

**Connecticut Yankee Atomic Power Company**

**Haddam Neck Plant  
362 Injun Hollow Road  
East Hampton, CT 06424-3099**

**Semi-Annual Groundwater Monitoring Report  
Third and Fourth Quarter 2005  
Quarterly Sampling Events**

**Prepared by  
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(Appendices included in PDF format on attached CD-ROM)

# 1 Introduction

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## 1.1 Groundwater Monitoring Program Overview

This report presents a compilation of the groundwater analytical results and related field measurements associated with two groundwater-sampling events conducted during third and fourth quarter 2005 at the Connecticut Yankee Atomic Power Company (CYAPCo or CY) Haddam Neck Plant (HNP) located in Haddam Neck, Connecticut (CT). These groundwater-sampling events were performed in compliance with the quarterly groundwater monitoring program Quality Assurance Project Plan (GMP QAPP 2005) and Phase II Hydrogeologic Investigation Work Plan (HIWP, 2002), and to provide characterization data input to the CY License Termination Plan (LTP 2005).

The objective of this monitoring report is to provide a summary and evaluation of the groundwater analytical results and groundwater elevation data to develop an understanding of plume status concerning substances of concern (SOCs) at the HNP. A focused list of individual radioactive and non-radioactive constituents has been identified as SOCs that constitute groundwater contamination at the site. The radiological SOCs at HNP have been identified as tritium (H3), strontium-90 (Sr-90), cesium-137 (Cs-137), and cobalt-60 (Co-60), all predictable byproducts of the nuclear fission reaction that was the heat source for this power generating plant. Boron, the only non-radioactive SOC identified at the facility, was used as a neutron absorber in the primary cooling water, and when detected above background levels in environmental samples at HNP is used as an indicator of plant-related contamination and also as an effective tracer of potentially contaminated groundwater. Boron will be evaluated as part of the ongoing RCRA Corrective Action Program (CAP) under regulatory authority of the United States Environmental Protection Agency (USEPA) and in accordance with the Connecticut Property Transfer Act.

The primary scope of the Groundwater Monitoring Program (GWMP) is to assess groundwater conditions in the industrial area, the site of former plant operations and probable source areas, and the upper peninsula area, which is adjacent to the industrial area, by conducting quarterly sampling events. These two areas are where SOCs have been historically detected and migration pathways are likely, resulting in the greater number of wells in the monitoring network. An overview of the HNP property and the various area designations is provided in Figure 1-1.

## 1.2 Groundwater Monitoring Program Plans and Procedures

The third and fourth quarter of 2005 GWMP sampling and analysis was conducted following specific guidance under applicable CY procedures. The framework for the GWMP is outlined as an internal CY HNP procedure that describes the methodology for

implementing the required quarterly groundwater sampling and analysis (RPM 5.3-0). The GWMP Work Plan and Inspection Record (WP&IR) states specific permits, tags, and the required approval signatures needed to initiate and complete each quarterly sampling event. The Groundwater Sampling Event Planning and Data Management procedure (RPM 5.3-3) documents what elements should be in a Groundwater Sampling Event Plan, including data quality objectives (DQOs), sample records, analysis parameters, and equipment. The methodology for representative sample collection and field measurements, including groundwater levels, are described in the Groundwater Level Measurement and Sample Collection in Monitoring Wells procedure (RPM 5.3-1) and Sample Collection in Westbay Multi-port Monitoring Wells (RPM 5.2-9) as attached in Appendix A.

Additional sampling event-specific plans were developed for both the third and fourth quarter sampling events. A Groundwater Sampling Event Plan was developed following guidelines set forth in the Groundwater Sampling Event Planning and Data Management procedure. All sampling and analysis was performed in accordance with the requirements of the GMP QAPP (Reference GMP QAPP 2005).

## 2 Groundwater Flow and Direction

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### 2.1 Background

Groundwater elevation measurements are collected from each monitoring well sampled during the quarterly groundwater sampling events to provide a synoptic picture of hydrogeologic conditions at the facility. These groundwater elevation data are collected to enhance the understanding of groundwater flow and direction, which are essential to assessment of plume status for the primary SOCs at HNP. The groundwater elevations were measured in accordance with the Groundwater Level Measurement and Sample Collection in Monitoring Wells procedure (RPM 5.3-1).

The groundwater and surface monitoring well network at HNP is shown by specific area in Figures 2-1 and 2-2. The industrial and upper peninsula area locations are shown in Figure 2-1 and lower peninsula locations in Figure 2-2.

As part of the plant monitoring effort, procedures have been implemented to ensure valid, consistent data are collected to provide quality control for the evaluation of hydraulic data and modifications to the hydrogeologic conceptual site model (CSM) as needed. Civil surveys to establish horizontal and vertical positions of the monitoring wells at HNP have been performed. In addition to providing horizontal control for the wells surveyed, an accurate vertical datum was established for the wells surveyed to the nearest 0.01-foot, enabling quality control for accurate groundwater elevations.

During the summer and fall 2005 additional monitoring wells were installed at HNP. These newly installed monitoring wells were either replacements for monitoring wells destroyed as part of decommissioning activities, or represent new monitoring locations implemented to provide additional site characterization. A summary of the replacement wells and new monitoring wells is provided in Table 2-1. Many of the newly installed monitoring wells were not completed at the time of the third quarter sampling event and results from those monitoring wells are included in the fourth quarter data.

A network of pressure transducers was installed in selected groundwater monitoring wells and one surface water monitoring location to collect continuous water levels and temperatures throughout HNP for an extended period of time. The pressure transducers network was installed between January 14 and January 27 2004, and the pressure transducer have been collecting elevation data since January 27, 2004.

