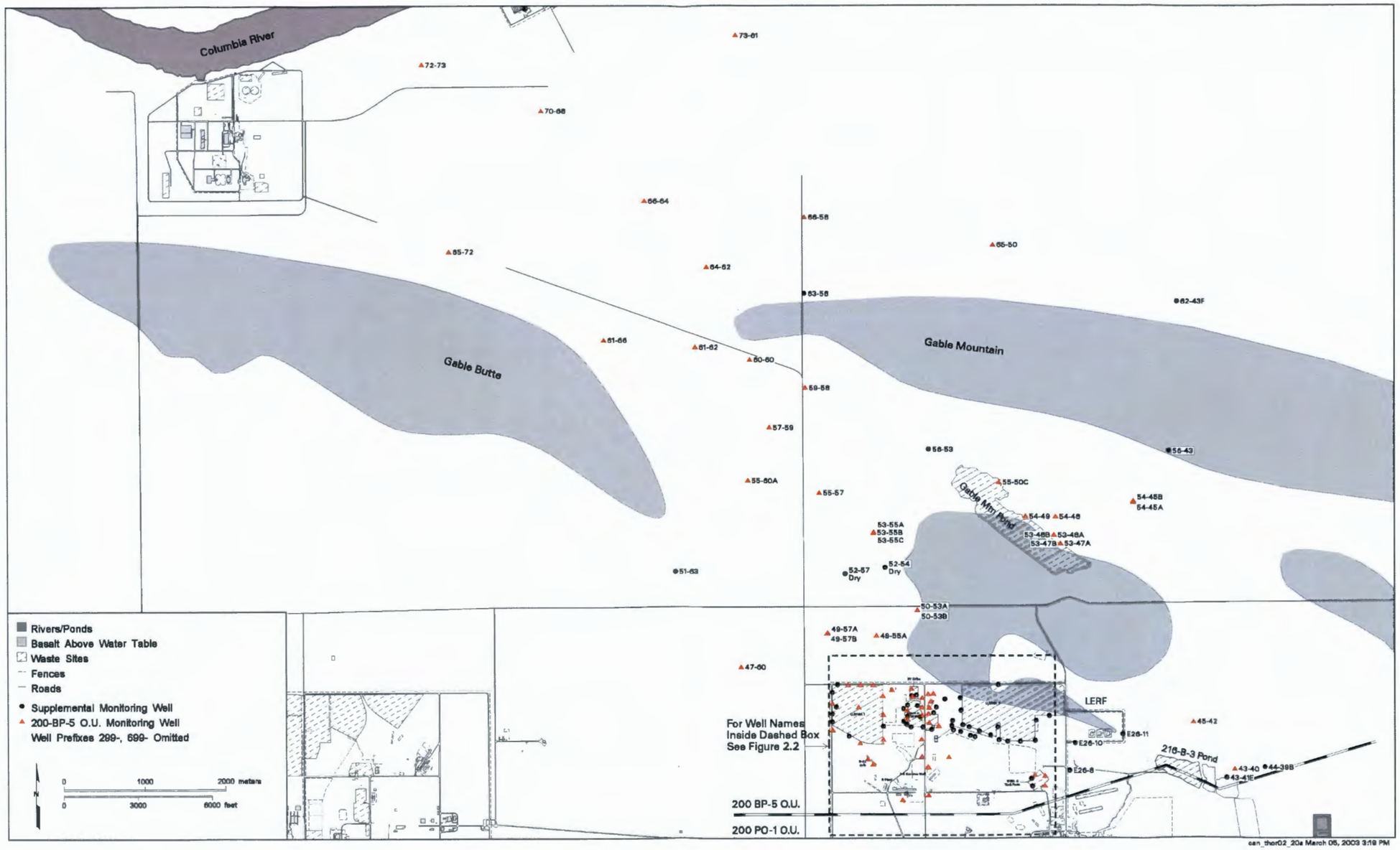

Figure 2.3. Revised 200-BP-5 Groundwater Monitoring Network (600 Area)

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The wells to be monitored in the vicinity of the Gable Mountain Pond for the 200-BP-5 Operable Unit are indicated in Table 2.2. The COCs associated with Gable Mountain Pond are Sr-90 and nitrate. The wells selected for the monitoring network are the same as previously defined, but analytes and frequencies have changed somewhat. Specifically, the sampling frequency for wells 699-53-47B, 699-53-48A, 699-53-48B, 699-54-45A, 699-54-45B, and 699-54-49 will be sampled on a 3-year basis rather than annually. However, wells 699-53-47A and 699-55-50C will continue to be sampled annually. In addition, well 699-55-50C will be analyzed for COCs of regional extent (technetium-99, tritium, nitrate, and iodine-129) in order to define the easterly boundary of the plumes extending north of the 200 East Area to the Gable Mountain Gap. Sampling of the wells at Gable Mountain Pond is becoming difficult, and may not be possible for some wells, owing to the decline in water levels.

It should be noted that the revised monitoring network constitutes the minimal requirements for definition of groundwater contaminant plumes in the unconfined aquifer associated with the 200-BP-5 Operable Unit and for monitoring of basalt-confined aquifers. Many additional wells and constituents in the area are sampled in support of AEA and RCRA groundwater monitoring objectives (PNNL-14111, or the most recent version). These wells are listed in Appendix B. Data from these wells will be available as supplemental information to that obtained from the CERCLA monitoring network as defined in this plan.

2.3 Proposed Wells

Several areas within the 200-BP-5 Operable Unit were identified where additional monitoring wells may be needed.

The first area of concern was the region north of Gable Mountain Gap (Figure 1.2). It is known that tritium contamination has passed from the 200-BP-5 Operable Unit through the gap and is presently intersecting the Columbia River at or near the tritium MCL (20,000 pCi/L; see tritium map in Appendix C). In particular, concern was expressed that significant levels of Tc-99 may also be present in the area north of the gap. A map is presented (Appendix C) that shows recent monitoring data for technetium-99 in the area from 200 East to the Columbia River. The map indicates that adequate monitoring data is available to demonstrate that Tc-99 concentrations north of the gap are well below the MCL for technetium-99 (900 pCi/L). Thus, it is believed that additional wells are not needed for the area north of the gap.

Geostatistical modeling results suggested, however, that new wells south of the gap would be useful in better defining the 900 pCi/L contour for technetium-99. Several potential well locations were indicated (Appendix A). Several locations have been eliminated based on hydrogeological considerations (e.g., groundwater flow directions) and others appear to be infeasible owing to limited aquifer thickness at the proposed locations. However, it is concluded that a new well on the western margin of the Tc-99 plume is especially important in better defining plume extent and geometry (i.e., proposed well locations number 2 and 6 of the geostatistical analysis; shown on Figure 16 in Appendix A). This area is also important from a hydrogeological standpoint in that a new well may provide information regarding groundwater flow (based on the gradient of the water table) and will help in better defining the elevation of the top of basalt.

A primary consideration in determining the feasibility of this potential well location is a determination of unconfined aquifer thickness. A map of aquifer thickness is presented in Figure 2.4 that has been prepared using top of basalt data (PNNL-12261) and recent water table measurements in the area (Appendix C). A new well location has been identified that is in the vicinity of the locations suggested by the geostatistical model. This location is near the crest of an anticlinal structure that results in aquifer

thinning (Figure 2.4). The location of the proposed well has been shifted slightly to the south in order to intersect sufficient unconfined aquifer thickness to support groundwater sampling activities. It is estimated that aquifer thickness at the proposed location should be about 4 meters (12 feet).

It is also proposed that well 699-52-57 be deepened, if possible. This well currently is dry (i.e., the bottom of the well screen is above the water table). A review of well construction and logging information suggests that this well was not drilled to the top of basalt. Deepening the well to the top of the basalt should permit lowering the depth of the screen, thereby allowing sampling activities to be performed. Geologic logging will be conducted during well deepening to clearly define the top of basalt at this location. It is suggested that this well may lie in an erosional window where the Elephant Mountain basalt member has been removed, thereby juxtaposing the unconfined aquifer in the Hanford formation and the upper basalt confined aquifer in the Rattlesnake Ridge interbed (Figure 2.4). Collection of geological information during well deepening should provide a better understanding of the extent of the basalt erosional window in this area.

With regard to installation of the new groundwater monitoring well and the deepening of well 699-52-57, these activities will be performed based on programmatic priorities and budget availability. New well needs for the Hanford Site are considered on an annual basis. The actual time of installation will be determined through a negotiated priority list between the Washington Department of Ecology, the U.S. Environmental Protection Agency, and the U.S. Department of Energy. New well installation and well development activities will be conducted in accordance with the requirements in the description of work prepared specifically for those wells.

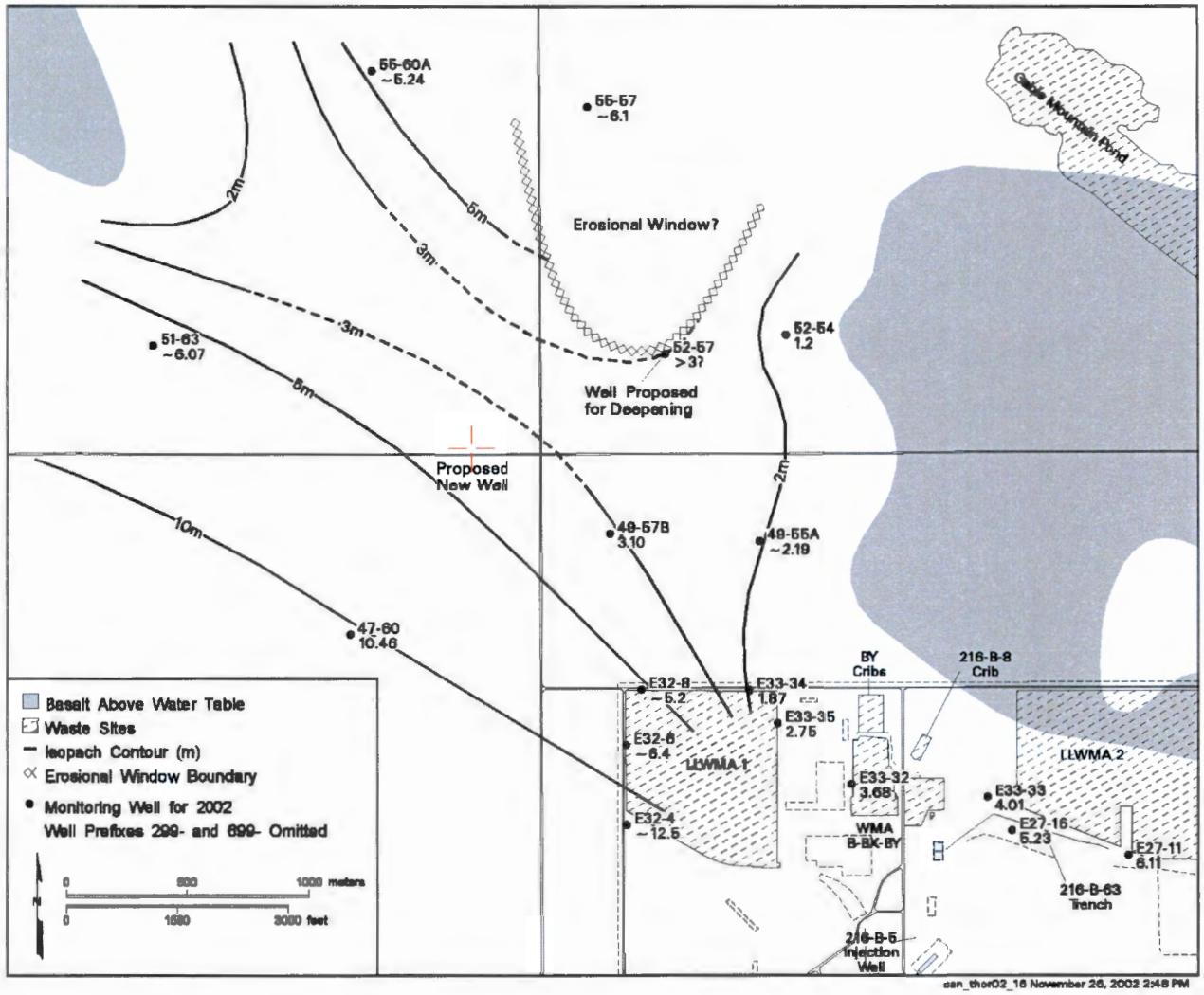

Figure 2.4. Aquifer Thickness Map

2.4 Groundwater Level Monitoring

Water levels in the groundwater system are monitored on the Hanford Site primarily to help determine the direction and rate of groundwater flow. This information is used to interpret observed contaminant plume movements and to predict future movement. Other uses of water level information include the identification of recharge and discharge areas, assessing the interaction between groundwater and surface water, assessing the interaction between aquifers, calibration of groundwater-flow models, assessing the impact of liquid effluent disposal practices on groundwater flow, and optimizing monitoring networks.

A list of wells used for water-level measurements, criteria for their selection, and hydrogeologic units monitored, and a description of the techniques used to collect the data are provided in PNNL-13021. Procedures for groundwater level measurements are presented in the subcontractor procedure manual (DFSNW-SSPW-001). Static water levels are measured in the monitoring well prior to sampling and a minimum of two consistent measurements are taken to confirm precision of the measurement. The wells identified in PNNL-13021 will be used for 200-BP-5 Operable Unit groundwater level monitoring activities.

It is difficult to assess current flow direction and velocity in the 200-BP-5 Operable Unit owing to the small hydraulic gradient present in the northwestern portion of the 200 East Area and the 600 Area to the north of 200 East. It is important to improve our ability to measure water levels accurately, however, in order to obtain information that may help us understand contaminant movement in the operable unit and to predict future changes in contaminant distribution. It is recommended that a set of water level measurements be obtained for wells in the 200-BP-5 Operable Unit at nearly the same time to minimize time effects. These measurements should be taken during a season when barometric pressure and/or storm effects are at a minimum (typically June through August).

It is also recommended that gyroscopic surveys be conducted in selected boreholes to correct water table elevation measurements for borehole deviation. This work is currently underway in the operable unit. In situ flow meter (colloidal borescope) measurements have also been conducted in FY 2000 to determine local groundwater flow directions (PNL-13788). Additional borescope measurements or tracer tests should be considered as another approach for improving our understanding of flow conditions in the 200-BP-5 Operable Unit.

3.0 Quality Assurance Project Plan

The groundwater monitoring project's quality assurance/quality control (QA/QC) program is designed to assess and enhance the reliability and validity of groundwater data[1]. The primary quantitative measures or parameters used to assess data quality are accuracy, precision, completeness, and the method detection limit. Qualitative measures include representativeness and comparability. Goals for data representativeness for groundwater monitoring projects are addressed qualitatively by the specification of well locations, well construction, sampling intervals, and sampling and analysis techniques. Comparability is the confidence with which one data set can be compared to another. The QC parameters are evaluated through laboratory checks (e.g., matrix spikes, laboratory blanks), replicate sampling and analysis, analysis of blind standards and blanks, and interlaboratory comparisons. Acceptance criteria have been established for each of these parameters, based on guidance from the U.S. Environmental Protection Agency (OSWER-9950.1), and are specified in the laboratory contract and analytical procedures. When a parameter is outside the criteria, corrective actions are taken to prevent a future occurrence and affected data are flagged in the database.

This section identifies individuals and organizations participating in the project and discusses specific roles and responsibilities. The quality objectives for measurement data and the special training requirements for the staff performing the work are also documented. Changes may occur in the QA/QC program. These changes will be documented in future revisions to the groundwater monitoring project's QA plan and this sampling and analysis plan.

3.1 Project Management

The following subsections address the basic areas of project management and will ensure that the project has a defined goal, that the participants understand the goal and the approach to be used, and that the planned outputs have been appropriately documented.

3.1.1 Project/Task Organization

PNNL will be responsible for collection, packaging, and shipment of groundwater samples to the laboratory. PNNL may subcontract this work to qualified subcontractors in accordance with the requirements of this sampling and analysis plan. The Hanford Groundwater Monitoring Project (HGMP) sampling task lead will provide oversight for all sampling and field analytical measurements. The HGMP will obtain radiological control, health and safety, waste management, and purgewater management support from the Hanford Site contractor responsible for all field activities. The HGMP will perform quality assurance assessments on sample collection and analysis activities.

3.1.2 Quality Objectives and Criteria for Measurement Data

The detection limits and precision and accuracy requirements for each of the analyses to be performed are presented in Table 3.1. The groundwater analytical method descriptions presented in Table 3.1 are summarized from the groundwater QA/QC plan[1] and PNNL-13080. In some cases,

[1] PNNL. 2000. The Hanford Ground-Water Monitoring Project Quality Assurance Project Plan. QA Plan ETD-012, Rev. 2. Pacific Northwest National Laboratory, Richland, Washington.

Table 3.1. Analytical Performance Requirements and Action Levels

Type of COC	COCs	Analytical Method	Action Level (MCL)	Contract Required Detection Limit	Precision (%RSD)[a]	Recommended Recovery (%)
Radionuclide	Tc-99	Chemical separation and liquid scintillation beta counting; laboratory specific procedure	900 pCi/L	15 pCi/L	±20%	70-130%
	Co-60	Gamma spectrometry; Method 901.1 (EPA-600/4-80-032) or equivalent	100 pCi/L	25 pCi/L	±20%	70-130%
	Cs-137	Gamma spectrometry; Method 901.1 (EPA-600/4-80-032) or equivalent	200 pCi/L	15 pCi/L	±20%	70-130%
	Sr-90	Gas proportional counting; method 905.0 (EPA-600/4-80-032) or equivalent	8 pCi/L	2 pCi/L	±20%	70-130%
	Pu 239/240	Chemical separation/alpha spectrometry; laboratory specific procedure	1.2 pCi/L	1 pCi/L	±20%	70-130%
	Uranium	Fluorometry or laser kinetic phosphorimetry; laboratory specific procedure	30 µg/L	0.1 µg/L	±20%	70-130%
	Tritium	Liquid scintillation; Method 906.0 (EPA-600/4-80-032) or equivalent	20,000 pCi/L	400 pCi/L	±20%	70-130%
	I-129	Chemical separation and low-energy photon scintillation; laboratory specific procedure	1 pCi/L	1 pCi/L	±20%	70-130%
Anion	Nitrate	EPA Method 300.0 (EPA-600/R-93-100)	45,000 µg/L as NO_3	250 µg/L as NO_3	±25%	75-125%
	Cyanide	Method 9010/9012 (SW-846)	200 µg/L	5 µg/L	±25%	75-125%

(a) Relative standard deviation is calculated from a set of replicate sample values as follows:

$$RSD = \frac{\text{standard deviation}}{\text{Mean}} \times 100.$$

commonly accepted EPA analytical methods are referenced since they are commonly used in most environmental laboratories (e.g., gamma spectrometry or anions). In other cases (e.g., radionuclide specific methods for analysis of technetium-99), standard methods are not available and laboratory specific procedures must be used. The laboratory specific procedures referred to in Table 3.1 (or equivalent) are those associated with the current statement of work between Flour Daniel Hanford Incorporated and Severn Trent Laboratories of Richland, Washington (Contract Number 615, Rev. 6, 1999). Methods other than those specified here may be acceptable. The contract required detection limit (CRDL) may change as contracts change and could in some cases be higher but still serve to support monitoring a contaminant at the indicated action levels.

3.1.3 Special Training Requirements/Certification

Training or certification requirements needed by sampling personnel shall be in accordance with the requirements of the Hanford Analytical Services Quality Assurance Requirements Documents (HASQARD), Vol. 1, Administrative Requirements (DOE-RL 1999).

Field personnel will typically have completed the following training before starting work:

- Occupational Safety and Health Administration 40-Hour Hazardous Waste Worker Training
- 8-hour hazardous waste worker refresher training (as required)
- Radiation Worker II Training
- Hanford General Employee Training.