As part of the Phase I hydrogeologic characterization effort, the hydrogeologic CSM at the HNP proposed three primary hydrostratigraphic units: 1) the unconsolidated deposits, 2) the shallow bedrock, and 3) the deep bedrock. Additional information developed from the hydraulic response to various pumping and de-watering activities

within the hydrogeologic units associated with decommissioning further refined the hydrogeologic CSM at the site. Based on the hydraulic response to the pumping activities, the hydrostratigraphy has been refined to include two major units that comprise an unconfined aquifer and a confined aquifer. The unconfined aquifer occurs within the unconsolidated deposits and the more fractured portions of the shallow bedrock and is defined by the water table. Those parts of shallow bedrock included in the unconfined aquifer typically do not include a sporadic confining layer of till. The confined aquifer comprises the deeper, more competent bedrock.

A third aquifer is recognized in the northwestern portion of the site. This perched aquifer is located in the restricted portion of the property, and shallow groundwater occurs within swampy deposits present in that area. This groundwater is believed to be in equilibrium with the storm water pond. A small stream discharges to the pond, and the pond water flows through a weir to a culvert on the southeast end of the pond. This perched groundwater is not believed to contribute significant recharge to the unconfined aquifer, due to the low permeability of the swampy deposits and the continuous discharge from the pond to the culvert.

The aquifer designation for all monitoring wells included in the third and fourth quarter sampling effort is included in Table 2-1. Table 2-1 also provides well construction material and development information for the groundwater-monitoring network, including horizontal coordinates and the vertical elevations of the measuring points for water level gauging.

The data from the pressure transducer network is used to generate potentiometric maps for each of the three aquifers. The relationship between groundwater flow and direction at the industrial and upper peninsula areas, and the distribution of SOCs is discussed in Section 6 of this report.

## 2.2 Groundwater Elevation Data

A network of 33 data-logging pressure transducers was installed in monitoring wells at HNP and in the Connecticut River adjacent to the plant in January 2004. This network was designed to provide an automated record of changes in water level elevation across the industrial portion of the site. These long-term water elevation data form the basis for meeting the following data needs:

- Quantify the horizontal hydraulic gradient across the site.
- Identify the apparent groundwater flow direction across the site.
- Quantify the apparent vertical pressure differences between the identified aquifer units across the site.
- Identify aquifer response to recharge events (e.g., rainfall events) and groundwater extraction events (e.g., mat sump operation).

- Quantify aquifer response to tidal fluctuations and general river stage variations in the Connecticut River.

As a secondary data point, the pressure transducers log water temperature at the same frequency as the water level.

The transducer system was installed starting in the last week of January 2004. The data loggers were initially set up to record measurements on one-minute intervals and were subsequently re-programmed to record measurements on five-minute intervals in May 2004. The transducers are downloaded quarterly, with more frequent downloads if data are required for specific needs. Significant events related to the water level monitoring system during the third and fourth quarter 2005 are shown in Table 2-2.

The transducer system includes two data-logging barometric pressure transducers. These units are maintained at atmospheric conditions because the submersible transducers deployed in the monitoring wells are not barometric pressure-compensated. The electronic data are downloaded from the monitoring well data loggers and the barometric pressure transducers using a portable computer. Data from the submerged transducers are then corrected for barometric pressure fluctuations using proprietary software from the transducer manufacturer that calculates the corrected pressure indicated by the submerged transducers. The resulting pressure measurements are converted to water elevations by calculating the resultant height of the water column in each well at the time of measurement and adjusting for the measured well head elevation. The water elevations calculated from the transducer data are then compared to periodic manual measurements collected using water level sounders for accuracy and precision assessment.

The detailed hydrographs for each instrumented location (i.e., the monitoring wells and the river) are included in Appendix B of this document. The hydrographs are presented semiannually for each monitored location, three individual hydrographs are presented; one graph of the observed water elevation only, one graph of the water level and associated temperature, and one graph of the water level compared to total daily rainfall as recorded at HNP. A data quality assessment of the hydrograph data evaluation was developed and is also included in Appendix B. The overall hydrographs are summarized and discussed in the following subsections.

### **2.2.1 Third and Fourth Quarter 2005 Hydrographs**

The hydrographs for the third and fourth quarter of calendar year 2005 are discussed in the following subsections.

#### **Connecticut River**

The Connecticut River exhibited strong, regular tidal fluctuation and only small variations in seasonal river stage during the period from July through December 2005.

During the third and Fourth quarter 2005, the Connecticut River exhibited a steady water level elevation of approximately 1 foot MSL +/- about 1.5 feet of regular fluctuation due to tide. However, during October, due to rain in excess of one inch on

several days, the water elevation in the river was between 2 and 6 feet MSL for about 20 days.

The Connecticut River transducer was removed in December, 2005. This transducer was replaced in March 2006 with a permanent transducer in the discharge canal.

#### **Reactor Foundation Mat Dewatering Sump**

The foundation mat dewatering sump, that was located adjacent to the reactor containment building on the plant-south side, was in nearly-continuous operation for the life of the HNP. Evaluation of the construction drawings of the mat sump indicated that it was in communication with the unconfined and confined aquifers at the site. A data logging pressure transducer in the sump recorded water levels from the beginning of 2004 through the end of September 2005.

The mat sump was equipped with two submersible electric pumps that operated on a level control systems to maintain a depressed water level in the sump. The sump pumps operated on a ten-foot control level, with the pumps starting when water reached an approximate elevation of -13 feet MSL, and stopping when water reached an approximate elevation of -23 feet MSL. These pumps were shut-off in August 2005 to allow groundwater levels to recharge to natural conditions. The long-term average dynamic water elevation in the mat sump during pumping had been approximately -20 feet MSL. In October, when the mat sump transducer data was last downloaded, the water level had recharged to approximately 3 ft MSL.

#### **Unconfined Aquifer:**

All of the monitoring wells screened in the unconfined aquifer exhibited seasonal variations in water level. The characteristics of the wells screened in the unconfined aquifer are summarized in Table 2-3. Several of the wells were observed to exhibit draw-down in response to dewatering activities in the foundation mat sump before it was permanently shut-off in August 2005. The characteristics of the wells screened in the unconfined aquifer are summarized in Table 2-3.