3.1.4 Documentation and Records

Field sampling documentation will be consistent with HASQARD, Vol. 2, *Sampling Technical Requirements* (DOE-RL 1998), and shall be kept in accordance with DFSNW-SSPM-001, Sampling Services Procedures Manual, or equivalent, including the following procedures:

- Procedure 1-1, "Chain of Custody/Sample Analysis Request"
- Procedure 1-5, "Field Logbooks"

Laboratory analytical documentation will be consistent with *Statements of Work for Environmental and Waste Characterization Analytical Services* (RFS 1999) for groundwater sampling. Overall project documentation will be in accordance with the PNNL Standards-Based Management System.

3.2 Measurement/Data Acquisition

The following subsections present the requirements for sampling methods, sample handling and custody, analytical methods, and field and laboratory quality control. The requirements for instrument calibration and maintenance, supply inspections, and data management are also addressed.

3.2.1 Sampling Design

A summary of the sampling design is presented in Sections 1.4 and 2.0. Section 4.0 presents figures and tables that identify the sampling locations, total number of samples to be collected, sampling procedures to be implemented, analyses to be performed, and sample bottle requirements.

3.2.2 Sampling Methods Requirements

The procedures to be implemented in the field should be consistent with those outlined in DFSNW-SSPM-001, *Sampling Services Procedures Manual*, or equivalent, including the following:

- Procedure 1-1, "Chain of Custody/Sample Analysis Request"
- Procedure 1-2, "Project and Sample Identification for Sampling Services"
- Procedure 1-5, "Field Logbooks"
- Procedure 2-5, "Laboratory Cleaning of Sampling Equipment"
- Procedure 2-6, "Sample Packaging and Shipping"
- Procedure 3-1, "Groundwater Sampling"
- Procedure 3-4, "Purgewater Management"
- Procedure 6-1, "Control of Monitoring Instruments"
- Procedure 6-2, "Turbidity Measurements"
- Procedure 6-3, "pH Measurements"
- Procedure 6-5, "Field Analysis of Conductivity using the YSI Model 30 Conductivity/Salinity and Temperature Meter"
- Procedure 6-7, "Temperature."

3.2.3 Sample Identification

A sample and data tracking database will be used to track the samples from the point of collection through the laboratory analysis process. The Hanford Environmental Information System (HEIS) database is the repository for laboratory analytical results. The HEIS sample numbers will be issued to the sampling organization for this project.

3.2.4 Sample Handling, Shipping, and Custody Requirements

All sample handling, shipping, and custody requirements will be performed in accordance with DFSNW-SSPM-001, *Sampling Services Procedure Manual*, Procedure 2-6, "Sample Packaging and Shipping," and Procedure 1-1, "Chain of Custody/Sample Analysis Request" or equivalent. Sample transportation shall be in compliance with applicable regulations for packaging, marking, labeling, and shipping of hazardous materials, hazardous substances, and hazardous waste mandated by the U.S. Department of Transportation (49 *Code of Federal Regulations* 171-177) in association with the International Air Transportation Authority, DOE requirements, and applicable program-specific implementing procedures. Sample custody during laboratory analysis is addressed in the applicable laboratory standard operating procedures. Laboratory custody procedures will ensure that sample integrity and identification are maintained throughout the analytical process.

3.2.5 Analytical Methods Requirements

Analytical parameters and methods are listed in Table 3.1. Laboratory-specific standard operating procedures for analytical methods are in place.

3.2.6 Quality Control Requirements

Quality control procedures must be followed in the field and laboratory to ensure that reliable data are obtained. When performing this field sampling effort, care should be taken to prevent the cross-contamination of sampling equipment, sample bottles, and other equipment that could compromise sample integrity.

Table 3.2 lists the field quality control requirements for sampling. If only disposable equipment is used or equipment dedicated to a particular well, then an equipment rinsate blank is not required. If no volatile organic compound samples are collected, then a field transfer blank is not required.

Table 3.2. Field Quality Control Requirements

Sample Type	Frequency	Purpose
Duplicate	5% (1 sample in 20)	To check the precision of the laboratory analyses.
Equipment rinsate blank	One per 10 well trips	To check the effectiveness of the decontamination process.
Field transfer blank	One per day when volatile organic analytes are sampled	To check for contamination from sample site.
Field trip blank	5% (1 sample in 20)	To check for contamination from containers or during transportation.

Laboratory quality control requirements are specified in the laboratory *Statement of Work for Environmental and Waste Characterization Analytical Services* (RFSH-SOW-93-0003).

3.2.7 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

All onsite environmental instruments shall be tested, inspected, and maintained in accordance with DFSNW-SSPM-001, *Sampling Services Procedure Manual*, Procedure 6-1, "Control of Monitoring Instruments," or equivalent. The results from all testing, inspection, and maintenance activities shall be recorded in a bound logbook in accordance with procedures outlined in DFSNW-SSPM-001, *Sampling Services Procedure Manual*, Procedure 1-5, "Field Logbooks".

3.2.8 Instrument Calibration and Frequency

All onsite environmental instruments shall be calibrated in accordance with DFSNW-SSPM-001, *Sampling Services Procedure Manual*, Procedure 6-1, or equivalent. The results from all instrument calibration activities shall be recorded in a bound logbook in accordance with procedures outlined in DFSNW-SSPM-001, *Sampling Services Procedure Manual*, Procedure 1-5, or equivalent. Tags will be attached to all field screening and onsite analytical instruments, noting the date when the instrument was last calibrated and the calibration expiration date.

3.2.9 Inspection/Acceptance Requirements for Supplies and Consumables

All inspection and acceptance activities for supplies and consumables shall meet the requirements of HASQARD, Vol. 1, Administrative Requirements (DOE/RL-96-68).

The lot number from the manufacturer-certified, pre-cleaned sample containers shall be recorded in the sampler's logbook.

3.2.10 Data Management

The contract laboratories report analytical results electronically. The data resulting from the implementation of this SAP shall be loaded into the Hanford Environmental Information System (HEIS) database. Field-measured parameters are entered manually or through electronic transfer. Paper data reports and field records are considered to be the record copies and are stored at PNNL.

All reports and supporting analytical data packages will be subject to final technical review by qualified reviewers before submittal to regulatory agencies or inclusion in reports or technical memoranda. Electronic data access, when appropriate, shall be through computerized databases (i.e., HEIS). Where electronic data are not available, hard copies will be provided in accordance with Section 9.6 of the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement; Ecology et al. 1998).

3.2.11 Sample Preservation, Containers, and Holding Times

Sample preservation, container, and holding-time requirements will be prepared for specific sample events as specified on the sampling authorization forms and chain-of-custody forms in accordance with the requirements indicated in RFSH-SOW-93-0003 and the specific analytical method.

3.2.12 Field Documentation

Field documentation shall be kept in accordance with HASQARD, Vol.2, *Sampling and Technical Requirements* (DOE/RL-96-68), and DFSNW-SSPM-001, *Sampling Services Procedure Manual*, including the following procedures:

- Procedure 1-1, "Chain of Custody/Sample Analysis Request"
- Procedure 1-5, "Field Logbooks."

3.3 Assessment/Oversight

3.3.1 Assessments and Response Actions

The HGMP compliance and quality programs group may conduct assessments and response actions in accordance with Section 9.0 of the groundwater monitoring project's QA plan to verify compliance with the requirements outlined in this sampling and analysis plan, project work packages, the project quality management plan, procedures, and regulatory requirements.

Deficiencies identified by one of these assessments shall be reported to HGMP management. When appropriate, corrective actions will be taken by the project engineer in accordance with HASQARD, Vol. 1, Section 4.0 (DOE/RL-96-68), to minimize recurrence.

3.3.2 Reports to Management

Management shall be made aware of all deficiencies identified by self-assessments. Identified deficiencies shall be reported to the HGMP manager.

3.4 Data Verification and Reporting

3.4.1 Data Review, Validation, and Verification Requirements

The data undergo a validation/verification process according to a documented procedure, as discussed and referenced in the project QA plan[1], to confirm that sampling and chain-of-custody documentation is complete, sample numbers can be tied to the specific sampling location, samples were analyzed within the required holding times, and analyses met the data quality requirements specified in the SAP. Quality control data are evaluated against the criteria listed in the project QA plan and data flags are assigned when appropriate. In addition, data are screened by scientists familiar with the hydrogeology of the unit, compared to historical trends or spatial patterns, and flagged if they are not representative. Other checks on data may include comparison of general parameters to their specific counterparts (e.g., conductivity to ions; gross alpha to uranium), calculation of charge balances, and comparison of calculated versus measured conductivity. If necessary, the laboratory may be asked to check calculations or re-analyze the sample, or the well may be re-sampled.

3.4.2 Interpretation and Evaluation

After data are validated and verified, the acceptable data are used to interpret groundwater conditions at the site. Interpretive techniques may include

- Hydrographs - graph water levels versus time to determine decreases, increases, seasonal, or man-made fluctuations in groundwater levels.
- Water-table maps - use water-table elevations from multiple wells to construct contour maps to estimate flow directions. Groundwater flow is assumed to be perpendicular to lines of equal potential. Borescope data collected in the B-BX-BY assessment are also useful in defining groundwater flow directions in the 200-BP-5 Operable Unit in view of the low hydraulic gradients present locally (PNNL-13404 and PNNL-11826).
- Trend plots - graph concentrations of chemical or radiological constituents versus time to determine increases, decreases, and fluctuations. Trend plots may be used in tandem with hydrographs and/or water-table maps to determine if concentrations relate to changes in water-level or in groundwater flow directions.
- Plume maps - map distributions of chemical or radiological constituents areally in the aquifer to determine extent of contamination. Changes in contaminant distribution over time aid in determining movement of plumes and direction of flow.
- Contaminant ratios - can sometimes be used to distinguish between different sources of contamination.

Contaminant concentrations are also compared to drinking water standards, statistically-derived threshold values, or other concentration limits established in State or Federal regulations or agreements. In CERCLA programs, for example, concentrations may be compared to levels defined in records of decision, interim records of decision, or other agreements.

3.4.3 Reporting

Data and interpretations of monitoring results for the 200-BP-5 Operable Unit are reported annually along with the rest of the Groundwater Project (e.g., PNNL-13788). That report presents contaminant distribution maps, water level maps, and concentration trend plots of contaminants for wells of interest, and meets the annual reporting requirements of RCRA and DOE Orders. CERCLA activities, including

groundwater remediation and monitoring, are summarized. Data from the entire groundwater project are also available through the HEIS database.

3.4.4 Change Control

The approach to making changes in 200-BP-5 monitoring activities and associated documentation and approval requirements are defined in Table 3.3.

Table 3.3. Change Control Requirements

Type of Change	Action	Documentation
Adding constituents, wells, or increasing sampling frequency	Project management approval; notify DOE and regulatory staff if appropriate.	Enter information into sampling tracking system.
Deleting constituents of concern, wells, or reducing sampling frequency (elective change)	Need DOE and regulatory staff approval.	Enter information into sampling tracking system; place copy of letter or signed meeting minutes in project file.
Unavoidable changes (e.g., dry wells, delayed samples, one-time missed samples due to equipment failure, etc.)	Notify DOE and regulatory staff.	Enter information into sampling scheduling system; place copy of letter or meeting minutes in project file.
Revision to SAP.	Revise plan; obtain DOE and regulatory approval; distribute plan.	Place copy of SAP with signed concurrence page in project file; prepare revised Federal Facility Agreement and Consent Order Change Control Form.

4.0 Field Sampling Plan

Monitoring for the 200-BP-5 Operable Unit is part of the Hanford Groundwater Monitoring Project. Procedures for groundwater sampling, documentation, sample preservation, shipment, and chain-of-custody requirements are described in Pacific Northwest National Laboratory (PNNL) or subcontractor manuals (DFSNW-SSPM-001) and in the quality assurance plan[1]. Samples generally are collected after three casing volumes of water have been purged from the well or after field parameters (pH, temperature, specific conductance, and turbidity) have stabilized. For routine groundwater samples, preservatives are added to the collection bottles before their use in the field. Samples to be analyzed for metals are usually filtered in the field so that results represent dissolved metals. However, unfiltered samples are sometimes specified if total metal concentrations (i.e., dissolved and particulate) are needed.

Procedures for field measurements are specified in the subcontractor's or manufacturer's manuals. Analytical methods are specified in contracts with laboratories, and most are standard methods from Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods (SW-846). Alternative procedures meet the guidelines of SW-846, Chapter 10. Analytical methods are described in PNNL-13080 (2000).

4.1 Sampling Objectives

The objective of the field sampling plan is to clearly identify project sampling and analysis activities. The field sampling plan uses the sampling design identified in the DQO process and presents this design using primarily figures and tables whenever possible to identify sampling locations, the total number of samples to be collected, sampling procedures to be implemented, and the specific constituents of concern to be analyzed.

4.2 Sampling Locations and Frequency

The groundwater wells to be sampled in support of the 200-BP-5 OU are listed in Table 4.1 and shown on Plate 1, as identified in Section 2.2. Table 4.1 also lists the specific COCs for analysis for each well and sampling frequency, as determined in Section 2.2. The quality control sampling requirements for these samples are listed in Table 3.2. Samples are to be collected in accordance with the procedures listed in Section 4.3.

Information regarding samples to be collected will be input into the project's scheduling system. Sampling of the 200-BP-5 Operable Unit monitoring network will be coordinated with RCRA and AEA sampling activities to avoid duplication and minimize well trips.

Additional constituents are identified in PNNL-14111 that are needed for the AEA guard wells to support interpretation and regional monitoring needs.

Changes to the monitoring network due to monitoring wells taken out of service require approval from DOE and applicable regulatory agencies. This approval can be documented in meeting minutes. Change control requirements are presented in Table 3.3.

[1] PNNL. 2000. *The Hanford Ground-Water Monitoring Project Quality Assurance Project Plan.* QA Plan ETD-012, Rev. 2. Pacific Northwest National Laboratory, Richland, Washington.

Table 4.1. Sample Analytes and Frequency for 200-BP-5 Operable Unit Monitoring Wells

Well Name	Tc-99	Tritium	Nitrate	I-129	Cyanide	Co-60	Uranium	Sr-90	Cs-137	Pu-239/240	Sampling Frequency
299-E27-14	X		X								Annual
299-E27-15	X		X								Annual
299-E27-7	X		X								Annual
299-E28-17			X				X	X	X	X	Annual
299-E28-18				X			X				Annual
299-E28-2	X	X		X				X	X	X	Annual
299-E28-21							X				Annual
299-E28-23							X	X	X	X	Annual
299-E28-24							X	X	X	X	Annual
299-E28-25							X	X	X	X	Annual
299-E28-26	X		X				X				Annual
299-E28-27	X		X	X			X	X	X	X	Annual
299-E28-5							X	X	X	X	Annual
299-E28-6							X	X	X	X	Annual
299-E28-8	X						X	X	X	X	Annual
299-E32-10	X				X	X	X				Annual
299-E32-4	X	X	X	X							Annual
299-E32-6	X		X								Annual
299-E32-9	X		X	X							Annual
299-E33-12*	X										3-Year
299-E33-13	X				X		X				Annual
299-E33-15	X		X								Annual
299-E33-16	X		X	X			X				Annual
299-E33-18	X			X			X				Annual
299-E33-26	X				X	X	X				Annual
299-E33-28	X		X								Annual
299-E33-30	X		X								Annual
299-E33-338	X						X				Annual
299-E33-34	X	X	X	X	X	X	X				Annual
299-E33-35	X		X		X		X				Annual
299-E33-38	X		X	X	X	X	X				Annual
299-E33-39	X	X	X	X							Annual

Table 4.1 (contd). Sample Analytes and Frequency for 200-BP-5 Operable Unit Monitoring Wells

Well Name	Tc-99	Tritium	Nitrate	I-129	Cyanide	Co-60	Uranium	Sr-90	Cs-137	Pu-239/240	Sampling Frequency
299-E33-41	X						X				Annual
299-E33-42	X			X			X				Annual
299-E33-43	X			X			X				Annual
299-E33-44	X					X	X				Annual
299-E33-46	X		X				X				Annual
299-E33-7	X		X	X	X	X	X				Annual
699-43-40		X		X							3-Year
699-45-42		X		X							3-Year
699-47-60	X	X	X	X							Annual
699-49-55A	X	X	X	X	X	X					Annual
699-49-57A	X	X	X	X	X	X	X				Annual
699-49-57B*	X					X					3-Year
699-50-53A	X		X	X	X	X					Annual
699-53-47A			X					X			Annual
699-53-47B			X					X			3-Year
699-53-48A			X					X			3-Year
699-53-48B								X			3-Year
699-53-55A	X										3-Year
699-53-55B	X										3-Year
699-53-55C	X	X	X	X	X	X					Annual
699-54-45A			X								3-Year
699-54-45B			X								3-Year
699-54-48								X			3-Year
699-54-49			X					X			3-Year
699-55-50C	X	X	X	X				X			Annual
699-55-57	X		X	X	X	X					Annual
699-55-60A	X	X	X	X	X	X					Annual
699-57-59	X	X	X	X							Annual
699-59-58	X	X	X	X							Annual
699-60-60	X	X	X	X							3-Year
699-61-62	X	X	X	X				X			3-Year
699-61-66	X	X	X	X							3-Year

Table 4.1 (contd). Sample Analytes and Frequency for 200-BP-5 Operable Unit Monitoring Wells

Well Name	Tc-99	Tritium	Nitrate	I-129	Cyanide	Co-60	Uranium	Sr-90	Cs-137	Pu-239/240	Sampling Frequency
699-64-62	X	X	X								3-Year
699-65-50	X										3-Year
699-65-72		X									3-Year
699-66-58	X	X									3-Year
699-66-64	X	X									3-Year
699-70-68	X	X									3-Year
699-72-73	X	X	X								3-Year
699-73-61		X									3-Year
* Basalt confined.											

4.3 Sampling Procedures

The procedures to be implemented in the field should be consistent with those outlined in DFSNW-SSPM-001, *Sampling Services Procedure Manual*, or equivalent, including the following:

- Procedure 1-1, "Chain of Custody/Sample Analysis Request"
- Procedure 1-2, "Project and Sample Identification for Sampling Services"
- Procedure 1-5, "Field Logbooks"
- Procedure 2-5, "Laboratory Cleaning of Sampling Equipment"
- Procedure 2-6, "Sample Packaging and Shipping"
- Procedure 3-1, "Groundwater Sampling"
- Procedure 3-4, "Purgewater Management"
- Procedure 6-1, "Control of Monitoring Instruments"
- Procedure 6-2, "Turbidity Measurements"
- Procedure 6-3, "pH Measurements"
- Procedure 6-5, "Field Analysis of Conductivity using the YSI Model 30 Conductivity/Salinity and Temperature Meter"
- Procedure 6-7, "Temperature."

4.4 Sample Management

Sample and data management activities will be performed in accordance with the PNNL-QA Plan[1]. Specific procedures are referenced in the QA Plan.

Sample preservation, container, and holding-time requirements will be specified on sampling authorization forms and chain-of-custody forms in accordance with the requirements identified in RFSH-SOW-93-0003 and the specific analytical method prepared for specific sample events.

4.4.1 Sample Custody

4.4.1.1 Field Custody.

All samples obtained for the project will be controlled from the point of origin to the analytical laboratory, as required by HASQARD Vol. 2, *Sampling Technical Requirements* (DOE/RL-96-68), and DFSNW-SSPM-001, *Sampling Services Procedure Manual*, Procedure 1-1, "Chain of Custody/Sample Analysis Request," or equivalent.

4.4.1.2 Laboratory Custody Procedures.

Sample custody during laboratory analysis is controlled by an approved laboratory standard operating procedure associated with the current statement of work between Flour Daniel Hanford Incorporated and Severn Trent Laboratories of Richland, Washington (Contract Number 615, Rev. 6, 1999).

4.4.2 Sample Preservation, Containers, and Holding Times

Sample preservation and container details will be addressed on the sampling authorization form and chain of custody form in accordance with the requirements specified in RFSH-SOW-93-0003 and requirements of the analytical method.

4.4.3 Sample Packaging and Shipping

Sample packaging and shipping will be performed in accordance with DFSNW-SSPM-001, *Sampling Services Procedure Manual*, Procedure 2-6, "Sample Packaging and Shipping," or equivalent.