#### **Confined Aquifer:**

Monitoring wells screened within bedrock underlying the unconfined formation are considered to be in the confined aquifer. The characteristics of the wells screened in the confined aquifer are summarized in Table 2-4. The confined aquifer wells are generally not clearly and immediately responsive to local precipitation; however, the 13+ inches of rain in October 2005 affected all the wells onsite and, specifically, recharged the aquifers to natural groundwater conditions. Most of the confined wells exhibit pressure fluctuations that appear coincidental with the tidal fluctuations observed in the river.

Transducer data indicate an overall increase in water levels of the confined aquifer monitoring wells after the mat sump was shutoff in August 2005. As with the monitoring wells completed in the unconfined aquifers, the confined monitoring wells that were sampled as part of the quarterly groundwater monitoring event exhibited transient drawdown effects during sample collection.

### **2.2.2 Third Quarter 2005 Groundwater Flow Maps**

Groundwater flow maps for unconfined and confined aquifers have been developed based on groundwater elevations measured on September 11, 2005 (Table 2-5). The groundwater flow maps for each aquifer are discussed in the following sections.

#### **Unconfined Aquifer**

The groundwater elevations measured in the unconfined aquifer are representative of the water table surface across the plant property. Groundwater contours mapped in the unconfined aquifer are largely inferred, and generally consistent with the surface topography. Based on the inferred contours, groundwater flow in the unconfined aquifer is generally south and southeast, towards the Connecticut River. The groundwater contours as mapped depict discharge to the Connecticut River (Figure 2-3).

Groundwater flow in the unconfined aquifer is impacted by the presence of subsurface barriers to flow. In the central portion of the industrial area several deep concrete structures are present from the ground surface to the top of bedrock. These structures include the reactor containment building (RCB), the discharge tunnels and service building walls. As shown in Figure 2-3, the groundwater contours are mapped much farther to the north in the central portion of the industrial area relative to the western portion of the site where the subsurface concrete structures are not present. In the central portion of the industrial area, the RCB and the discharge tunnels displace the groundwater contours. The displacement of the contour is a function of the presence of the subsurface concrete structures impeding groundwater flow in the unconsolidated sediments portion of the unconfined aquifer in the area of the RCB and discharge tunnels.

#### **Confined Aquifer**

Groundwater flow in the confined aquifer for the third quarter 2005 is illustrated in Figure 2-4. Groundwater flow in the confined aquifer is generally to the south and southeast, similar to the flow direction exhibited by the unconfined aquifer. During the third quarter, groundwater across the site was recovering from cessation of de-watering activities and the discontinuation of the mat sump operations. While most of the unconfined aquifer had recovered to ambient levels, the confined aquifer in the central portion of the industrial area was continuing to reach equilibrium. Based on the large upward gradients observed in monitoring well pair MW-109D/S and in the deep Westbay multilevel monitoring wells, groundwater in the confined aquifer is interpreted to discharge to the Connecticut River. MW-109D and MW-109S are adjacent to the river and screened in the confined and unconfined aquifers, respectively. The strong upward gradient in the deeper monitoring wells is consistent with both discharge to the river, and a flow direction towards the Connecticut River for the confined aquifer (Table 2-5).

### **2.2.3 Fourth Quarter 2005 Groundwater Flow Maps**

Groundwater flow maps for each of the three aquifers have been developed based on groundwater elevations measured on November 6, 2005 (Table 2-5). The groundwater flow maps for each aquifer are discussed in the following sections.

### **Unconfined Aquifer**

Groundwater measured elevations in the unconfined aquifer related to the fourth quarter sampling effort are shown in Figure 2-5. The groundwater elevations measured in the unconfined aquifer are representative of the water table surface in the plant property. Potentiometric contours mapped in the unconsolidated unit are largely inferred, and generally consistent with the surface topography. Consistent with the third quarter groundwater flow maps, groundwater flow in the unconsolidated unit is generally southeast, towards the Connecticut River. Groundwater elevations across the FINP are generally higher in the fourth quarter relative to the third quarter. The groundwater contours are mapped to depict discharge to the Connecticut River.

The impacts of subsurface barriers interpreted in the third quarter results are also evident in the fourth quarter water levels. The contours are displaced to the north in the central portion of the industrial area, where the RCB and discharge tunnels are located (Figures 2-5). The displacement of the contours is a function of the presence of the subsurface concrete structures (i.e., RCB and discharge tunnels) that impede groundwater flow in the unconsolidated portion of the unconfined aquifer.

### **Confined Aquifer**

Groundwater flow in the confined aquifer for the fourth quarter is illustrated in Figure 2-6. While the results from the third quarter had indicated that the confined aquifer in the central portion of the industrial area were still recovering from the effects of de-watering activity and the cessation of the mat sump, water levels in the confined aquifer in the fourth quarter appear to have equilibrated. Groundwater flow in the confined aquifer is to the south and southeast, similar to that exhibited in the unconfined aquifer. (Figure 2-6).

The large upward gradients observed in monitoring well pair MW-109D/S and the Westbay multi-level wells in the third quarter results are also present in the fourth quarter, consistent with both discharge to the Connecticut River, and a flow direction towards the river.

### 3 Groundwater Sampling and Analysis

This monitoring report includes the laboratory analytical results for two quarterly groundwater-sampling events. In addition, additional analyses were performed on samples collected from Westbay Multi-port (MP) wells installed in the industrial area.

The third quarter (2005 Q3) sampling event occurred between October 10 and November 2, 2005. The fourth quarter (2005 Q4) sampling event occurred between December 6 and December 28 2005. Multi-port well samples were collected between July and November, 2005. Additionally, Westbay multi-port wells were sampled during the fourth quarter sample event. The analytical results of these samples are discussed in detail in Section 4.

The groundwater samples were forwarded to an offsite laboratory for radiochemical and inorganic analyses. This report includes a discussion of data validation and provides a summary of the radio-analytical results and associated quality assurance (QA) data. Some biases were observed in the radio-analytical data at low-level concentrations near the reported MDC. These positive and negative biases were observed in rank order trend plots for several nuclides. In some cases where a positive bias was observed, these results were concluded to be false positives and part of the underlying background or baseline distribution based on the homogeneity and normality of the results. These biases are generally limited to analyses performed via liquid scintillation counting (LSC) and gas proportional counting (GPC).

Measurements of field parameters were included as components of the groundwater sampling and are discussed in Section 3.1 and Section 3.2. Copies of the groundwater sampling procedures are included in Appendix A.

Groundwater samples were collected by low-flow sampling methodology utilizing either a peristaltic pump or a stainless steel submersible pump with dedicated polyethylene tubing. As a result of low water level conditions, monitoring well MW-102D was manually purged and sampled during both sample events with a dedicated polyethylene bailer rather than using a pump.

Groundwater samples were collected from each zone in MP Westbay wells MW118A, MW-119, MW-120 and MW-121A using specialized Westbay sampling equipment. It was not necessary to purge each zone prior to sampling as the sample is collected directly from a measurement port that is located within the zone.

The containment mat sump (CMS) was not sampled during the course of these sample events as it was grouted and filled in.

### 3.1 Description of Field Measurements

Several types of field measurements were recorded in each well prior to sampling. Data obtained from these measurements included groundwater levels, the presence or absence of separate-phase fluid, and water quality parameters. These field measurements are essential components for the evaluation of water quality and hydrogeologic conditions at the plant.

Depth-to-water and bottom-of-monitoring-well sounding measurements were determined using an electronic water level meter with a 0.01 foot resolution. Water quality parameters recorded included specific conductance, pH, dissolved oxygen, temperature, oxidation-reduction potential and turbidity. These parameters are continuously measured prior to the sampling of each well until they have stabilized within a 10 percent variation. This procedure is performed to confirm that well conditions have stabilized during the low-flow purging step, indicating enough water has been removed from the well so that a representative groundwater sample can be collected. These parameters were measured using a multi-parameter meter, with sensors arrayed within a flow-through cell. The field parameter data sheets summarizing these measurements are included in Appendix C.

### 3.2 Summary of Field Measurements

The water quality parameter field measurements for the third and fourth quarter 2005 sampling event are summarized in Tables 3-1 and 3-2, respectively. Field Daily Reports (FDRs), which are field notes that document the sampling of each well, are provided in Appendix C. As recorded in the field notes, the field parameters typically stabilized within an acceptable range. One of the criteria for the low-flow sampling methodology employed was to collect samples where the turbidity level had stabilized in the range of 5 to 15 nephelometric turbidity units (NTUs). This range is typically used to indicate the absence of fine silt and particulate matter that may adversely affect the analytical results of the groundwater sample. With few exceptions, the turbidity levels of the groundwater samples were within this range and reasonably consistent with previously collected data.

As noted in past groundwater reports, pH was historically high at monitoring wells MW-106D and MW-122D. Both monitoring wells have been replaced (MWR-106D and MWR-122D) since the second quarter 2005 sampling event, and during the third and fourth quarter 2005 groundwater-sampling events the pH readings from monitoring well MWR-106D and MWR-122D were reported to be in the 6.6 to 9.4 pH range. These wells have trended as high as 11.18 to 11.39 during the December 2001 sampling event. The current pH values for MWR-106D are in the normal range (6.6 to 7.45), but the pH observed for MWR-122D is still somewhat high (8.75-9.4). The most likely cause of the historic elevated pH in these wells was intrusion of cement grout into the screened intervals during well construction. While the replacement for MW-106D has removed the elevated pH values in the replacement well, remnants of the concrete grout may be present in the proximity of the screened interval of MWR-122D.

### 3.3 Sample Locations

Monitoring wells sampled during the third quarter 2005 event are located within the industrial area, parking lot, peninsula and support building areas, as indicated in Table 3-3. Several monitoring wells (MW-103D, MW-103S, MW-114S, and MW-115S) were planned but not sampled during this sample event due to insufficient water or inaccessibility attributed to decommissioning activities. As previously identified, the CMS was physically removed from the sampling network. Several new wells were sampled during the third quarter (MW-131, MW-131D&S, MW-132D&S, MW-134 and MW-135).

Monitoring wells MW-114S and MW-115S were planned but not sampled during the fourth quarter event due to insufficient water. Monitoring wells sampled during the fourth quarter 2005 sample event are located within the industrial area, parking lot, peninsula and EOF areas, as indicated in Table 3-4. Several replacement wells were sampled during the fourth quarter (MWR-103D&S, MWR-105D&S and MWR-122D). New wells sampled during this round included MW-103A and MW-103B. The Westbay multi-port wells were also sampled as part of the fourth quarter round.

Fourth quarter 2005 groundwater samples were collected from each zone in Westbay multi-port wells, MW-118A, MW-119, MW-120 and MW-121A using specialized Westbay sampling equipment during the December 2005 timeframe.