4.4.4 Field Documentation

Field documentation will be kept in accordance with HASQARD, Vol. 2, *Sampling and Technical Requirements* (DOE/RL-96-68), and DFSNW-SSPM-001, *Sampling Services Procedure Manual*, including the following or equivalent:

- Procedure 1-1, "Chain of Custody/Sample Analysis Request"
- Procedure 1-5, "Field Logbooks"

4.5 Management of Waste

Waste generated by sampling activities will be managed consistent with an established waste management plan and the requirements of DFSNW-SSPM-001, *Sampling Services Procedure Manual*, or equivalent. A waste control plan will be prepared for the 200-BP-5 Operable Unit prior to initiation of the groundwater sampling activities identified in this plan. Purgewater determinations and purgewater handling for the wells covered in this plan will be completed and managed in accordance with the Strategy for Handling and Disposing of Purgewater at the Hanford Site, Washington (DOE/RL 1990) or applicable procedures. Because of the benefit to CERCLA monitoring from wells providing supplemental information for the 200-BP-5 network (Appendix B), investigation derived waste from supplemental sampling activities may be handled as CERCLA waste.

Unused samples and associated laboratory waste for the analysis will be dispositioned in accordance with the laboratory contract and agreements. In accordance with DFSNW-SSPM-001, *Sampling Services Procedure Manual*, and 40 *Code of Federal Regulations* 300.440, HGMP approval is required before returning unused samples or waste from offsite laboratories.

5.0 Health and Safety

All field operations will be performed consistent with PNNL health and safety requirements and the requirements of the *PNL Radiological Control Implementing Procedures*[2], as implemented via subcontracts and workorders. Where necessary, a work planning package will be prepared that will further control site operations. The work planning package will include, as appropriate, a job hazard analysis, and/or a site-specific health and safety plan, and applicable radiological work permits.

The sampling procedures and associated activities will implement as low as reasonably achievable practices to minimize the radiation exposure to the sampling team, consistent with the requirements defined in *PNL Radiological Control Implementing Procedures*[2].

[2] PNNL. 2000. PNL Radiological Control Implementing Procedures. PNL-MA-266, Rev. 1. Pacific Northwest National Laboratory, Richland, Washington.

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Appendix A

Geostatistical Analysis of Tc-99 Groundwater Monitoring in the 200-BP-5 Operable Unit

Technetium-99 Mapping and Plume Monitoring Evaluation

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Pacific Northwest National Laboratory

Introduction

This report summarizes the results of a geostatistical study for analysis of the spatial uncertainty of technetium-99 for the Hanford Groundwater Monitoring project. We used the data set from the most recent annual report (FY 2001) supplemented where necessary by wells that were sampled in FY 1999 or FY 2000, but not in FY 2001. We used geostatistical indicator simulation programs to create a suite of realizations of the Tc-99 distribution, post-process them, and generate maps of Tc-99. Those maps included the median concentration, the probability of exceeding the 900 pCi/L maximum concentration level (MCL), and spatial uncertainty relative to the edge of the plume. This analysis was used as the basis for ranking existing monitoring locations within the network, as well as identifying potential new sampling and/or well locations with high uncertainty and high probability of exceeding regulatory limits.

(1) Exploratory Data Analysis

The most recent Tc-99 data sampled in years 1999 to 2001 were included in the study. The locations of the three years of data are plotted in Figure 1, and the statistics of the three years of data are summarized in Table 1. The means of Tc-99 appear to increase from 1999 to 2001. The median of Tc-99 in year 1999 at first look is highest among the three years; however, most of the wells missing in year 1999 were observed with low Tc-99 in year 2000 and 2001. The Tc-99 data are plotted between different sampling years in Figure 2. The correlation between observations sampled in different years is very good with the coefficients of correlation ranging from 0.962 to 0.987. The measurements of Tc-99 from years 1999 to 2001 are plotted for each well in Figure 3. The magnitude of Tc-99 seems to have increased from 1999 to 2001, especially for those wells with high values of Tc-99.

In order to include Tc-99 data with good coverage over the area, we decided to use mainly the data from year 2001 but also include data from 2000 and 1999 where observations from 2001 are not available. The most recent annual average was used for each data location. The statistics of the combined data set is listed in the last column of Table 1 and the well locations of the combined data set are plotted in Figure 4. In addition to the samples from year 2001, one sample was from 2000, and 7 samples were from 1999. The distribution of the combined data shows a bimodal behavior (Figure 5), suggesting the approach of indicator simulation would be appropriate in mapping Tc-99.

Based on the distribution of Tc-99 in Figure 5, four cutoffs were chosen for calculating the indicator variograms of the combined Tc-99 data. The four indicator variograms and the fitted models are shown in Figure 6. The parameters of the models are listed in Table 2. Spherical models were fit to the experimental indicator variograms, with the shortest range of 270 m for the cutoff of 2700 pCi/L, and the longest range of 650 m for the cutoff of 50 pCi/L. As expected, the variogram ranges indicate that areas with high values of Tc-99 are not as laterally extensive as areas with low values.

Table 1. Summary Statistics of Tc-99 Data from 1999 to 2001 and the Combined Data

Tc-99	Year 1999	Year 2000	Year 2001	Combined Data Set
N of cases	37	45	50	59
Minimum	3.5	14.0	5.0	5.0
Maximum	5700.0	10000.0	12000.0	12000.0
Range	5696.5	9986.0	11995.0	11995.0
Median	280.0	76.0	87.0	94.0
Mean	1251.52	1376.04	1685.77	1604.76
95% CI Upper	1790.73	2065.28	2489.25	2301.29
95% CI Lower	712.31	686.81	882.29	908.23
Standard Dev	1617.24	2294.14	2827.19	2672.79
C.V.	1.29	1.67	1.68	1.67
Skewness(G1)	1.36	2.22	2.09	2.19
Kurtosis(G2)	1.02	5.06	4.06	4.70

Table 2. Parameters of the Fitted Models of the Indicator Variograms of the Combined Tc-99 Data

Cutoff (pCi/L)	CDF (%)	Nugget	Model	Sill	Range (m)
50	36	0	Spherical	1	650
300	56	0.1	Spherical	0.9	400
900	63	0	Spherical	1	275
2700	78	0.3	Spherical	0.7	200

(2) Stochastic simulation: Base case

Sequential indicator simulation (SISIM) was used to simulate the distribution of Tc-99 within a domain defined as follows:

Minimum of X = 571400 m, maximum of X = 574500 m, spacing = 50 m, nx = 63
Minimum of Y = 136500 m, maximum of Y = 141000 m, spacing = 50 m, ny = 91

500 simulations were generated of the Tc-99 concentration over the study area. The 500 simulated values provide an estimate of the distribution of Tc-99 at each grid node, which can be used to calculate several statistical parameters such as the average (E-type estimates), median, probability of exceedance and reference uncertainty index to any critical level (900 pCi/L in this case). The median, the probability of exceeding 900 pCi/L, and the reference uncertainty index were calculated and plotted in Figures 7 to 9. The map was blanked where basalt occurs above the water table. Since the simulations are conditioned to all samples in the combined data set, the results serve as the base case for the following analysis of ranking the existing wells and identifying the most valuable additional sample locations.

(3) Ranking of existing wells

The locations of the existing wells are clustered as observed in Figure 4. The following procedure was developed to evaluate the existing wells using the reference uncertainty index to the critical level (900 pCi/L) and the spatial redundancy.

a. For the first cycle, use all existing wells and the reference uncertainty index to 900 pCi/L (RUI900) of the 500 simulations of the base case for start.

b. Calculate the distance to the nearest well for all existing wells. Rank in ascending order, the shorter the distance to the nearest well, the higher the rank of redundancy.
c. Find the median of all RUI900 values of the simulations falling within a defined search radius centered at each existing well. A search radius of 150 m (3 times the grid spacing of 50 m) was used in the procedure. Assign the median RUI900 within the search radius to the well.
d. Rank the assigned RUI900 values at the existing wells. Small values indicate low uncertainty at a well, so it would be assigned a higher rank.
e. Calculate a combined rank that is the average of the rank of redundancy and the rank based on the RUI900 for each well. Rank the combined score as the final rank for each location.
f. Remove the well with the highest final rank from the existing wells, which is least important in terms of information provided.
g. Generate 500 simulations with the new reduced data set (i.e., all wells except the least valuable), and calculate the statistical parameters such as median and RUI900 for the new set of simulations.
h. Compare the median of the new simulations with the median of the base case. Calculate the root mean square error (RMSE).
i. Repeat Step (a) to (h) using the RUI900 conditioning to the reduced data and the locations of the reduced data for finding the next least important location until the maximum number of wells is removed.

We set the maximum number of wells being removed from the original list to be 25 (slightly less than half of the total number of 59). The values of RMSE are plotted against the number of removed wells in Figure 10. The RMSE values gradually increase as the number of removed wells increases, and no distinct breakpoints were found indicating a dramatic increase in error if more than a given number of wells were removed. Based on the gradual increase in RMSE and the distribution of the remaining wells, we decided to remove the 25 wells that were the least valuable from the rankings from the combined data set and re-run the simulations for comparison with the base case. The locations of the 25 removed wells are listed in Table 3, and plotted in Figure 11 along with the remaining wells. Table 4 lists the 34 wells retained in the monitoring network. As seen in the figure, the removed wells are often located very close to other nearby wells or in areas where the uncertainty to the critical level 900 pCi/L is very low. The order in which the 25 wells would be removed from the monitoring network is shown in Figure 12.

The median, probability of exceeding 900 pCi/L and the reference uncertainty index of the 500 simulations are plotted in Figures 13 to 15 for the reduced data set (i.e., the data set with 25 wells removed). Compared to the base case, the major features of the contours are well captured in the figures of the reduced data set after removing 25 wells. This suggests that the 25 wells could be removed without significantly impacting the mapping of the Tc-99 plume.

Table 3. Locations of the 25 Removed Existing Wells by the Removal Order

Rank	Well Name	Easting (m)	Northing (m)	Tc-99 (pCi/L)
1	299-E33-33	574080.137	137301.934	21
2	299-E33-335	573568.442	137222.229	54
3	299-E33-20	573847.598	137397.913	330
4	299-E33-16	573791.692	137465.297	3400
5	299-E32-2	572648.02	137467.509	31
6	299-E32-4	572603.743	137187.218	30
7	299-E32-5	572599.697	137285.125	25
8	299-E33-13	573706.488	137584.387	2800
9	299-E33-21	573474.448	137293.117	140
10	299-E32-7	572600.38	137647.05	32

11	299-E33-337	573821.8	137193.87	80
12	299-E33-5	573574.225	137606.421	4900
13	299-E32-3	572600.614	137383.996	28
14	299-E32-8	572663.39	137741.47	33
15	299-E33-339	573716.86	137221.51	75
16	299-E33-17	573878.517	137467.183	94
17	299-E33-45	573683	137347	2400
18	299-E33-9	573646.833	137485.878	5900
19	299-E33-31	573524.98	137491.439	3500
20	299-E33-32	573524.825	137354.019	1500
21	299-E33-36	574068.54	137239.981	9.4
22	299-E33-8	573475.297	137447.934	1300
23	299-E33-29	573227.858	137231.193	41
24	299-E33-14	573985.612	137567.216	26
25	299-E33-334	573514.716	137256.371	60

Table 4. Locations of the Remaining Wells After 25 Wells Removed

Well Name	Easting (m)	Northing (m)	Tc-99 (pCi/L)
299-E26-10	575588.999	137023.494	5
299-E28-2	573704.524	136863.879	42
299-E28-26	572941.553	137024.016	51
299-E28-27	573226.784	137070.063	13
299-E28-28	572804.351	137108.259	28
299-E28-8	573698.1	137074.3	51
299-E32-10	572951.13	137741.69	2600
299-E32-6	572600.4	137515.1	28
299-E32-9	572795.11	137741.69	110
299-E33-15	573810.288	137540.698	470
299-E33-18	573779.166	137386.064	2900
299-E33-26	573333.348	137681.471	7300
299-E33-28	573226.365	137375.019	170
299-E33-30	572923.796	137467.779	37
299-E33-338	573912.07	137238.24	18
299-E33-34	573104.458	137740.427	7600
299-E33-35	573220.798	137605.098	1900
299-E33-38	573591.158	137594.489	12000
299-E33-39	573843.523	137637.367	70
299-E33-41	573707.19	137369.94	2200
299-E33-42	573520.99	137424.38	3000
299-E33-43	573523.19	137325.43	520
299-E33-44	573706.411	137469.1635	7600
299-E33-46	573792.553	137278.365	1700
299-E33-7	573574.025	137695.968	10000
699-47-60	571474.38	137968.732	14
699-49-55A	573146.301	138351.781	16
699-49-57A	572544.276	138389.24	3200
699-50-53A	573649.666	138670.477	520

699-53-47A	575417.545	139489.296	5.3
699-53-55C	573114.995	139624.113	2000
699-55-57	572445.432	140119.853	1600
699-55-60A	571562.954	140267.374	27
699-57-59	571830.216	140923.719	76

(4) Additional sampling

The procedure of locating additional sampling locations that would be useful in monitoring the Tc-99 plume is similar to the one of ranking and removing the existing wells. The difference is to give higher rank to the potential locations with high RUI900 values (i.e., areas where there is considerable uncertainty about the location of the 900 pCi/L contour) and long distances to the nearest existing wells. In that way, we identify locations where an additional well should greatly decrease the uncertainty about the location of the edge of the plume (i.e., the 900 pCi/L contour). The combined scores at the potential locations are calculated using the two ranks as described previously. The detailed procedure is described as follows.

a. Determine RUI900 values for the potential locations. The 63 by 91 grid nodes of the simulation domain were used as potential locations.
b. Rank the RUI900 values by descending order, i.e., locations with higher RUI900 values receive higher rank.
c. Find the distance of the potential locations to the nearest existing wells. Rank the nearest distances at the potential locations by descending order.
d. Calculate a combined score with average of the rank of least redundancy and most uncertainty for each potential location. Rank the combined score as the final rank.
e. Add the location with highest rank to the existing wells. Repeat Step (b) to (e) until the maximum number of additional samples is reached. Note the added locations will be considered part of the existing wells in calculating the distance of the potential locations to the nearest existing wells.

We identified 10 additional well locations, assuming no more than 10 wells would be added in the next fiscal year. More or less could be identified as required by the project. The resulting 10 additional sampling locations are shown as red circles marked with the order of addition in Figure 16 and the locations are included in Table 5. The additional locations are well spread within the simulation domain, and are located mostly in areas with high RUI900 values, which will be helpful in capturing the boundary of the plume that exceeds 900 pCi/L.

Table 5. 10 Additional Sampling Locations

Rank	East (m)	North (m)
1	573650	140700
2	571950	138850
3	572550	140850
4	573700	139850
5	572000	139600
6	572150	138500
7	573500	138250
8	572850	138500
9	572950	138050
10	572150	140150

The same procedure was also applied to ranking 20 existing wells for which there were no Tc-99 measurements from years 1999 to 2001. The RUI900 values of the base case are used for back interpolating to the locations of the 20 wells. The 10 existing wells with highest ranks are listed in Table 6 and shown in Figure 17. Note that the interpolated RUI900 values at the 10 existing wells with highest rank are much lower than the additional sampling locations selected from the simulation grid nodes (Table 5) indicating that the existing wells would not be nearly as valuable as the new locations identified in Table 5. Only 2 of the existing wells that are not currently sampled appear to provide useful information (699-52-54 and 699-52-57).

Table 6. 10 Existing Wells with Highest Ranks of Addition

Order	Well Name	East (m)	North (m)
1	699-52-54	573254.242	139193.172
2	699-52-57	572761.346	139115.316
3	299-E28-18	573104.076	136767.778
4	299-E28-5	574033.843	136856.669
5	299-E34-11	574176.16	137581.78
6	299-E34-12	574411.004	137168.544
7	299-E34-9	574186.02	137429.82
8	299-E28-24	573785.436	136727.768
9	299-E33-12	573780.53	137632.223
10	299-E27-18	574299.61	137119.29

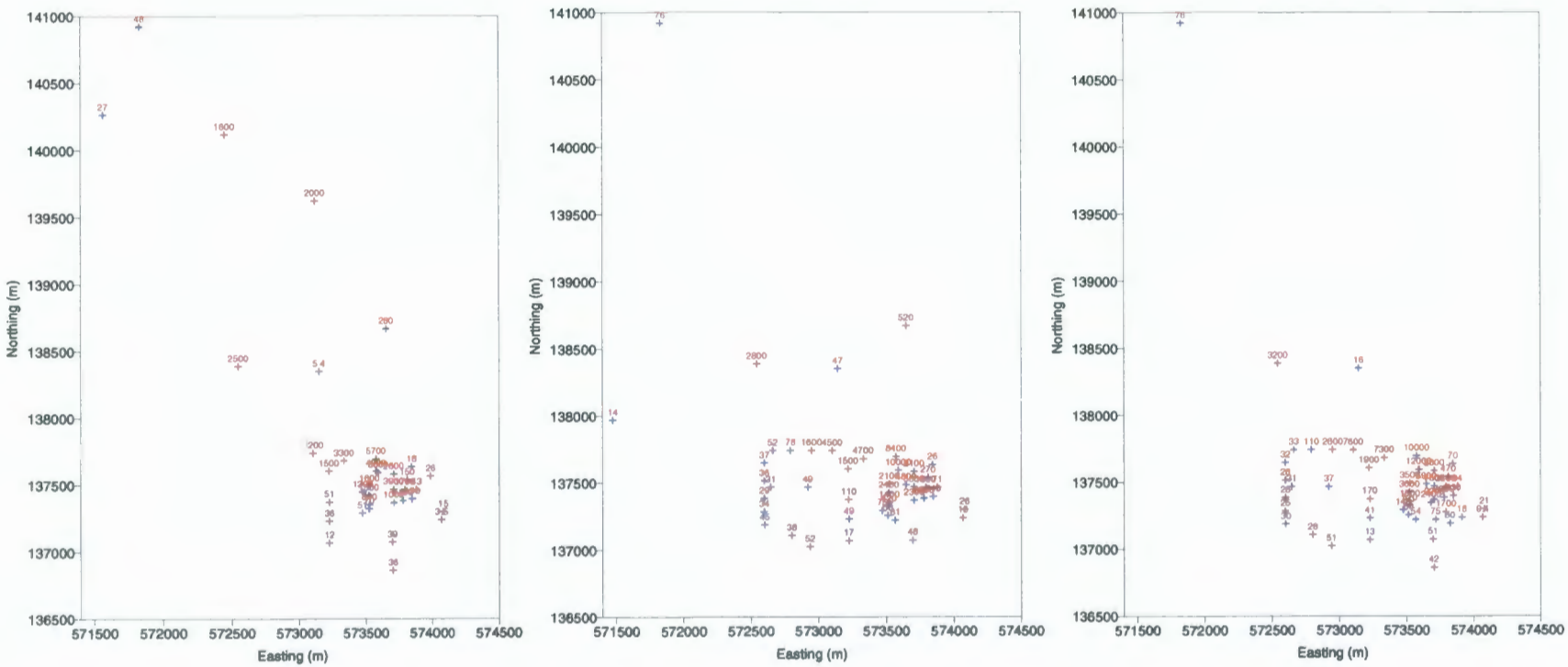

Figure 1. Locations of Tc-99 Data Sampled in Year 1999 to 2001 (from left to right)

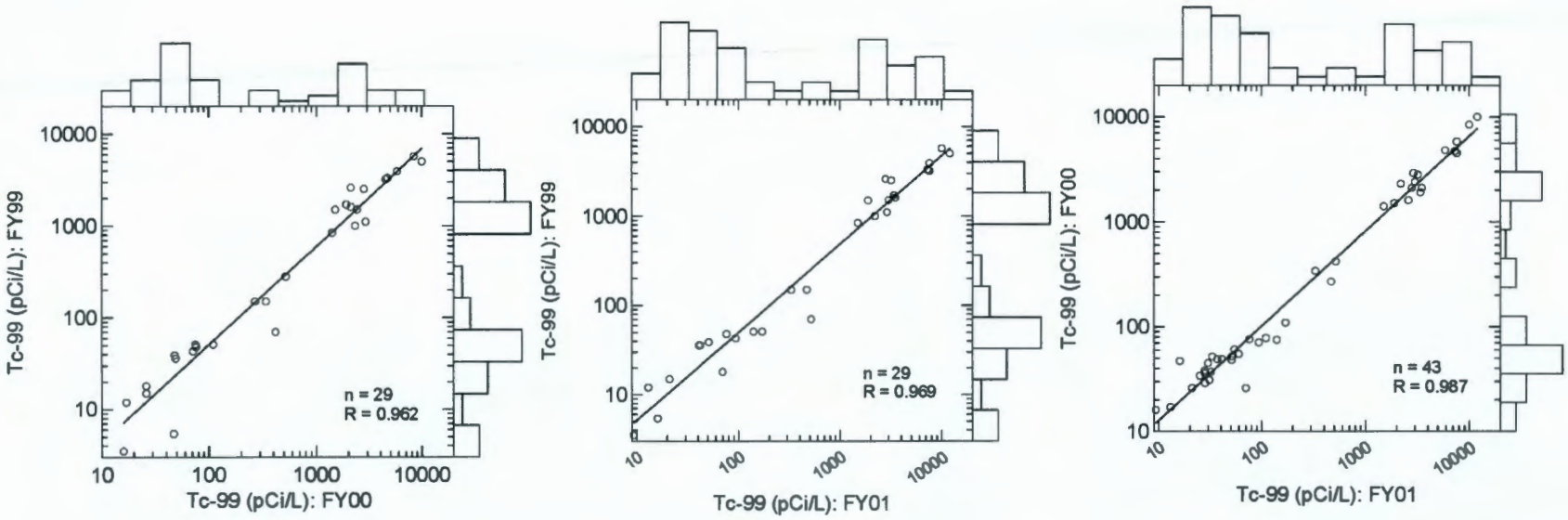

Figure 2. Scatter Plots of Tc-99 Data from Year 1999 to 2001. The number of pairs of data and the coefficient of correlation are shown in each plot.

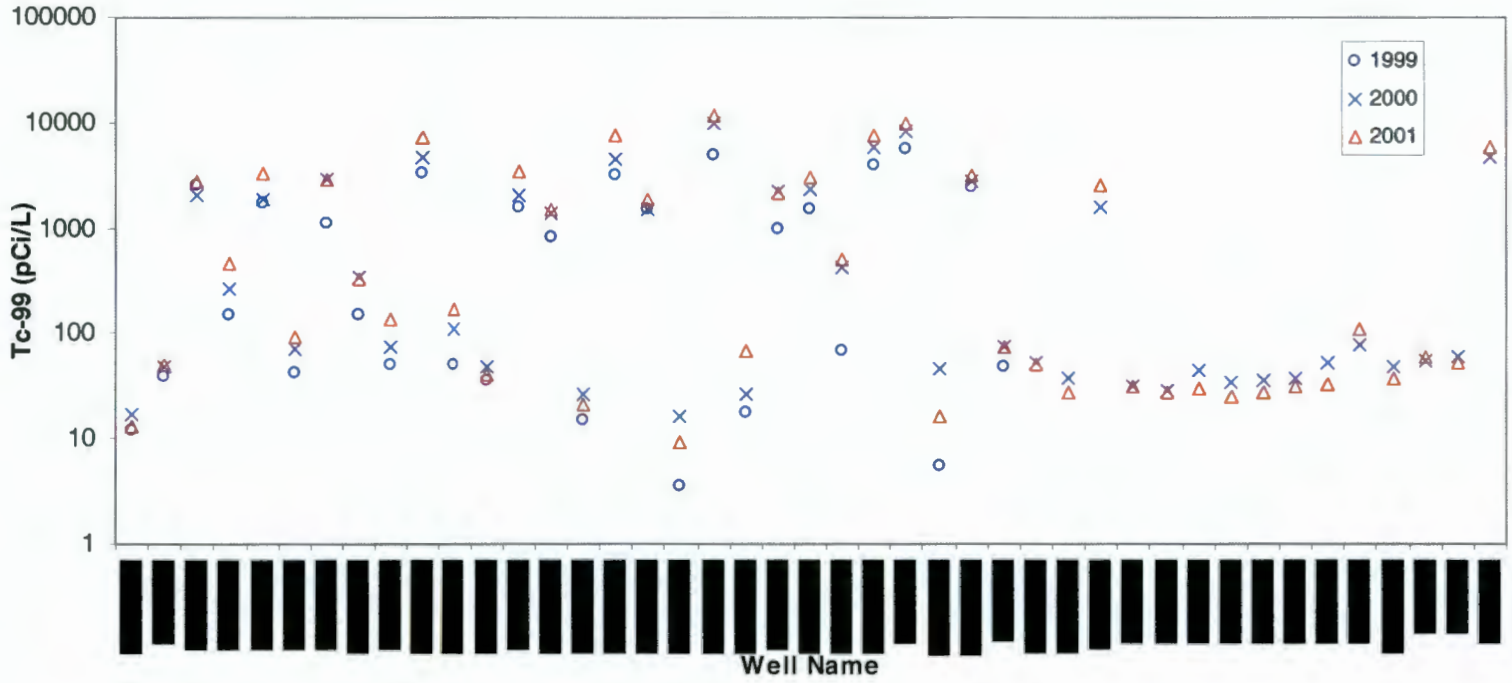

Figure 3. Tc-99 Data from Year 1999 to 2001 at BP5 Wells

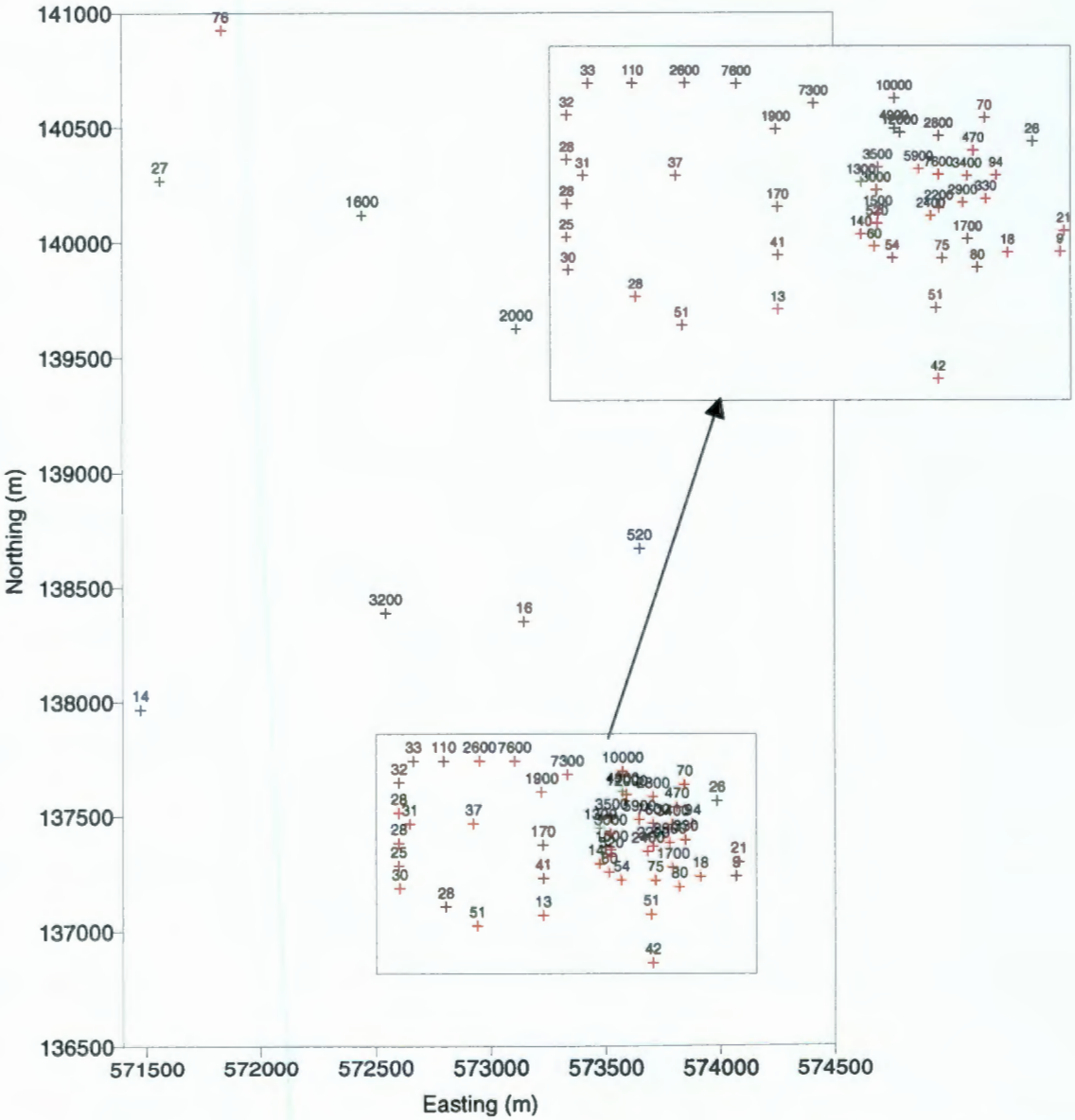

Figure 4. Locations of the Combined Tc-99 Data Sampled in 2001, 2000, and 1999 Labeled in Red, Blue, and Green, Respectively. A detailed map of the densely sampled area is provided above.

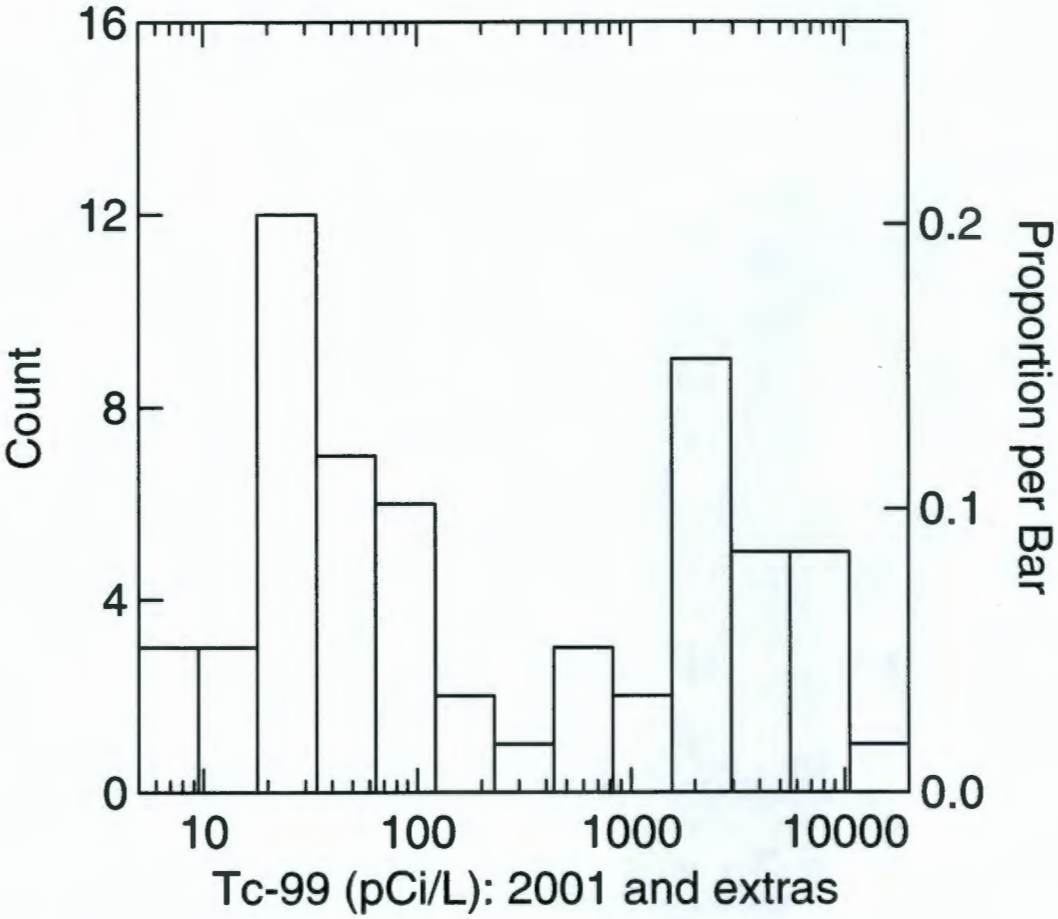

Figure 5. Histogram of the Combined Tc-99 Data. Most data are from year 2001 with additional data from 2000 and 1999.

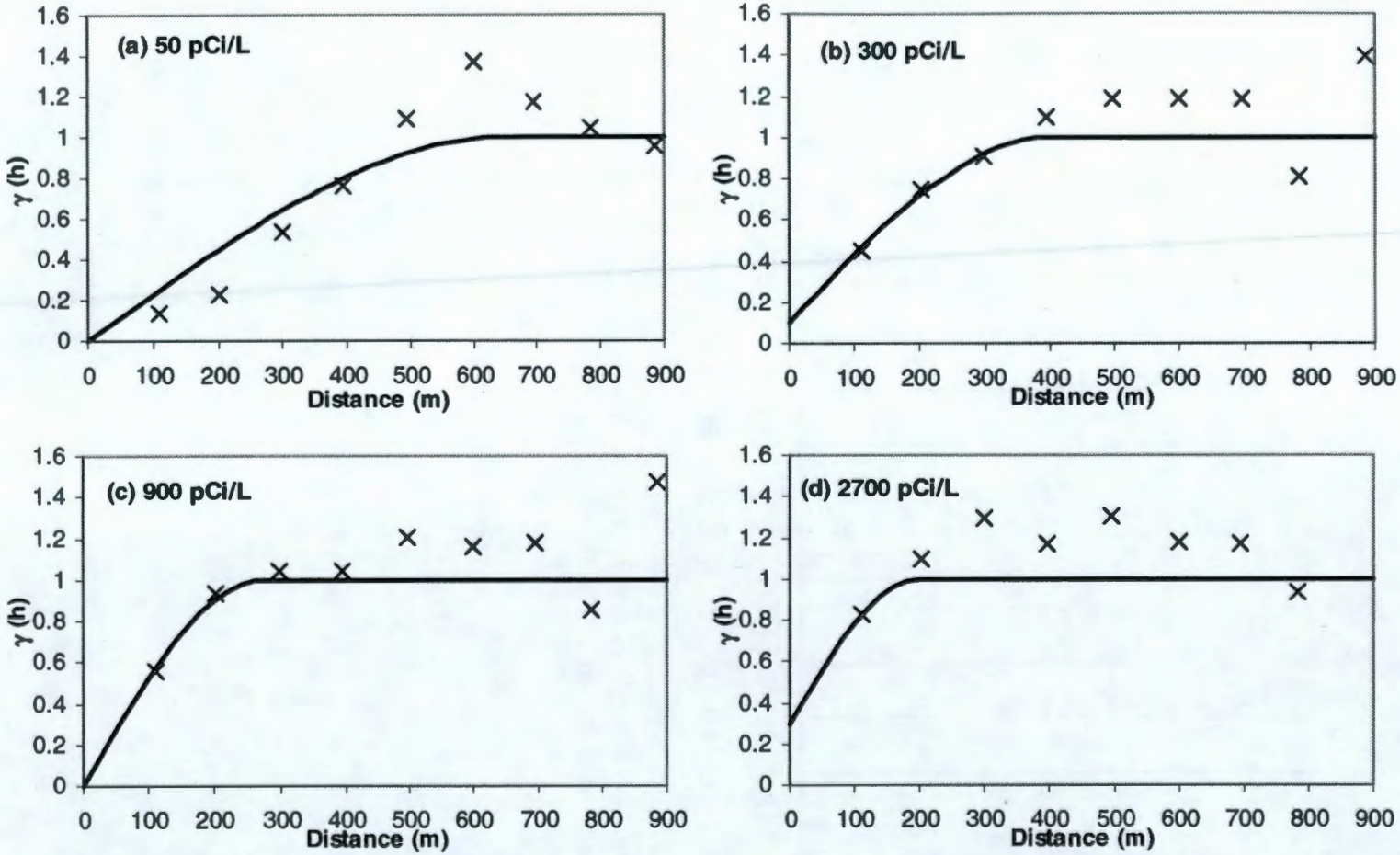

Figure 6. Indicator Variograms and the Fitted Models of Tc-99 Data

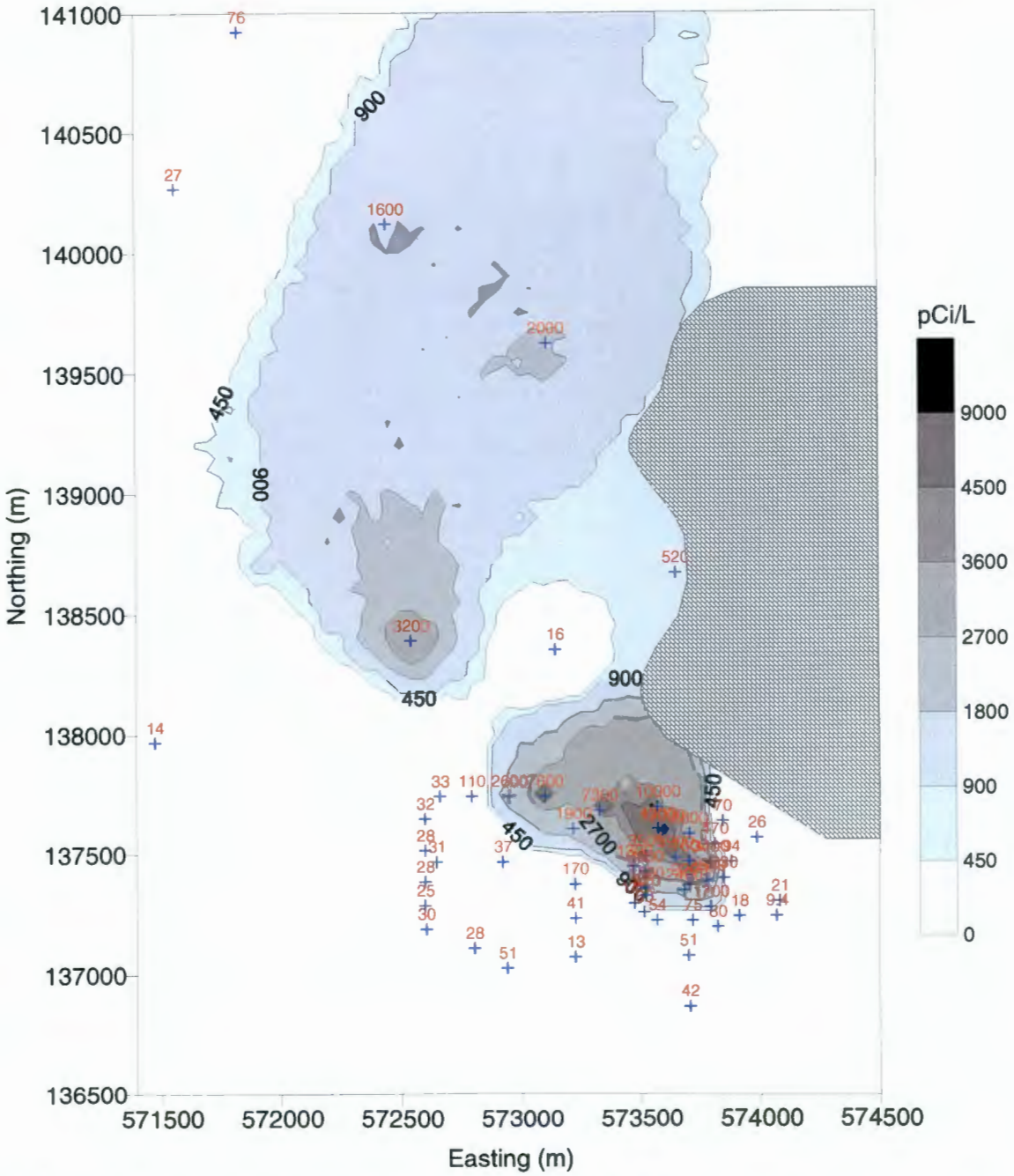

Figure 7. Median of 500 SISIM Simulations of Tc-99 of the Base Case and the Locations of Sample Data