### 3.4 Routine Lab Analyses

All wells sampled as part of the two quarterly sampling events were analyzed for gross alpha, gross beta and gamma isotopic analysis. A number of industrial area monitoring wells were also sampled and analyzed for boron, tritium and Sr-90. Samples were analyzed for the following constituents and by the listed methodologies:

- Boron via EPA method 6010B and 6020
- Gross Alpha via EPA method 900
- Gross Beta via EPA method 900
- Tritium via EPA method 906.0
- Gamma emitting fission and activation products by gamma spectroscopy
- Sr-90 via EPA method 905.5 and gas proportional counting

### 3.5 HTD Lab Analyses and Locations

In addition to the above analyses, samples from a subset of various locations were analyzed during each sampling event for Hard-To-Detect (HTD) plant-related radionuclides. These HTDs include alpha, beta and X-ray emitting, fission and activation product radionuclides. The HTD analytes and analytical methodologies included the following:

- Carbon-14 via liquid scintillation

- Iron-55 via liquid scintillation
- Nickel-63 via liquid scintillation
- Plutonium-241 via liquid scintillation
- Strontium-90 via EPA method 905.5 and gas proportional counting
- Tc-99 via liquid scintillation
- Alpha-emitting transuranics (isotopic plutonium, curium, americium) via alpha spectroscopy
- Beta-emitting Pu-241 via liquid scintillation

The lab analytical results are discussed in Section 4.0.

### **3.6 Total and Isotopic Uranium Analyses and Locations**

During the third and fourth quarter 2005 sampling events, a sub-set of samples were analyzed for total uranium by ASTM D 5174 using a kinetic phosphorescence analyzer (KPA). The results of analyses of the quarterly site-wide groundwater samples are discussed in Section 4.0.

A sub-set of the samples analyzed for total uranium, were selected for uranium isotopic analysis. These samples were analyzed for the following isotopic constituents and by the listed methodologies:

- U-234, U-235 and U-238 via alpha spectroscopy
- U-235, U-238, total U and U-235/Total Uranium ratio via inductively coupled mass spectrometry (ICP-MS)

The results of analysis of these uranium samples are discussed in Section 4.0.

## 4 Laboratory Analytical Results

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The observed concentrations of the SOCs were compared to selected standards. Groundwater has been designated by the CTDEP as a GA area. Under the CTDEP Remediation Standard Regulations (RSRs) the aquifer must be treated as a potential source of drinking water, and the RSRs for groundwater protection apply. For radiological constituents, the maximum contaminant level (MCL) promulgated under the Federal Safe Drinking Water Act regulations by the United States Environmental Protection Agency have been approved as site-specific RSRs.

The MCL for beta and photon emitters (such as Sr-90 and Cs-137) is a dose-based 4-mrem/year, calculated using an agency-specified target organ dose methodology. The concentration of a single nuclide in water that would result in a dose of 4-mrem/year is often used as the MCL. This concentration is referred to as the  $C_1$  concentration, or the derived dose concentration. If only a single beta/photon emitter is present in drinking water, the derived concentration is the MCL for that nuclide. If, however, multiple beta/photon emitters are present in the sample, the fractional dose contribution of each nuclide is summed to determine the total dose. It may be noted that by applying the NRC Total Effective Dose Equivalent (TEDE) calculation method, the yearly dose corresponding to the MCL concentrations for tritium and Sr-90 would be less than 1 mrem/yr for each nuclide.

Fifty-one (51) groundwater samples from forty-seven (47) locations within the existing site-wide monitoring well network were collected and analyzed during the third quarter 2005, groundwater-sampling event. Three (3) duplicates and one (1) equipment blank were also collected in this sampling effort. Boron, total uranium and radiochemical analytical results are summarized in Appendix D.1 and complete laboratory analytical data packages are included as Appendix D.2. Total, or unfiltered groundwater samples were collected for all constituents.

A total of forty-nine (49) samples were collected for analysis from forty-five (45) conventional monitoring wells or locations during the fourth quarter 2005 sampling event. Three (3) duplicates and one (1) equipment blank were collected from the conventional wells. Samples were also collected from 16 zones in 4 Westbay MP well locations in the industrial area. The samples were collected at multi-port depths ranging from 30 to 465 feet below ground surface (BGS). One (1) duplicate and four (4) rinse blanks (one blank from each well) were collected from multi-port wells. Total or unfiltered samples were collected at all locations during this round. Boron, total uranium and radiochemical results are summarized in Appendix D.3 and complete lab analytical packages are provided in Appendix D.4.

December 2005 samples were collected from 21 zones in 4 Westbay MP well locations in the industrial area during the July 2005 to November-December 2005 time frame. The samples were collected at multi-port depths ranging from 30 to 465 feet BGS. Results are included in Appendix D.5 and D.6..

## 4.1 Boron

Boron is a good indicator element in groundwater at the HNP because it is chemically stable and was added to the water in the reactor vessel to control neutron flux when the plant was in operation. Therefore, the occurrence of elevated concentrations of boron in groundwater may be a general indicator of areas that have been impacted by previous releases.

Thirty-nine (39) samples were collected and analyzed for boron as part of the third quarter 2005 round. Three (3) of these samples were duplicates and one was a field blank. All results were detects with reported concentrations greater than the Method Detection Limit (MDL) of 4 micrograms per liter ( $\mu\text{g}/\text{L}$ ). Results ranged from 11.3  $\mu\text{g}/\text{L}$  at MW-100D to 570  $\mu\text{g}/\text{L}$  at MW-106S. Groundwater analytical results for the third quarter 2005 boron analyses are summarized in Table 4-1.

Boron was detected in all sixty-nine (69) samples analyzed in the fourth quarter 2005 with all results above the MDL of 4  $\mu\text{g}/\text{L}$ . The highest concentration was detected in well MW137 (1180  $\mu\text{g}/\text{L}$ ). Groundwater analytical results for the fourth quarter 2005 boron analyses are summarized in Table 4-1.

Boron was detected in all of the MP well locations analyzed at a concentration greater than the MDL. Results ranged from 73.1  $\mu\text{g}/\text{L}$  at MW-121A, zone 5 to 363  $\mu\text{g}/\text{L}$  at MW-118A, zone 4. Westbay MP well results for the July to November 2005 timeframe are summarized in Appendix D.5.

Boron contamination is likely present in groundwater at HNP as the orthoborate oxyanion ( $\text{BO}_3^{3-}$ ) which results directly from aqueous dissolution of boric acid ( $\text{H}_3\text{BO}_3$ ). Substantial quantities of boric acid solution were historically released from the former HNP tank farm and potentially from other locations within the industrial area. In addition to plant-related boron in groundwater, there appears to be a measurable naturally-occurring boron background concentration. A definitive background boron study has not been performed for groundwater at HNP, however, inspection of the boron analytical results suggests that a natural boron background concentration of about 100  $\mu\text{g}/\text{L}$  or less is present at the site. The actual ionic species of naturally-occurring boron at HNP is not defined and may differ from the orthoborate ion.

Observed boron concentrations of greater than 100  $\mu\text{g}/\text{L}$  appear related to plant releases. It is difficult to discern the apparent source of boron concentrations in groundwater between 50  $\mu\text{g}/\text{L}$  and 100  $\mu\text{g}/\text{L}$ ; thus, the distal boundaries of plant-related boron plumes are not clearly defined. Boron will be evaluated as part of the ongoing RCRA CAP and under regulatory oversight of both USEPA and CTDEP; however, boron concentrations in 2005 are all below the CTDEP approved RSR criteria for groundwater protection of 1,400  $\mu\text{g}/\text{L}$ .

The highest concentrations of boron observed at HNP are reported in shallow wells, with high concentrations historically found in the immediate vicinity of apparent release areas. The boron concentration in deep bedrock wells is substantially less than that in

the areas of apparent contamination, although boron was detected in all samples collected. This is consistent with the presence of a measurable boron background at the site.

## 4.2 Gross Alpha

The likely source of most gross alpha activity in the vicinity of HNP is dissolution of naturally occurring mineral deposits. These mineral deposits include natural uranium, thorium and their radioactive progeny including radium (Ra-226, Ra-224), which are likely present in the underlying crystalline bedrock. Natural levels of gross alpha activity can range as high as a few hundred pCi/L. Although it is possible that plant-related radionuclides contribute to some of the observed gross alpha activity, it is not probable. Alpha isotopic analyses for HNP related alpha-emitters (plutonium, americium, curium) generally result in non-detects with nominal detection sensitivities on the order of 0.3 pCi/L, or less.

Forty-five (45) samples were collected and analyzed for gross alpha activity in the third quarter 2005 including the two (2) duplicates and a field blank. Nine-teen (19) locations were detects with concentrations greater than the 2- $\sigma$  random uncertainty. Fourteen (14) samples detected concentrations greater than the laboratory required Minimum Detection Concentration (MDC) of 3 pCi/L. One (1) reported results exceeded the USEPA MCL of 15 pCi/L. The highest gross alpha concentration was observed at monitoring well MWR-105D (32.2 pCi/L). Gross alpha results for the third quarter 2005 are provided in Table 4-2.

Sixty-nine (69) samples were collected in December 2005 for gross alpha activity analysis resulting in thirty-six (36) samples with greater than the laboratory required Minimum Detection Concentration (MDC) of 3 picocuries per liter (pCi/L). The maximum gross alpha concentration observed in conventional wells was at monitoring well MW-103B, 39.1-pCi/L. Thirteen (13) detected results exceeded the USEPA MCL of 15-pCi/L. Ten (10) of the thirteen (13) results greater than the USEPA MCL were from multi-port wells. The highest concentration observed in Westbay multi-port wells was 410-pCi/L at MW-119, zone 2 (125-ft). Gross alpha results for December 2005 are provided in Table 4-2.

Gross alpha activity ranged from non-detect at MW-121A, zone 5 (105-ft) to 294-pCi/L at MW-118A, zone 3 (125-ft) for multi-port samples collected during the July to November 2005 time frame. Westbay MP analytical results are summarized in Appendix D.5.

## 4.3 Gross Beta

Gross beta activity in the vicinity of HNP may result from either naturally occurring or plant-related sources. Potassium-40 (K-40) is a radionuclide resulting from naturally occurring mineral deposits, which may account for relatively high percentage of gross beta activity in certain wells. High levels of gross beta activity in areas of plant-related contamination may be associated with beta emitters Sr-90 and Cs-137. The CT Public Drinking Water Quality Standard for gross beta radioactivity is 50 pCi/L and natural background levels may range as high as a few hundred pCi/L.

Forty-five (45) samples were collected and analyzed in the third quarter 2005 for gross beta activity and forty (40) results were detects with concentrations greater than the sample MDC. Thirty-six (36) samples detected gross beta activity at a concentration greater than the laboratory required MDC of 4 pCi/L. These concentrations ranged from 4.7 (MW-207) to 37.1 pCi/L (MW-130). None of these concentrations exceeded the CT Public Drinking Water Quality Standard MCL of 50 pCi/L. Gross beta results for third quarter 2005 are provided in Table 4-2.

Sixty-nine (69) samples were collected and analyzed in the fourth quarter 2005 for gross beta activity and fifty-five (55) results were detects with concentrations greater than the sample MDC and the laboratory required MDC of 4 pCi/L. The concentrations ranged as high as 45.3-pCi/L at MW133 in conventional wells. The highest gross beta activity concentration identified in Westbay multiport wells was 223-pCi/L at MW-119, zone 5. Three multiport wells exceeded the CT Public Drinking Water Quality Standard MCL of 50 pCi/L (MW-118A-3, MW-119-2 and MW-119-5). Gross beta results for fourth quarter 2005 are provided in Table 4-2.

Gross beta analyses were performed on fourteen (14) Westbay MP samples. Gross beta activity was detected at all locations. Gross beta results ranged from 6.0-pCi/L at MW121A-2, to 228-pCi/L at MW119-2. Results at five (5) locations exceed the CT Public Drinking Water Quality Standard MCL of 50 pCi/L. The gross beta activity in these samples is attributed to natural uranium decay series radionuclides including U-234, Th-234 and U-238. Westbay MP analytical results are summarized in Appendix D.5.