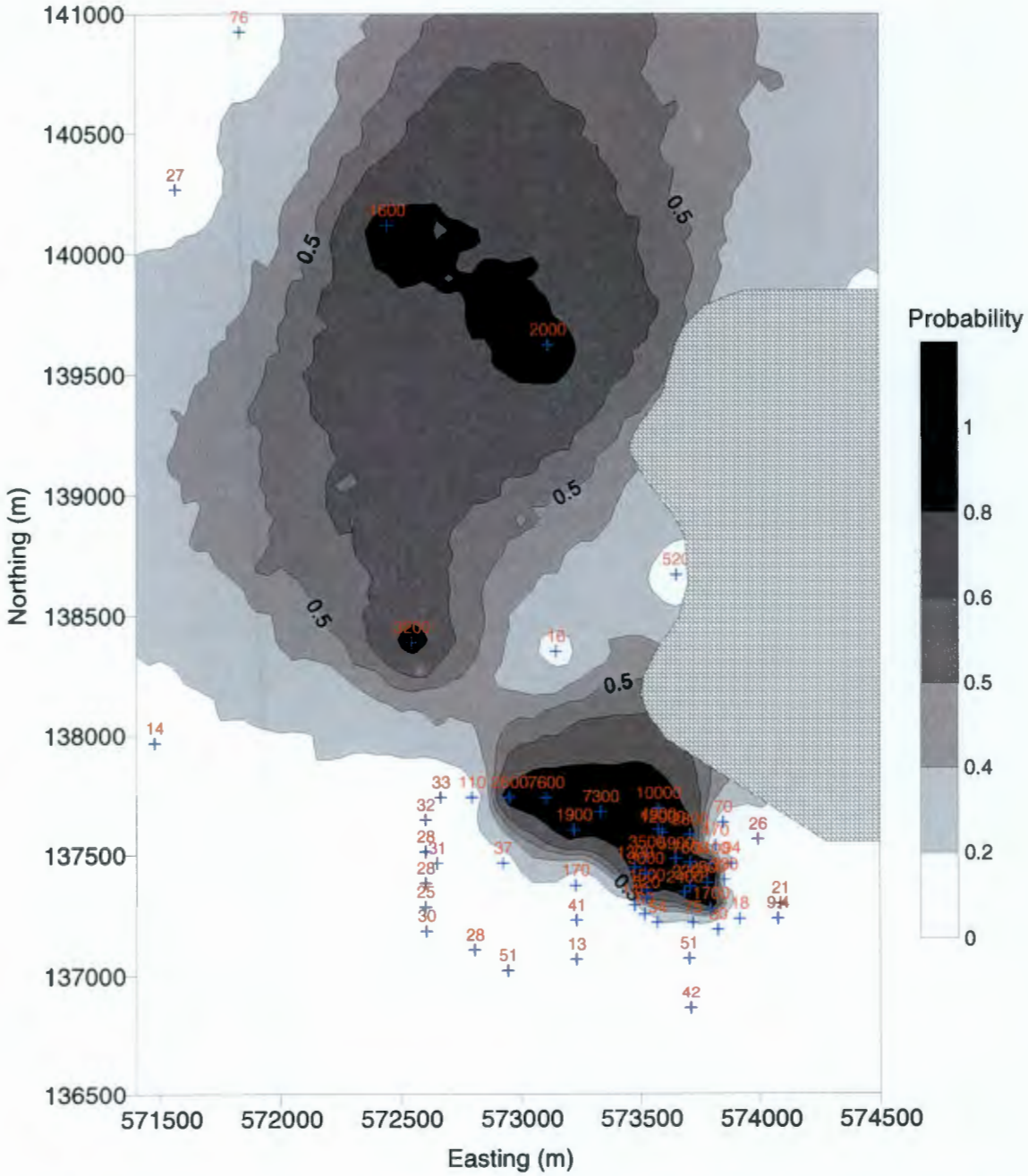

Figure 8. Probability of Exceeding 900 pCi/L of the Base Case and the Locations of Sample Data

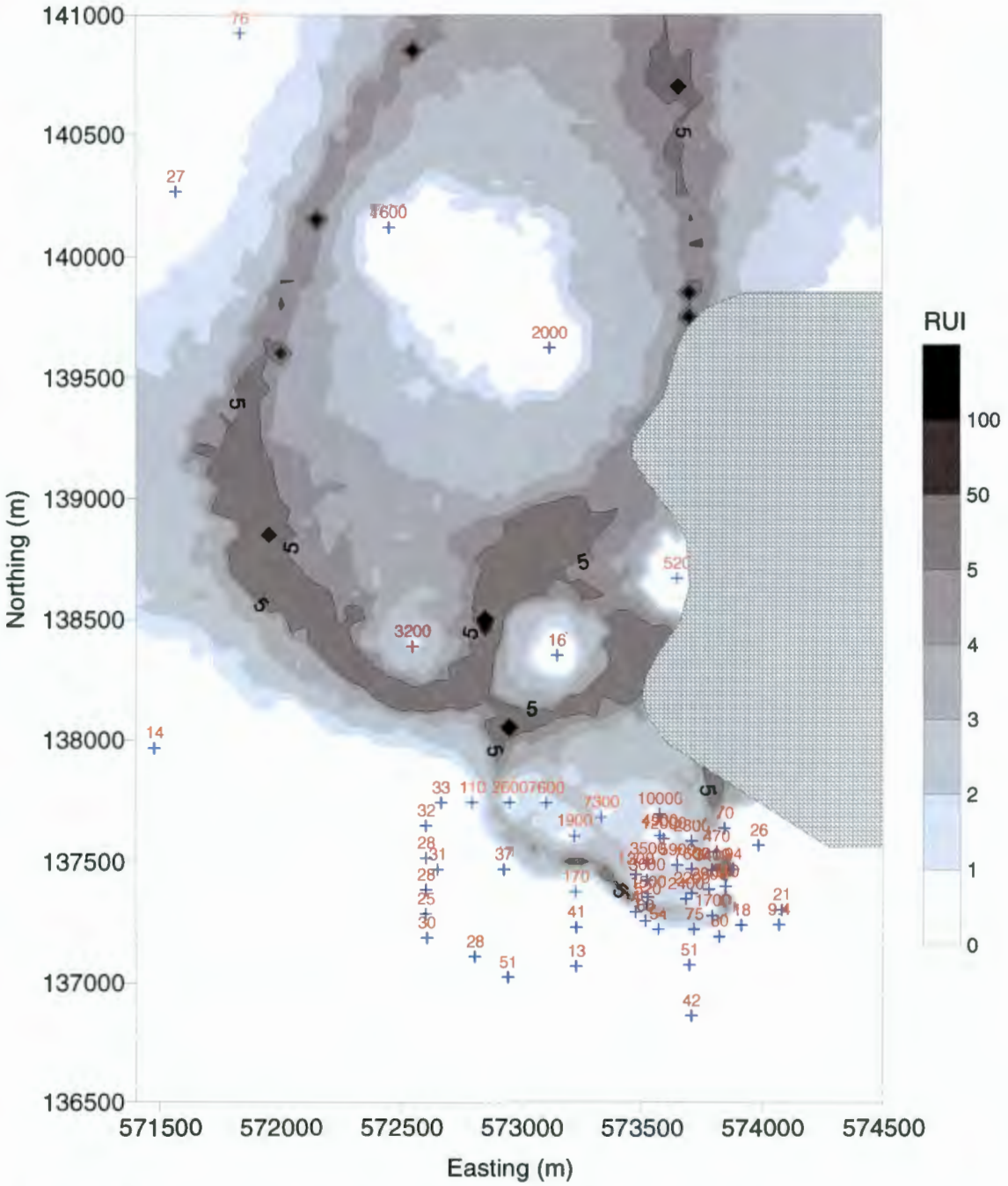

Figure 9. Reference Uncertainty Index to 900 pCi/L of the Base Case and the Locations of the Sample Data

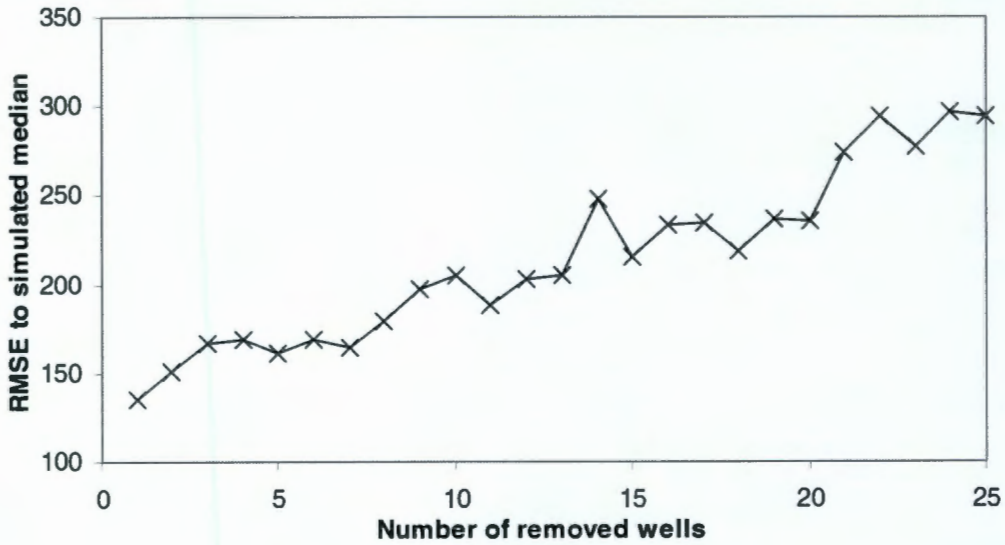

Figure 10. Root Mean Square Error of the Median Values Conditioning to the Reduced Data Compared to the Median of the Base Case

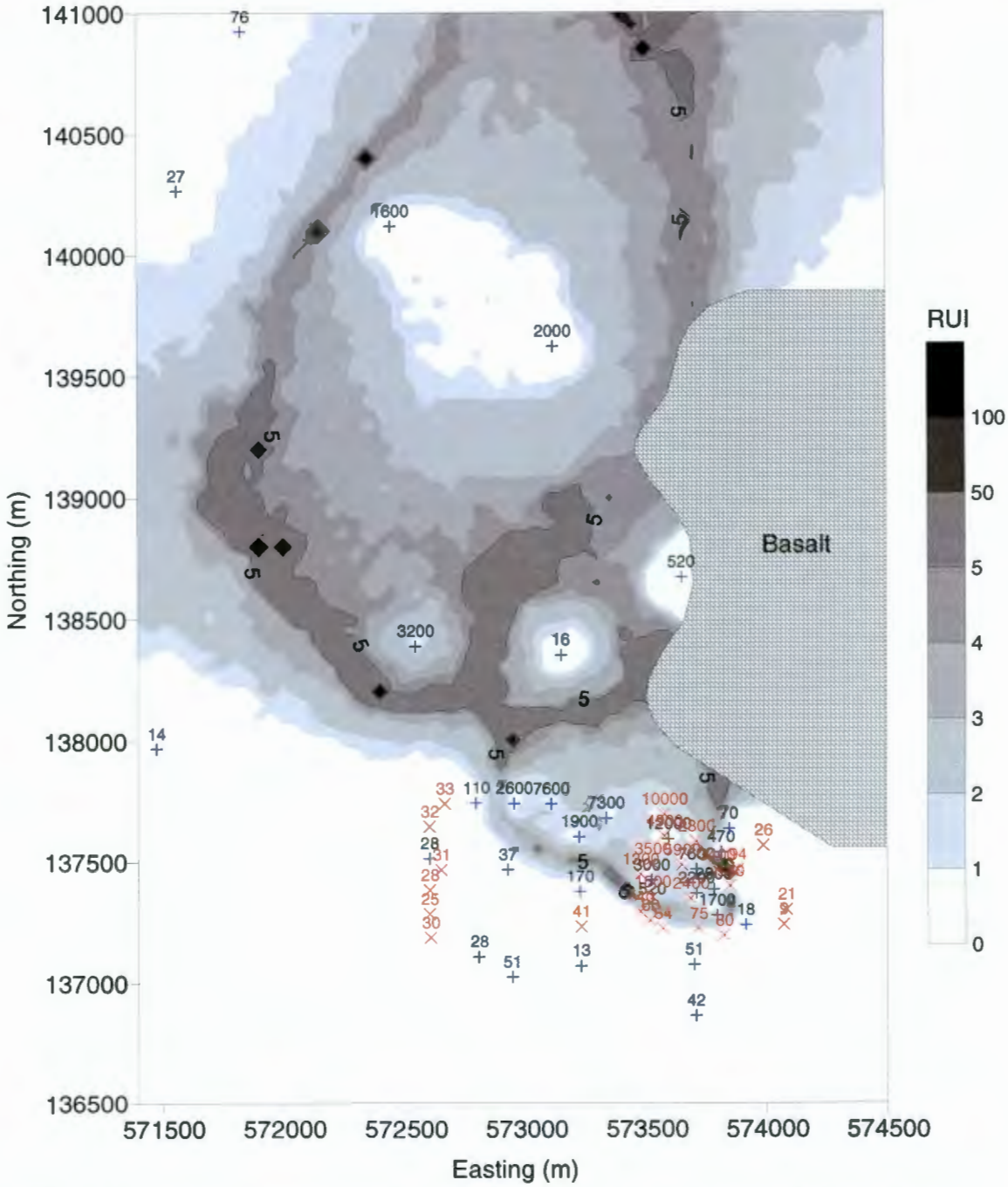

Figure 11. Reference Uncertainty Index to 900 pCi/L of the Base Case and the 25 Removed Wells. The original sample locations and 25 removed wells are labeled in blue and red crosses marked with Tc-99 value, respectively.

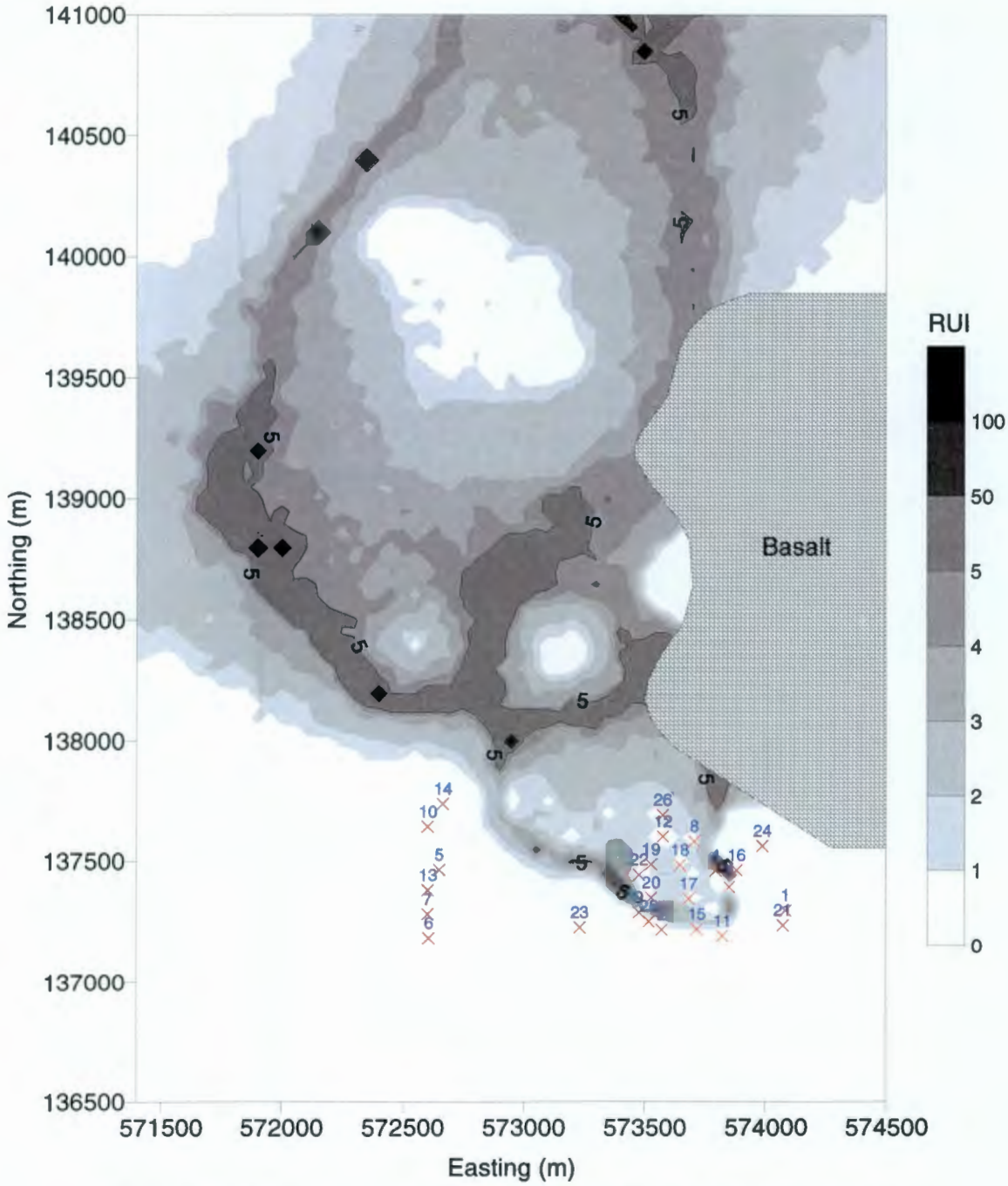

Figure 12. Reference Uncertainty Index to 900 pCi/L of the Base Case and the 25 Removed Wells in Red Cross Marked with the Rank of Removal

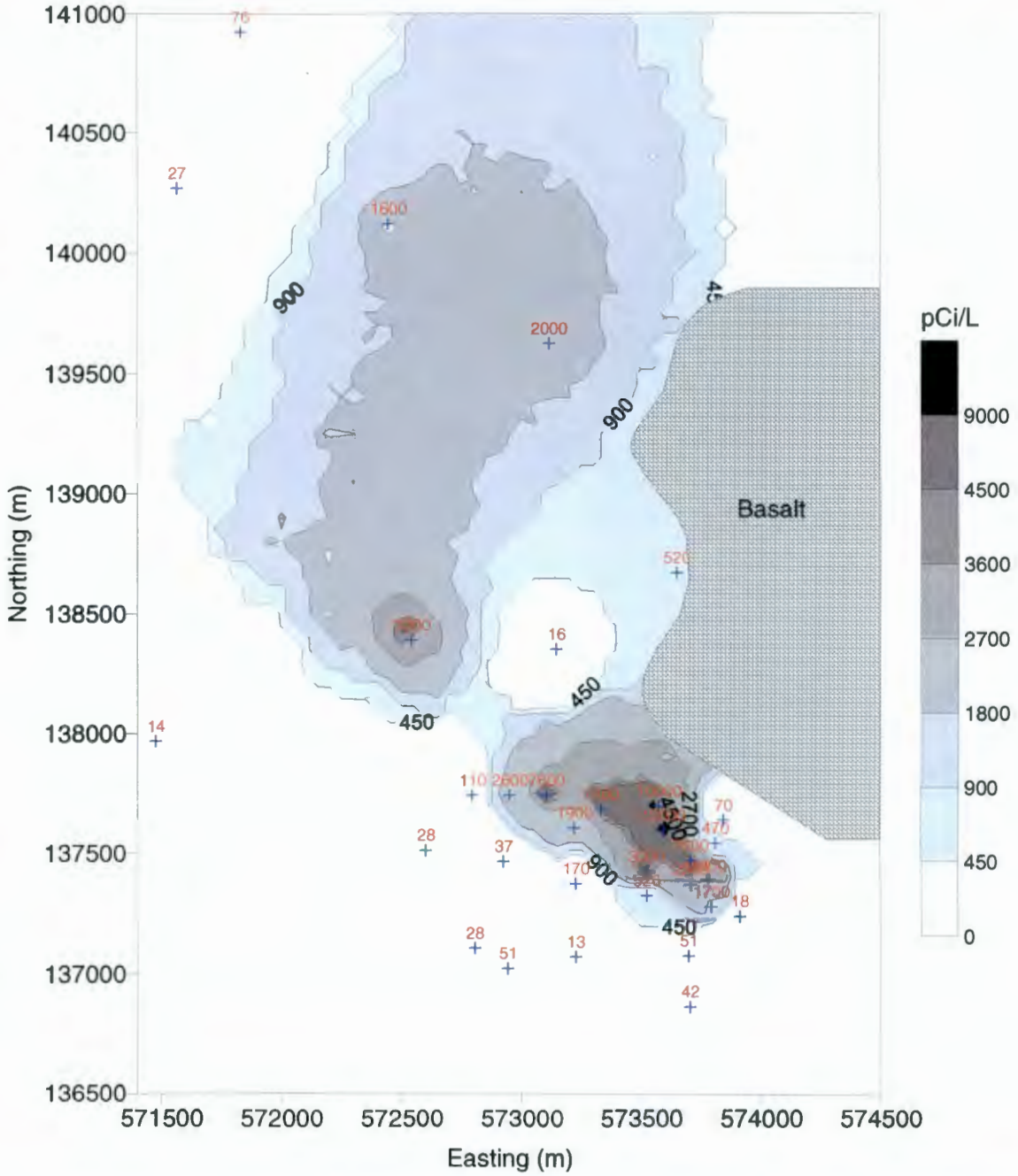

Figure 13. Median of 500 SISIM Simulations of Tc-99 Conditioning to the Reduced Data Set After Removing 25 Wells. The samples are plotted in blue cross labeled with Tc-99 value.

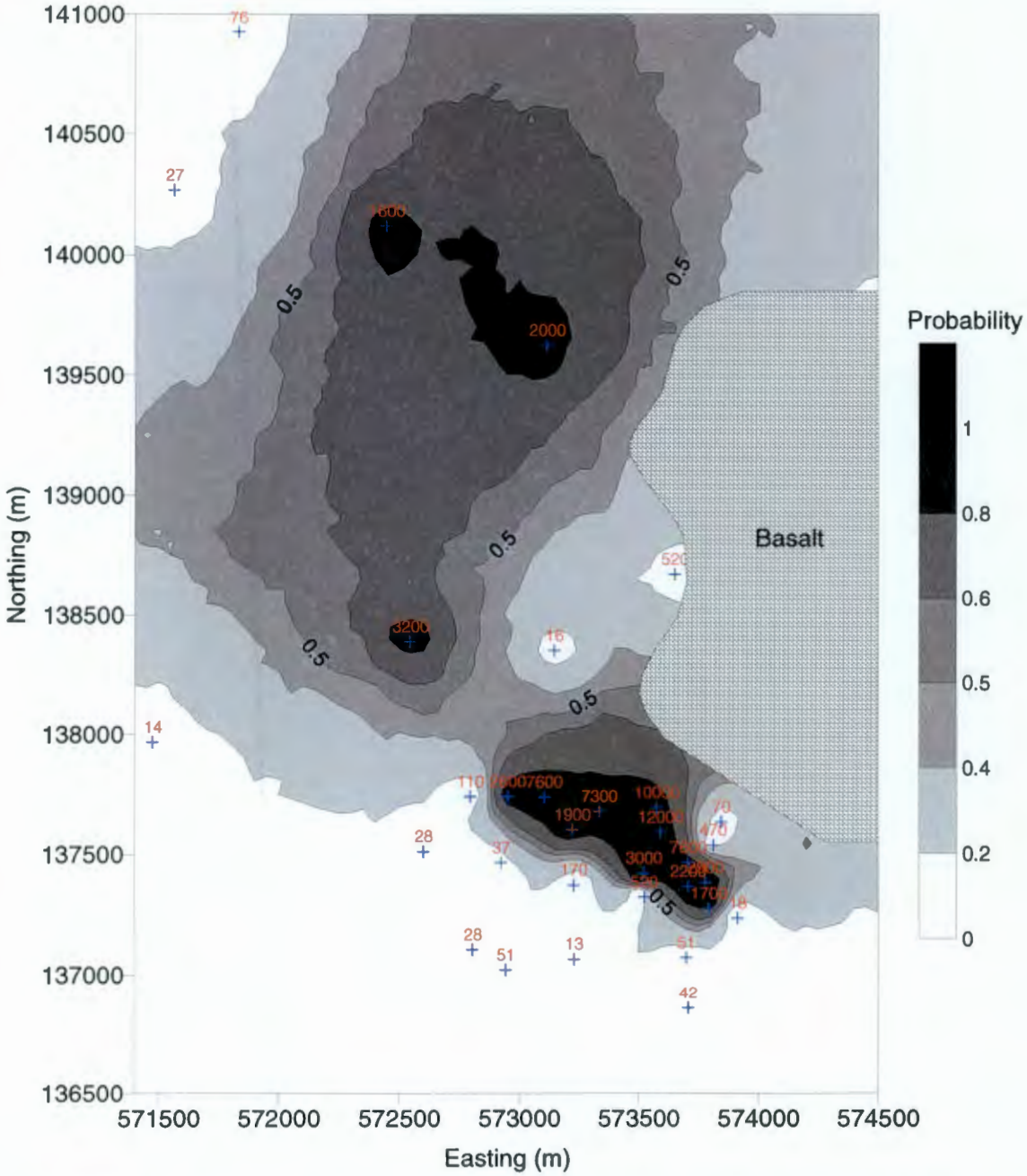

Figure 14. Probability of Exceeding 900 pCi/L of 500 SISIM Simulations of Tc-99 Conditioning to the Reduced Data Set After Removing 25 Wells. The samples are plotted in blue cross labeled with Tc-99 value.

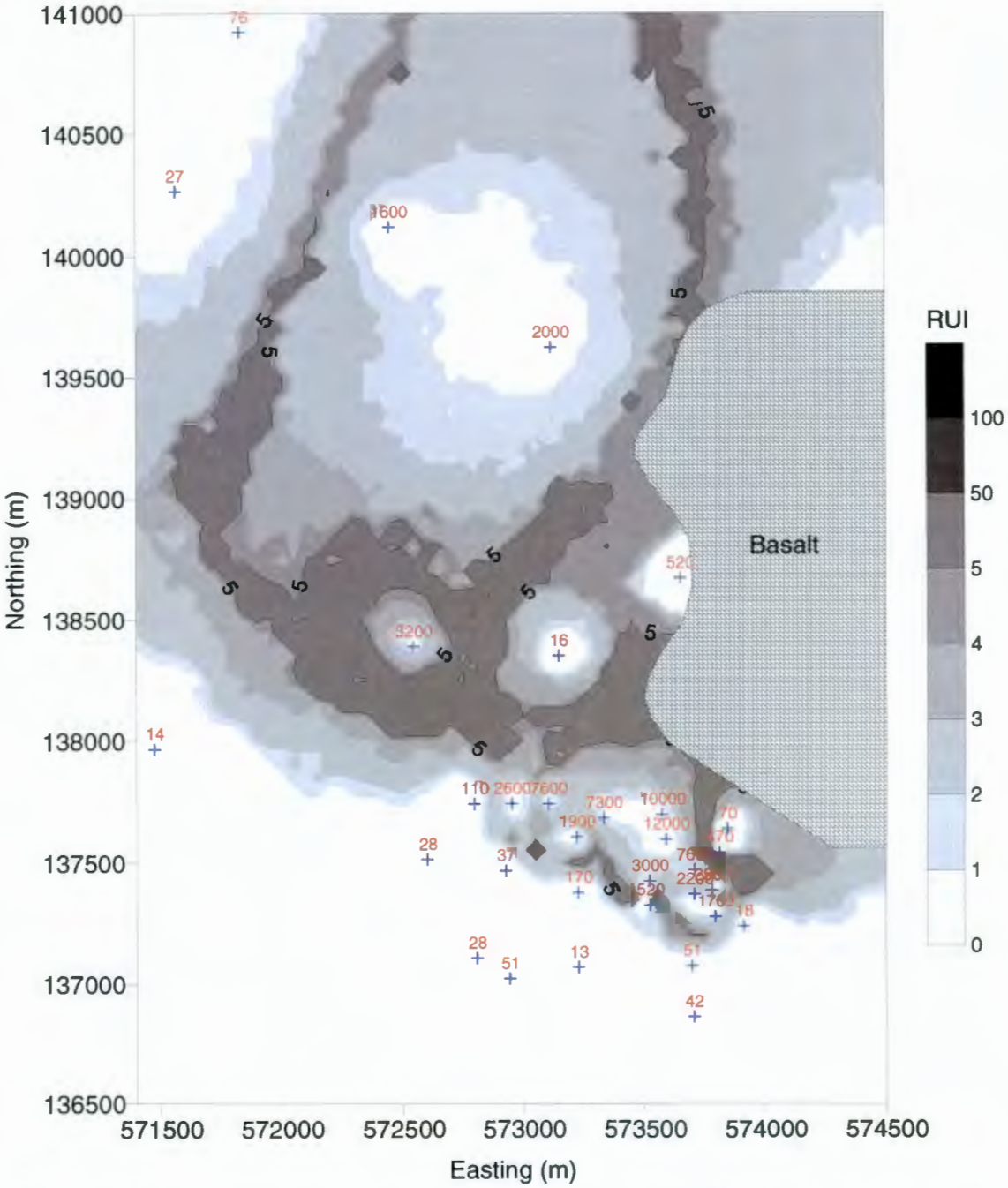

Figure 15. Reference Uncertainty Index to 900 pCi/L of 500 SISIM Simulations Conditioning to the Reduced Data Set After Removing 25 Wells. The samples are plotted in blue cross labeled with Tc-99 value.

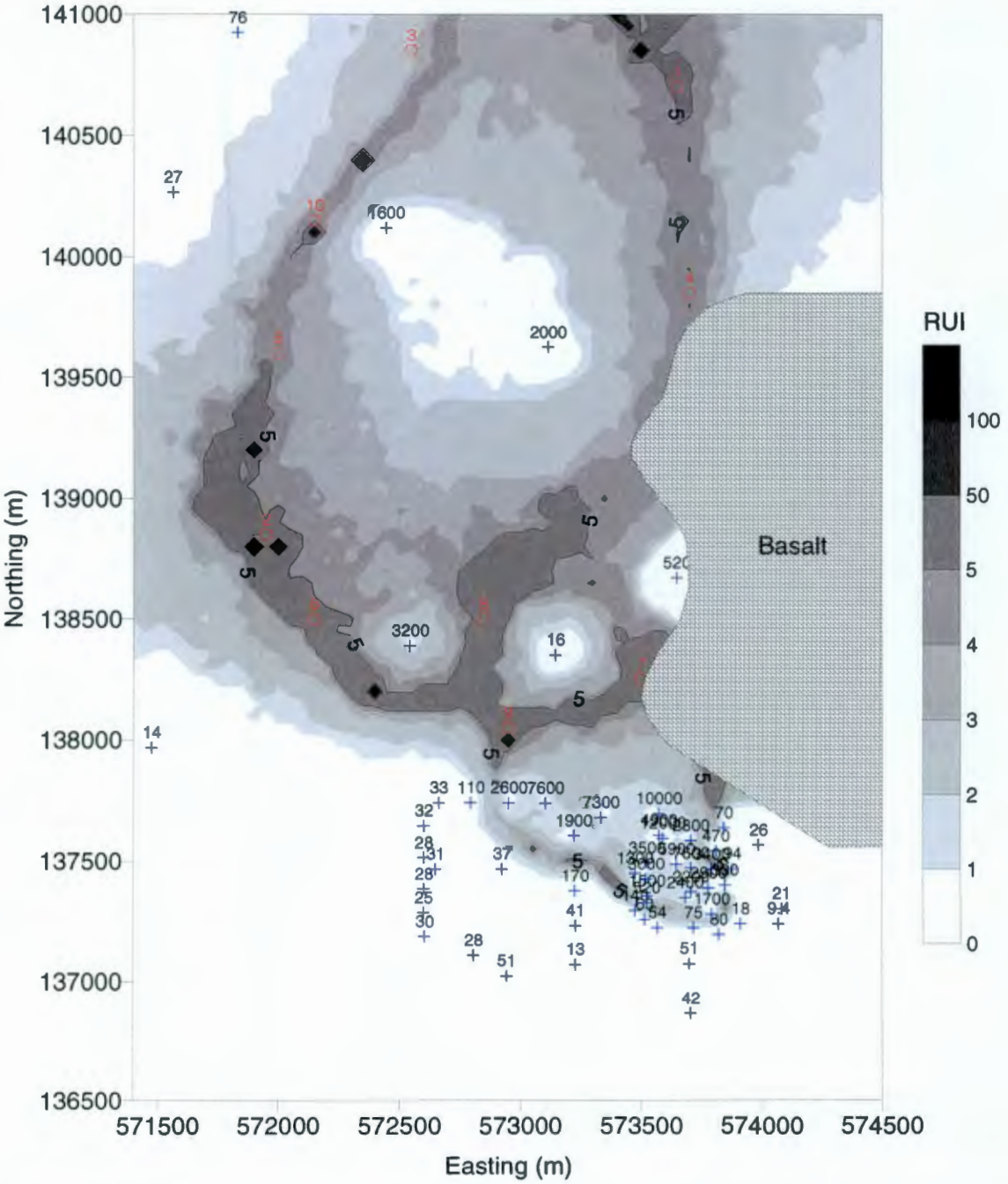

Figure 16. Reference Uncertainty Index to 900 pCi/L of the Base Case and the 10 Additional Sampling Locations Identified by the Study. The original sample locations are labeled in blue cross marked with Tc-99 value, and the additional sample locations in red circle marked with the rank of addition.

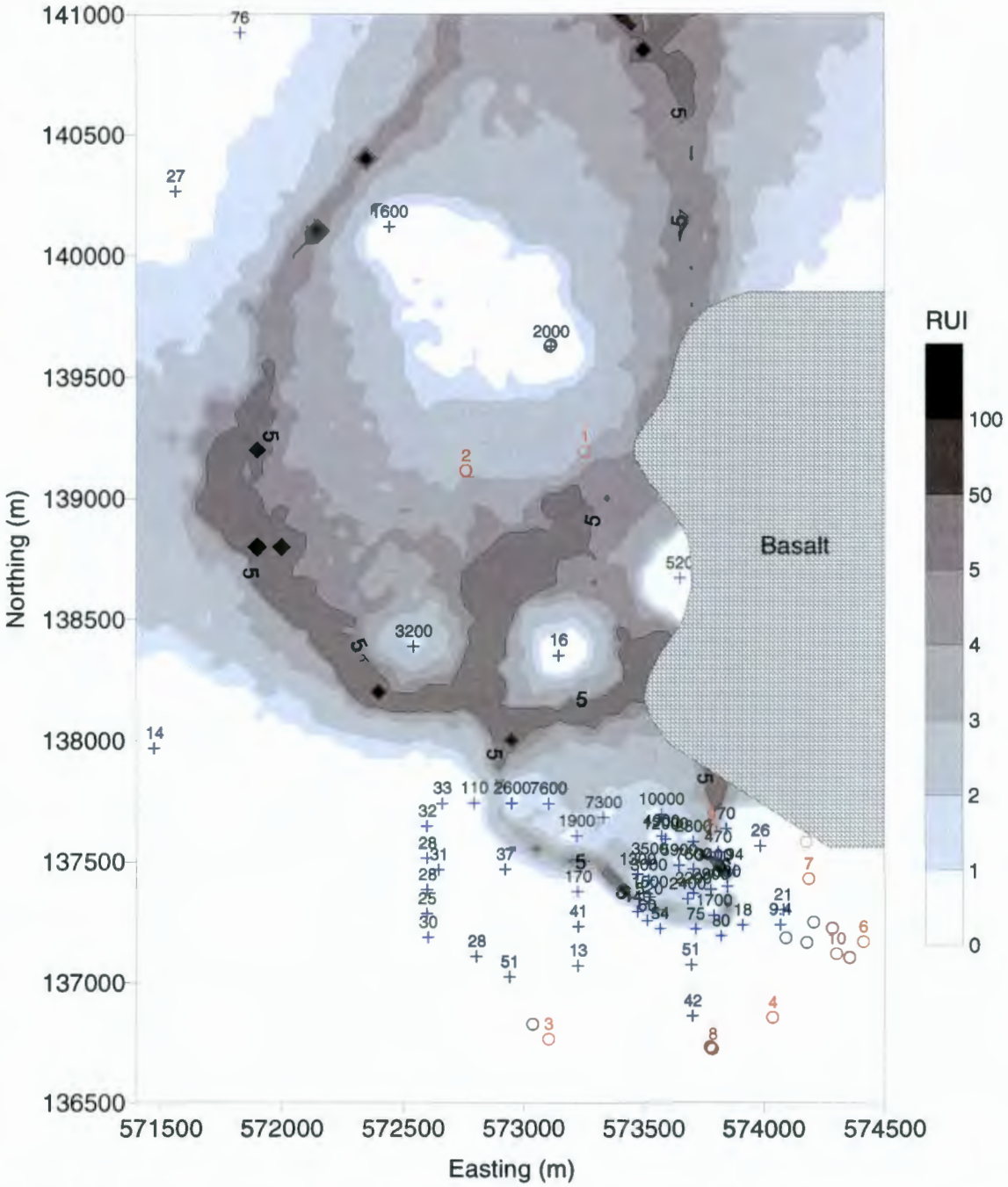

Figure 17. Reference Uncertainty Index to 900 pCi/L of the Base Case and the Locations of 20 Existing Wells with no Tc-99 Measurement. The original sample locations are labeled in blue cross marked with Tc-99 value. The 10 well locations with highest ranks are plotted in red circle marked with the rank of addition, the rest of the existing wells are plotted in black circle. Only locations 1 and 2 appear to provide valuable new information for plume monitoring.