#### 4.4 Tritium

In the third quarter of 2005, H-3 was detected in thirteen (13) of the thirty-five(35) wells sampled at a concentration greater than the sample MDC. Twelve (12) of these detects were at concentrations greater than the required MDC of 400 pCi/L. The highest concentrations of tritium were detected at monitoring wells MWR-105D (7,170 pCi/L) and MW-110D (5,350 pCi/L). Tritium was not detected at concentrations greater than the C<sub>4</sub> activity concentration of 20,000-pCi/L. Tritium results for the third quarter 2005 sampling event are summarized in Table 4-3.

Tritium was detected in thirty-five (35) of the sixty-one (61) wells sampled during the fourth quarter 2005 a concentrations greater than the sample MDC. Thirty-seven (37) of these detects were at concentrations greater than the required MDC of 400 pCi/L. All detected H-3 concentrations were below the C<sub>4</sub> activity concentration of 20,000 pCi/L. The highest tritium concentrations in conventional monitoring wells were observed at MW-132S (7,720 pCi/L), MW-137 (7,760 pCi/L) and MW-110D (8,010 pCi/L). Three (3) Westbay multi-port wells had tritium concentrations greater than 10,000-pCi/L including MW-118A-4 (10,200 pCi/L), MW-119-6 (12,900 pCi/L) and MW-119-5 (16,000 pCi/L). Tritium results for the fourth quarter 2005 sampling event are summarized in Table 4-3.

## 4.5 Co-60

Cobalt-60 was not detected in any 42 samples at concentrations greater than the sample specific MDC during the third quarter 2005. Cobalt-60 results are summarized in Appendix D.1.

Cobalt-60 was not detected in any of the sixty-one (61) locations analyzed during the fourth quarter 2005 sample event at concentrations greater than the sample specific MDC. The  $C_4$  concentration for Co-60 is 100 pCi/L. Appendix D.3 summarizes Co-60 results in all wells that were part of the fourth quarter 2005 sampling round.

Cobalt-60 was not detected in statistically significant levels in Westbay multi-port samples collected during the July through November 2005 timeframe (see Appendix D.5.)

## 4.6 Sr-90

Strontium-90 in groundwater at HNP is also associated with past nuclear power operations. Eight (8) out of thirty-three (33) wells sampled during the third quarter 2005 detected Sr-90 at concentrations greater than the sample MDC. Six (6) of these samples detected Sr-90 concentrations above the laboratory required MDC of 2 pCi/L. Monitoring well MW-130 exceeded the  $C_4$  concentration of 8 pCi/L and exhibited the highest Sr-90 concentration (16.2 pCi/L). The Sr-90 analytical results for the third quarter 2005 are provided in Table 4-2.

Thirteen (13) out of sixty-one (61) wells sampled in the fourth quarter 2005 sampling event detected Sr-90 at concentrations greater than the sample MDC, but only four (4) samples detected values above the laboratory required MDC of 2 pCi/L. None of the wells contained Sr-90 concentrations that exceeded the  $C_4$  concentration of 8-pCi/L. Monitoring well MW-103A exhibited the highest Sr-90 concentration (5.19-pCi/L). The Sr-90 analytical results for the fourth quarter 2005 are provided in Table 4-2.

Strontium-90 was not detected at concentrations greater than the sample MDC in Westbay MP samples collected during the July to November 2005 timeframe (see Appendix D.5.)

## 4.7 Cs-137

Any occurrence of Cs-137 in groundwater at HNP is the result of plant-related processes. None of the forty-two (42) samples analyzed detected Cs-137 above the sample MDC of about 3.5 -pCi/L, which is well below the  $C_4$  concentration of 200 pCi/L. Table 4-2 summarizes Cs-137 analytical results in all wells for the third quarter 2005 sampling round.

Cesium-137 was detected in three (3) of the sixty-two (62) wells analyzed during the fourth quarter 2005 event at concentrations greater than the sample MDC. One of these detections (16.7-pCi/L at MW-137) was greater than the lab required MDC of 15-pCi/L and all detections were well below the  $C_4$  concentration of 200 pCi/L. Table 4-2 summarizes Cs-137 results in all wells that were part of the fourth quarter 2005 sampling round.

Cesium-137 was not detected in statistically significant levels in Westbay MP samples collected during the July through November 2005 time frame (see Appendix D.5.)

## 4.8 Alpha Isotopic

Alpha isotopic analyses including isotopic plutonium (Pu) and isotopic americium (Am) were determined by chemical separation and alpha spectroscopy. Isotopic plutonium analyses include the alpha emitters, Pu-238 and Pu-239/240 and Pu-241, which is a beta emitter. Isotopic americium and curium analyses include Am-241, Cm-242 and Cm-243/244.

Thirteen (13) wells were sampled for alpha isotopic constituents during the third quarter 2005 sampling event. Thirty (30) wells were sampled as part of the fourth quarter sample event. All alpha isotopic results from both sampling events (215 results) were less than 2- $\sigma$  TPU and not statistically significant. All alpha isotopic results were less than the required MDC of 0.5 pCi/L. Alpha isotopic results are summarized as HTDs in Table 4-4.

Alpha isotopic analyses were performed on four (4) Westbay MP well samples for Am-241 during the July through November 2005 timeframe. All results were non-detects and less than the required MDC of 0.5-pCi/L.

## 4.9 Total Uranium

Total uranium analyses were determined by kinetic phosphorescence analysis (KPA). The method has trace analysis capabilities for soluble uranium on the order of parts per trillion (sensitivity of 0.1  $\mu\text{g}/\text{liter}$  based on the reported MDL). Total uranium analysis would include the response from isotopes of natural and enhanced uranium which include U-234, U-235 and U-238. Total uranium analysis results would also include the response from additional uranium isotopes characteristic of irradiated or spent nuclear fuel (SNF), if present. The SNF uranium isotopes include U-233 and U-236.