Appendix B

List of Supplemental Wells Potentially Used to Support CERCLA Groundwater Monitoring for the 200-BP-5 Operable Unit

Appendix B – List of Supplemental Wells Potentially Used to Support CERCLA Groundwater Monitoring for the 200-BP-5 Operable Unit

Well Numbers	Sampling Project
299-E18-1	Surveillance Central
299-E24-8	Surveillance Central
299-E26-10	LERF, Surveillance Central
299-E26-11	LERF, Surveillance Central
299-E26-8	Surveillance Basalt
299-E27-10	Surveillance Central, LLBG 2, LLBG 2-PA
299-E27-11	B-63, LLBG 2, LLBG 2-PA
299-E27-12	SST C
299-E27-13	SST C
299-E27-16	B-63
299-E27-17	B-63, LLBG 2, LLBG 2-PA, Surveillance Central
299-E27-18	B-63, Surveillance Central
299-E27-19	B-63
299-E27-8	B-63, LLBG 2, LLBG 2-PA
299-E27-9	B-63, LLBG 2, LLBG 2-PA
299-E28-10	Surveillance Central
299-E28-13	Surveillance Central
299-E28-28	LLBG 1, LLBG 1-PA, Surveillance Central
299-E28-7	Surveillance Central
299-E32-2	LLBG 1, LLBG 1-PA, Surveillance Central
299-E32-3	LLBG 1, LLBG 1-PA
299-E32-5	LLBG 1, LLBG 1-PA, Surveillance Central
299-E32-7	LLBG 1, LLBG 1-PA, Surveillance Central
299-E32-8	LLBG 1, LLBG 1-PA, Surveillance Central
299-E33-10	SST B
299-E33-17	SST B
299-E33-20	SST B
299-E33-21	SST B
299-E33-29	LLBG 1, LLBG 1-PA, SST B, Surveillance Central
299-E33-31	SST B
299-E33-32	SST B, Surveillance Central
299-E33-33	B-63, Surveillance Central
299-E33-334	SST B, Surveillance Central
299-E33-335	SST B, Surveillance Central
299-E33-337	SST B
299-E33-339	SST B
299-E33-36	B-63
299-E33-37	B-63, Surveillance Central
299-E33-9	SST B
299-E34-10	B-63, LLBG 2, LLBG 2-PA
299-E34-11	Surveillance Central
299-E34-12	LLBG 2, LLBG 2-PA
299-E34-2	LLBG 2, LLBG 2-PA, Surveillance Central
299-E34-3	LLBG 2, LLBG 2-PA
299-E34-5	LLBG 2, LLBG 2-PA, Surveillance Central
299-E34-7	LLBG 2, LLBG 2-PA, Surveillance Central
299-E34-8	B-63
299-E34-9	LLBG 2, LLBG 2-PA, Surveillance Central
699-43-41E	Surveillance Central
699-44-39B	Surveillance Central, B Pond
699-50-53B	Surveillance Basalt
699-52-19	Surveillance Central
699-52-46A	Surveillance Basalt
699-54-34	Surveillance Basalt
699-56-43	Surveillance Basalt
699-56-53	Surveillance Basalt
699-62-43F	Surveillance 100 FR3
699-63-58	Surveillance 100 BC5
C4124	Proposed new well NE of SST C
C4125	Proposed new well W/SW of SST C
C4126	Proposed new well SW of SST C
C4127	Proposed new well S of SST C

Appendix C

Proposed 200-BP-5 Operable Unit Groundwater Monitoring Network – Plate Maps

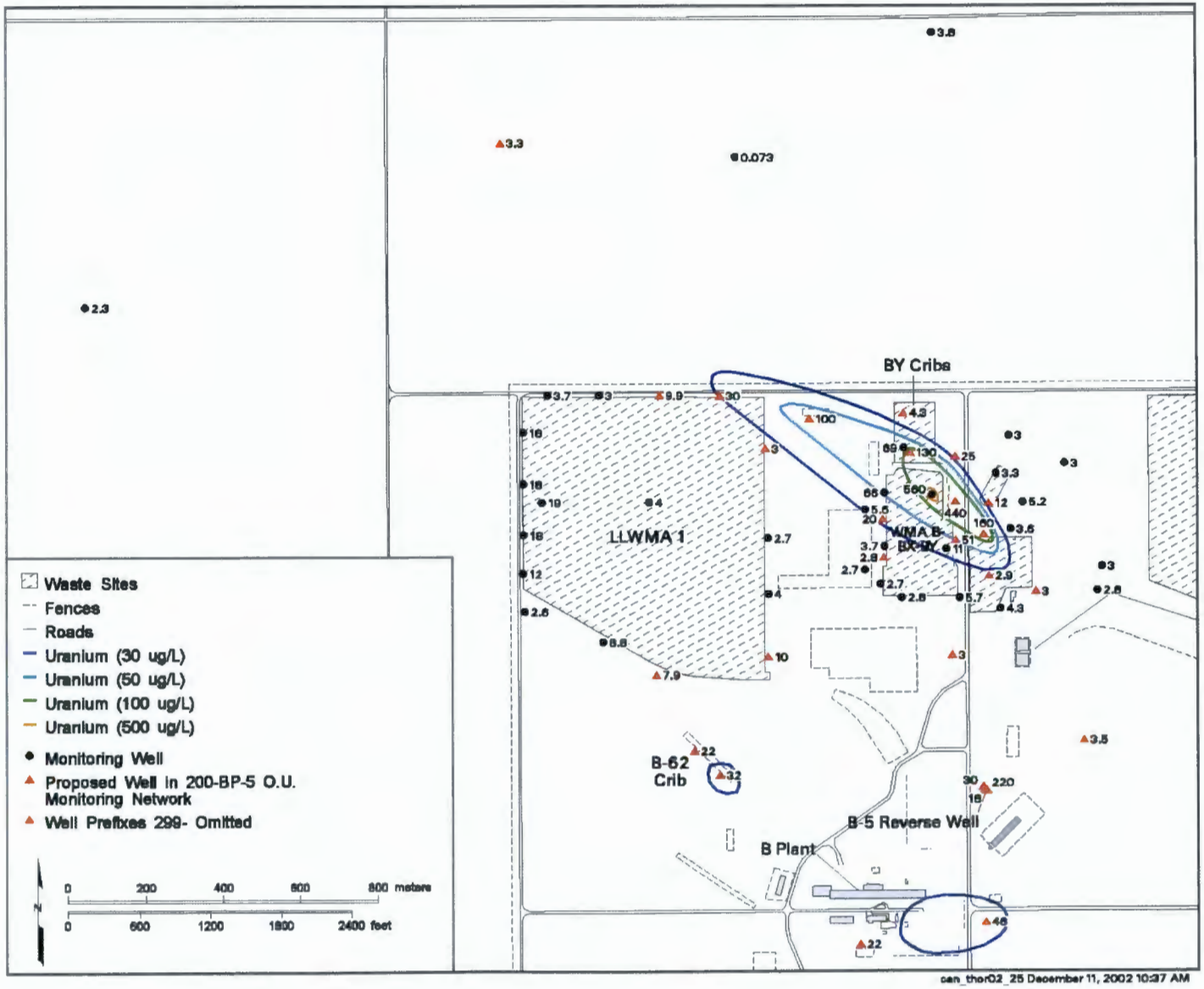

Figure C.1. Uranium Distribution in the 200-BP-5 Operable Unit

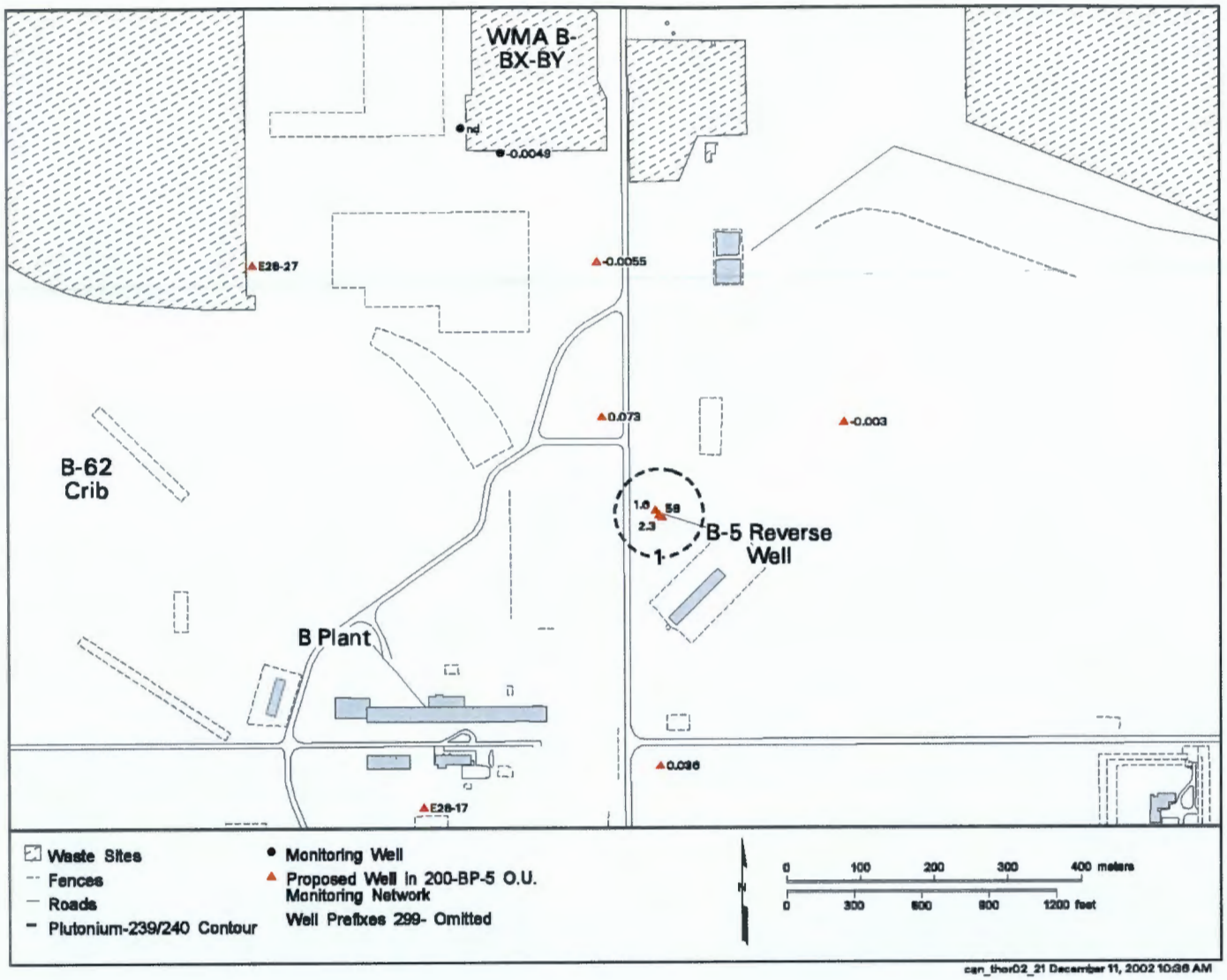

Figure C.2. Plutonium Distribution in the 200-BP-5 Operable Unit

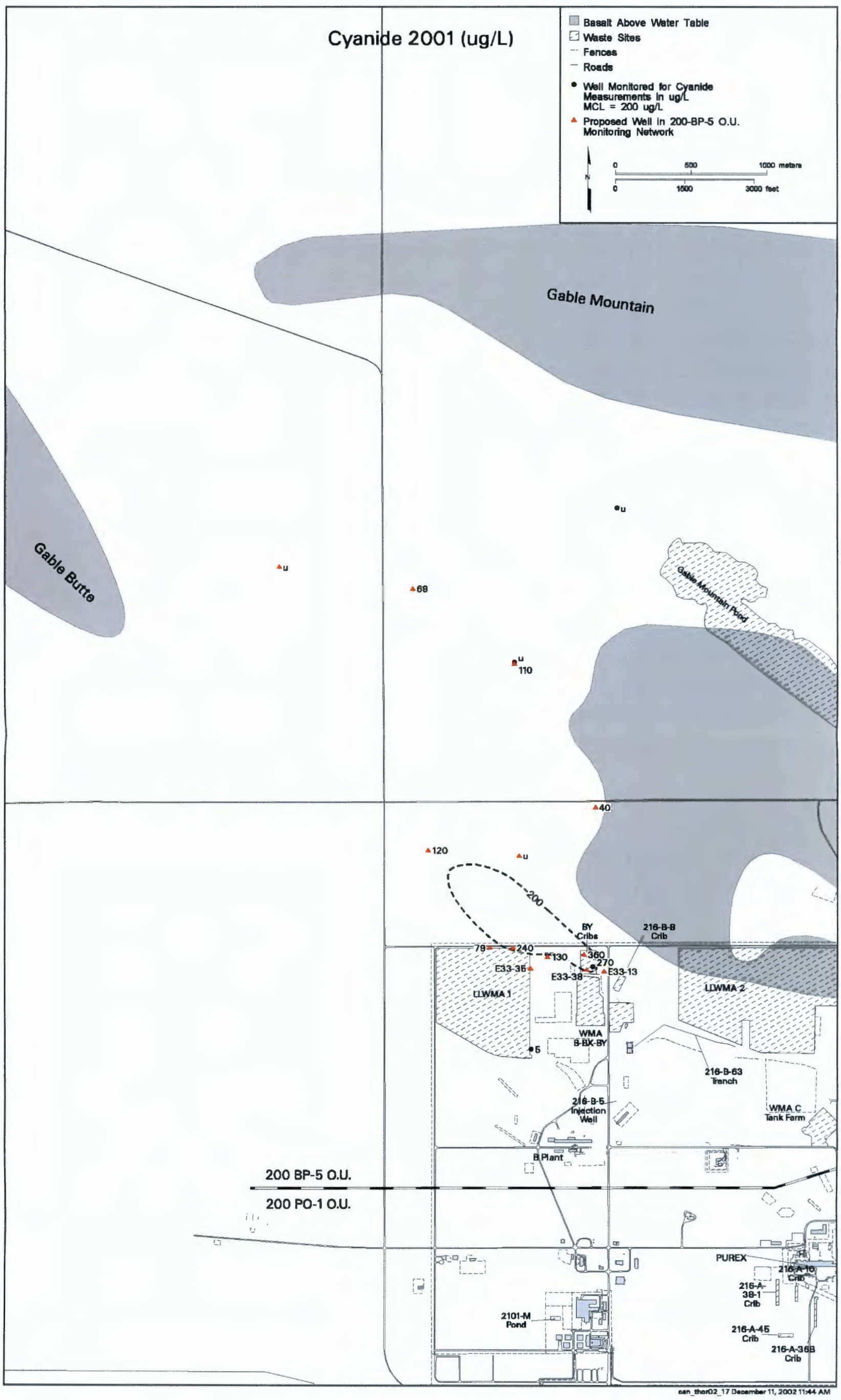

Figure C.3. Cyanide Distribution in the 200-BP-5 Operable Unit

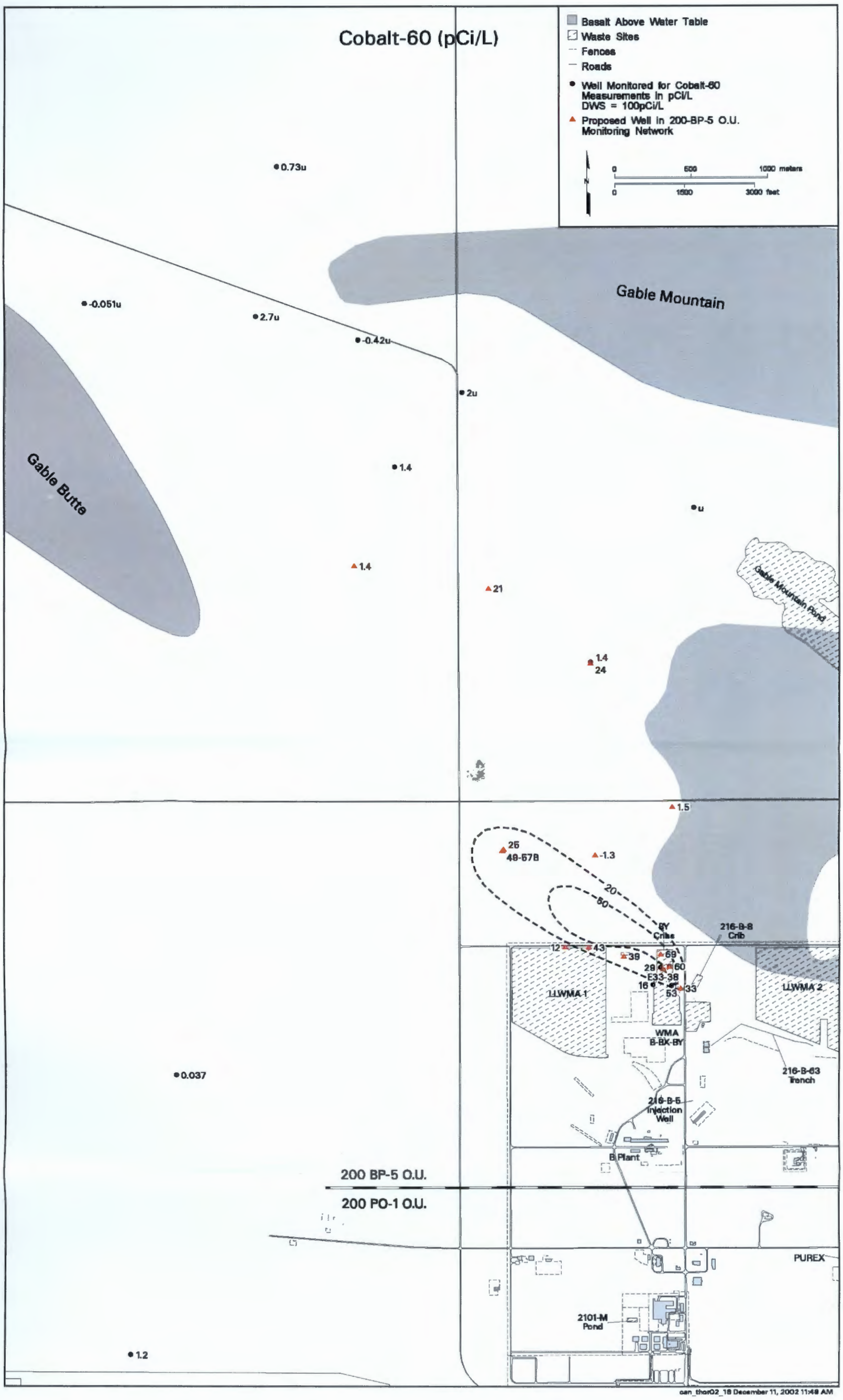

Figure C.4. Cobalt-60 Distribution in the 200-BP-5 Operable Unit

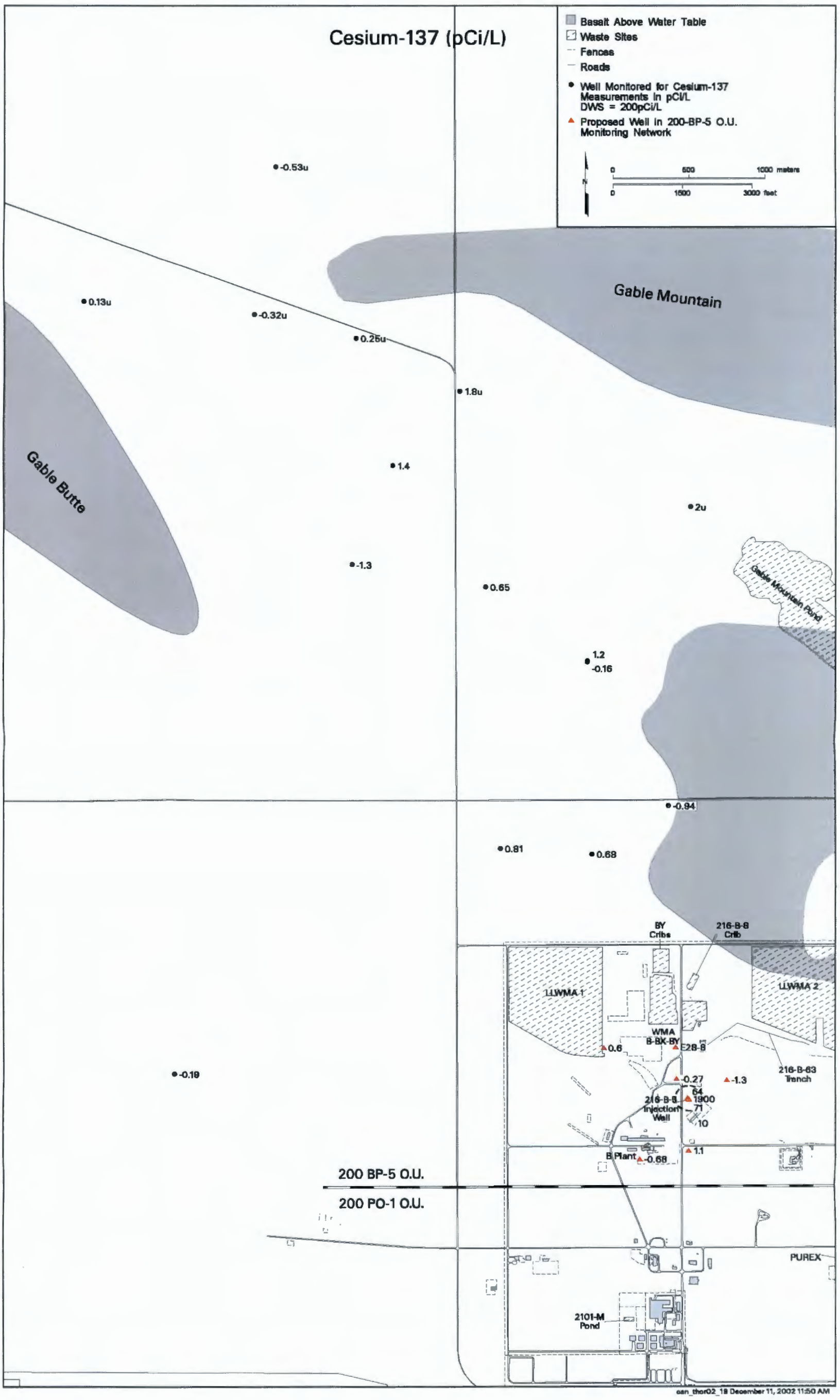

Figure C.5. Cesium-137 Distribution in the 200-BP-5 Operable Unit

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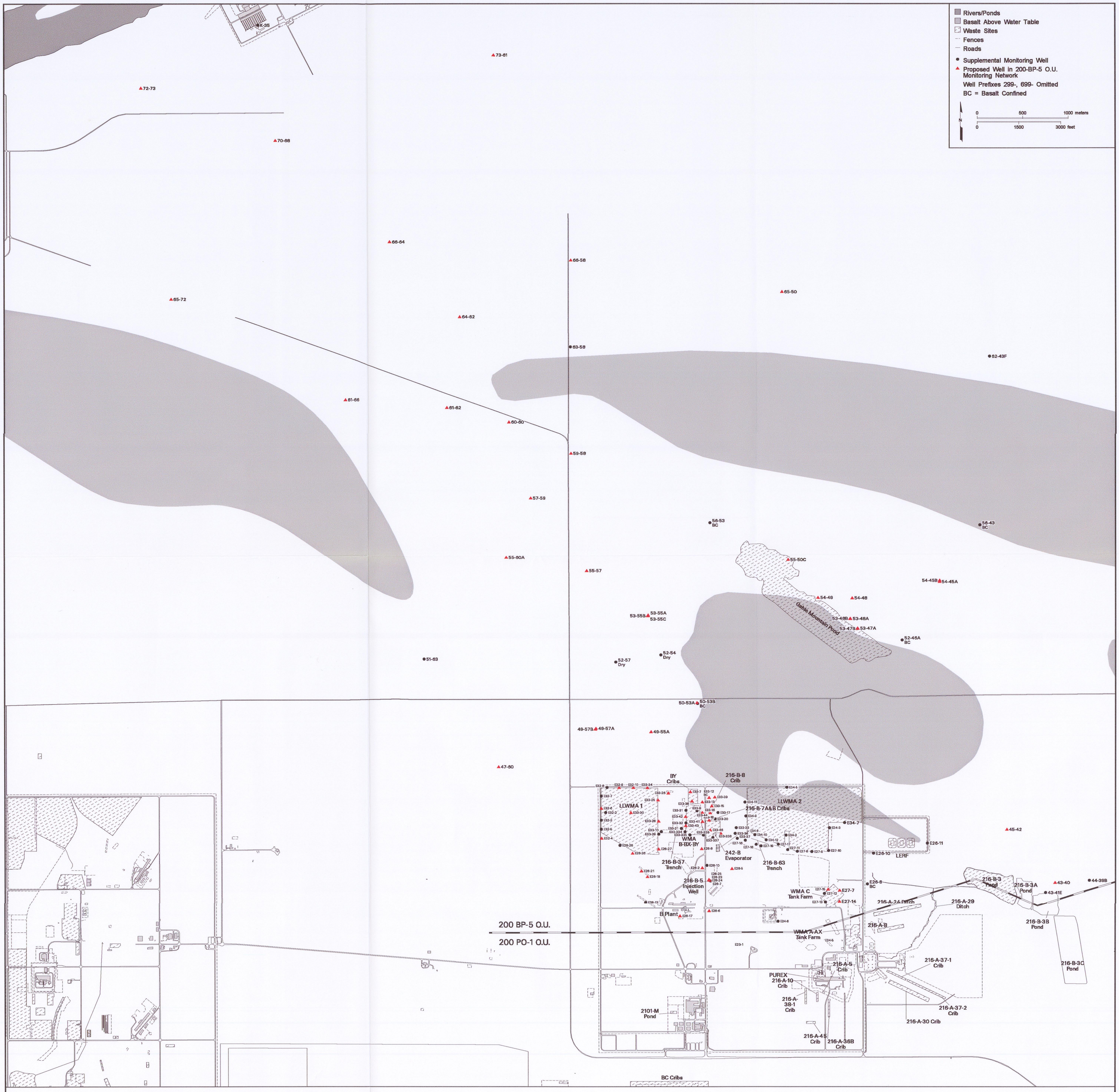

Plate 1. Monitoring Wells in the 200-BP-5 Operable Unit

can_thor02_15 March 06, 2003 1:38 PM

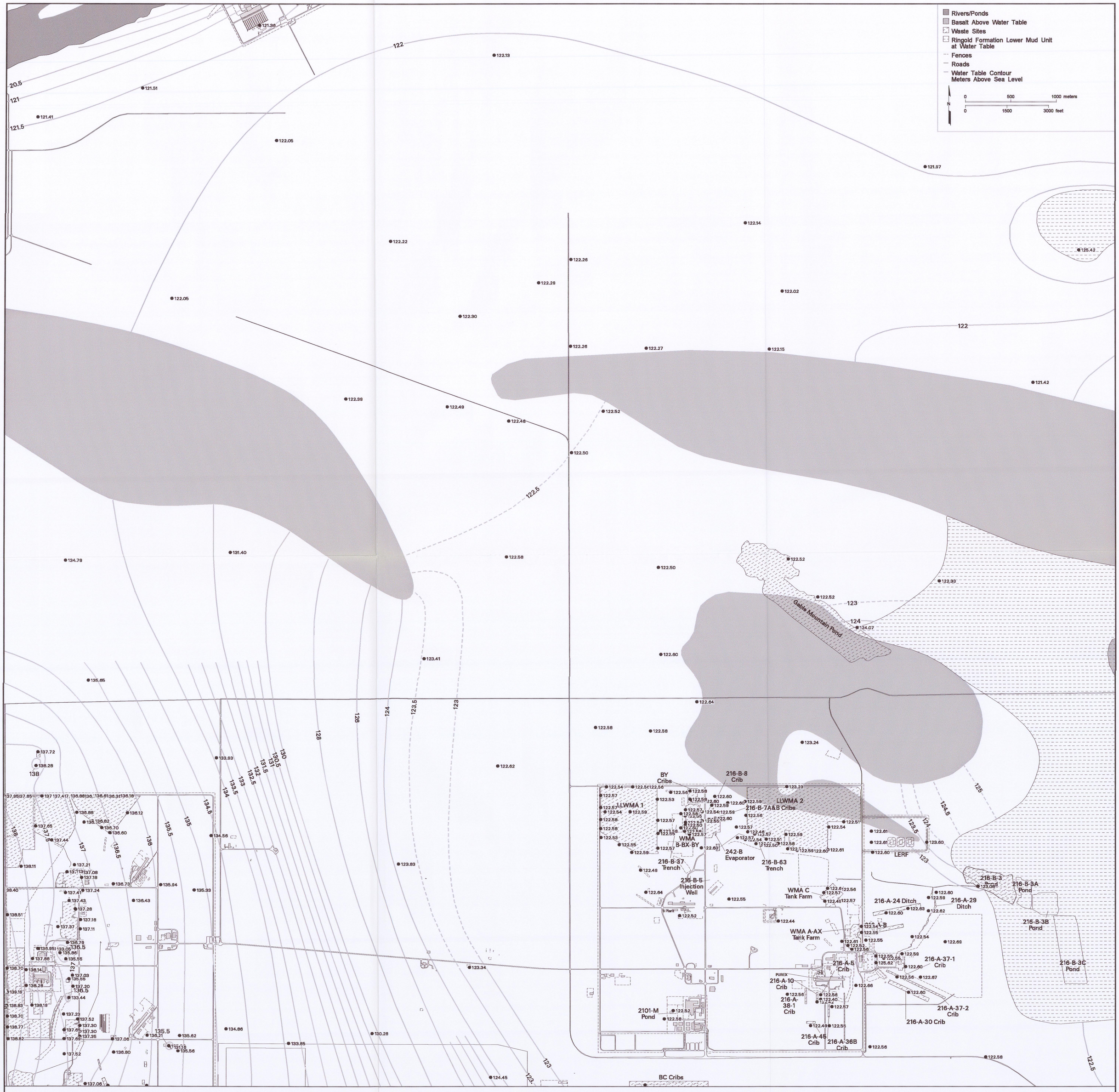

Plate 2. Water Table in the 200-BP-5 Operable Unit, March 2001

can_thor02_14 March 06, 2003 1:38 PM

Plate 3. Technetium-99 Average Activities, 2001

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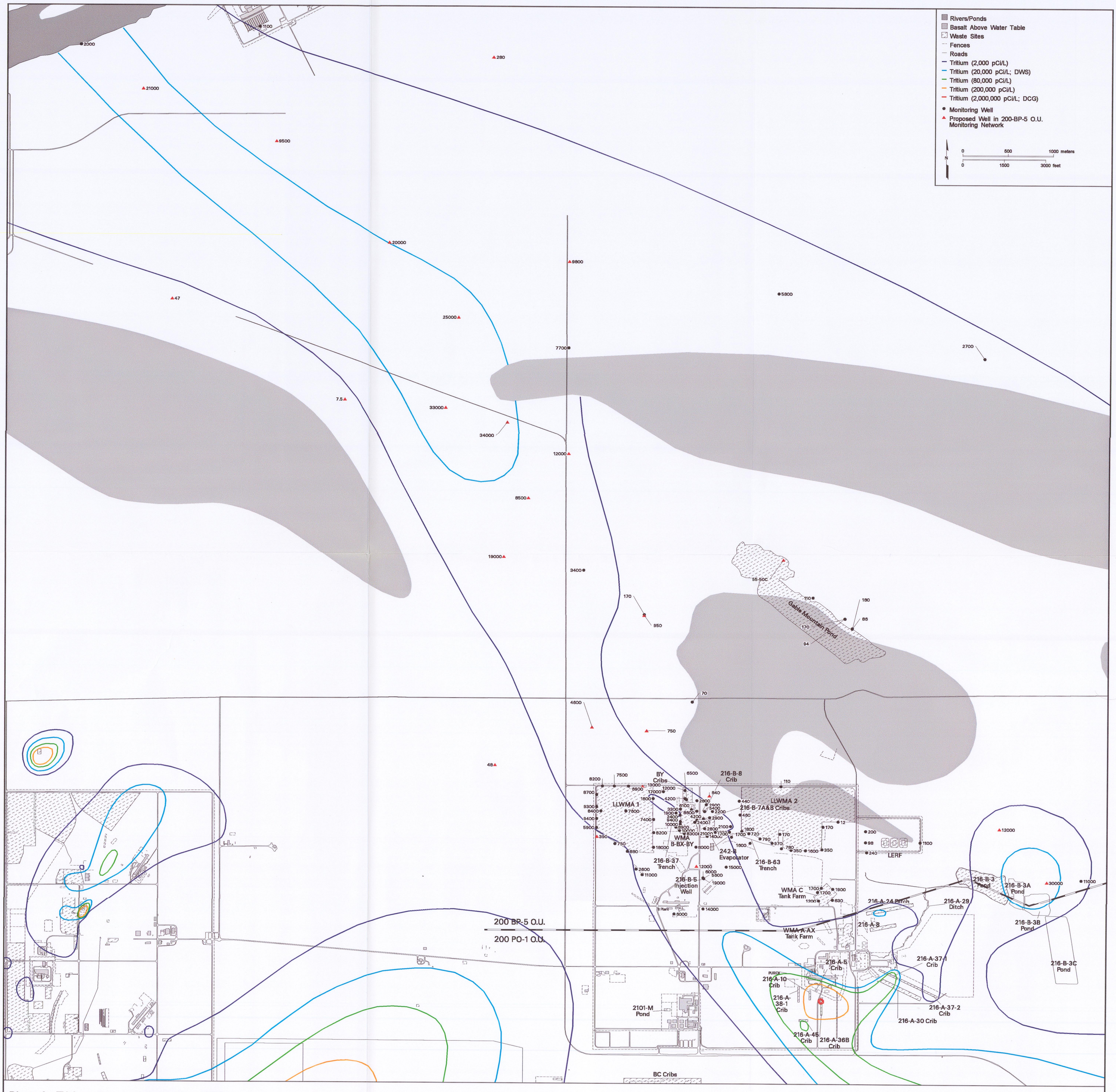

Plate 4. Tritium Average Activities, 2001

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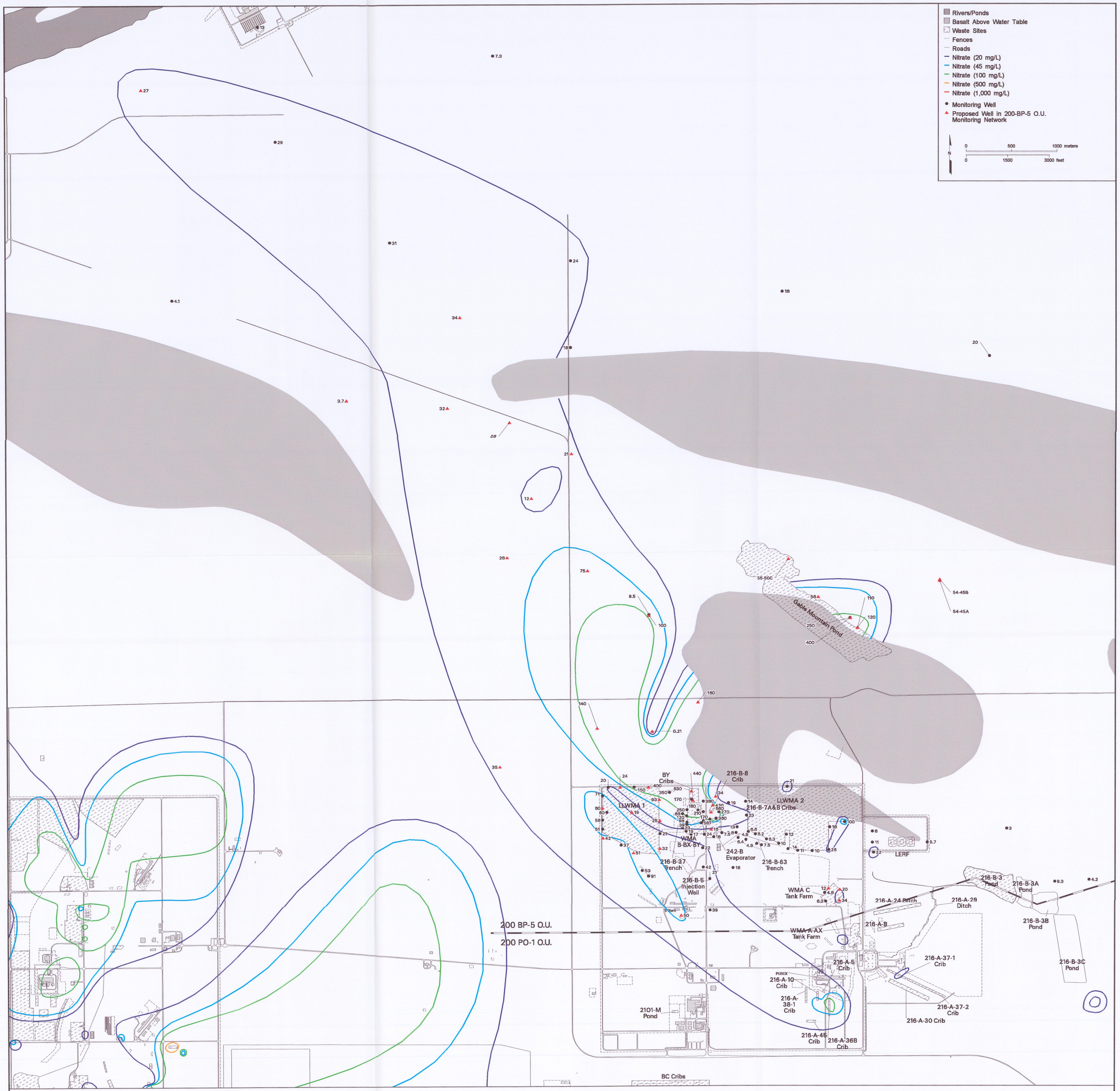

Plate 5. Nitrate Average Concentrations, 2001

can_thor02_06 March 05, 2003 1:37 PM

Plate 6. Iodine-129 Average Activities, 2001

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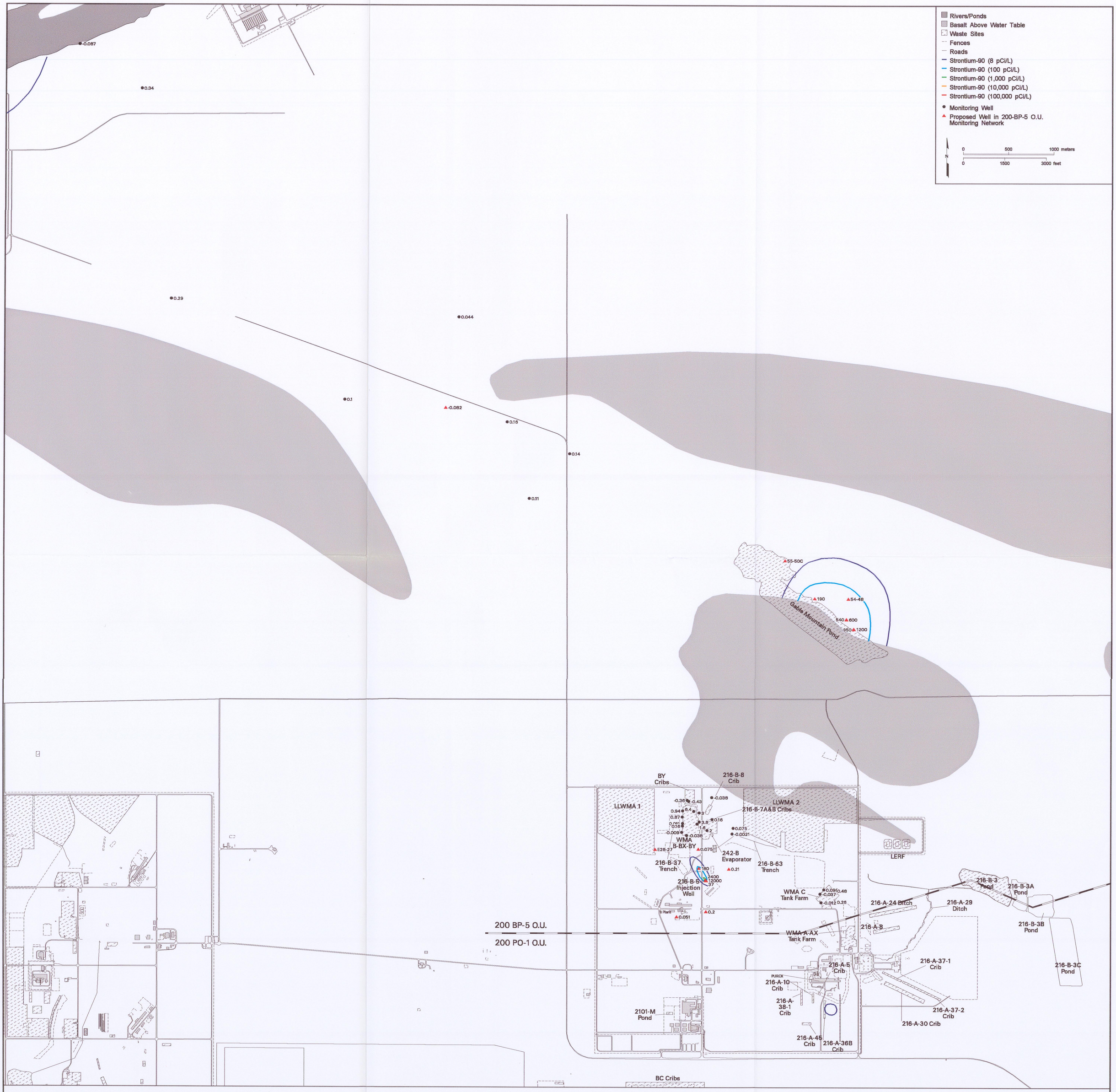

Plate 7. Strontium-90 Average Activities, 2001

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