Twenty-nine (29) wells were sampled and analyzed for total uranium as part of the third quarter 2005 round. Twenty-six (26) of these results were detects with reported concentrations greater than the Method Detection Limit (MDL). Higher results were typically observed in the deeper wells. The highest total uranium concentration was observed at MWR-106D (69.6- $\mu\text{g}/\text{L}$ ). All other results were less than the USEPA MCL of 30  $\mu\text{g}/\text{L}$ . Total uranium analytical results for third quarter 2005 are summarized in Table 4-5.

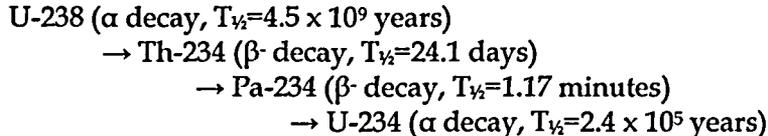
Thirty-seven (37) locations were sampled and analyzed for total uranium as part of the fourth quarter 2005 round. Twenty-nine (29) of these results were detects with reported concentrations greater than the Minimum Detection Limit (MDL) of 0.32- $\mu\text{g}/\text{L}$ . Higher concentrations were typically observed in the deeper wells. All results but two (MW-103B at 57.5- $\mu\text{g}/\text{L}$  and MWR-105D at 68.4- $\mu\text{g}/\text{L}$ ) were less than the USEPA MCL of 30  $\mu\text{g}/\text{L}$ . Total uranium analytical results for the fourth quarter 2005 are summarized in Table 4-5.

Nine (9) Westbay MP locations were sampled and analyzed for total uranium as part of the fourth quarter 2005 round. All results were detects with reported concentrations greater than the Minimum Detection Limit (MDL) of 0.32- $\mu\text{g/L}$ . The highest concentration observed was 676- $\mu\text{g/L}$  in MW-119 zone 5. Seven (7) of these results were greater than the USEPA MCL of 30  $\mu\text{g/L}$ . Total uranium analytical results for the fourth quarter 2005 are summarized in Table 4-5.

## 4.10 Uranium Isotopic/U-235 Enrichment

Monitoring wells that exhibited total uranium concentrations in excess of the USEPA MCL (30- $\mu\text{g/L}$ ) were analyzed for isotopic uranium by alpha spectrometry and ICP-MS as part of the fourth quarter 2005 sample event. These wells exhibited total uranium concentrations ranging from 31.6 to 676- $\mu\text{g/L}$ . All nine (9) wells exhibited detectable U-234 results with concentrations ranging from, 15.5- pCi/L (MW-120 zone 1) to 255-pCi/L (MW-119 zone 5). All U-235 results were detections with concentrations ranging from, 0.9- pCi/L (MW-120 zone 1) to 20.3-pCi/L (MW-119 zone 5). All wells also exhibited detectable U-238 results with concentrations ranging from, 16.3-pCi/L (MW-120 zone 1), to 258-pCi/L (MW-119 zone 5). All U-234 and U-238 results were greater than the EPA MCL of 15-pCi/L. Isotopic uranium analytical results for the fourth quarter 2005 are summarized in Table 4-6.

Uranium-234 is a progeny of U-238 following the decay of Th-234 as follows:



In an ideal, closed system, a U-234/U-238 ratio of unity is expected, due to radioactive decay equilibrium. Radioactive decay can influence this ratio somewhat in the natural environment. The presence of the intermediate progeny (i.e., Th-234, Pa-234) with associated solubility differences and alpha recoil mechanisms are such that the actual observed ratio of U-234 to U-238 in natural groundwater can vary from 0.5 to 40. The average observed U-234/U-238 ratio for these samples was  $1.06 \pm 0.14$  as summarized in Table 4.7. The U-234/U-238 results are typical of groundwater with natural uranium ratios.

These same wells were also analyzed for U-235, U-238 and total uranium mass by ICP-MS. The expected U-235 enrichment ratio (e.g., U-235 to total uranium mass ratio) for uranium, in groundwater or other environmental samples is less than 1% or about 0.72%. Uranium-235 mass to total uranium mass results for these samples were on average  $0.68\% \pm 0.02\%$  as summarized in Table 4-8. These results are typical of groundwater with natural U-235 enrichment ratios.

## 5 Data Quality Assessment

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Current quality assurance/quality control (QA/QC) efforts in support of the Groundwater Monitoring Program at the HNP are designed to assess and enhance the reliability and validity of field and laboratory measurements conducted to support these programs. General quality requirements are provided in References LTP 2005 and GMP-QAPP 2005.

### 5.1 Data Quality Metrics

On the analytical side, precision, accuracy, representativeness, comparability and completeness (PARCC) are the primary indicators used to assess laboratory data quality. These parameters are evaluated through laboratory QC checks (e.g., matrix spikes, laboratory blanks), replicate sampling and analysis, analysis of blind standards and blanks, and inter-laboratory comparisons.

Acceptance criteria have been established for each of these parameters. When a parameter is outside the criteria, corrective actions are taken to minimize future occurrence. Numerical criteria for evaluating precision, accuracy and completeness performance are generally available, while metrics for representativeness and comparability are more qualitative in nature.

#### 5.1.1 Precision

Precision is a measurement of the repeatability of a measurement or measurement technique. Precision was evaluated through the use of field duplicate samples and laboratory split or replicate samples. Field QC samples typically consist of duplicates, splits and blank samples. Field duplicate samples are used to assess sampling and measurement precision. Field split samples are used to assess measurement precision. Field splits and duplicates are typically examined to monitor laboratory operations and to identify potential problem areas where improvements are necessary.

### 5.1.1.1 Relative Percent Difference (RPD)

A commonly applied and useful metric for precision is known as the Relative Percent Difference (RPD). The RPD is determined for duplicate measurements by applying the following equation:

$$RPD = \frac{|S_1 - S_2|}{(S_1 + S_2)/2} \times 100$$

Where:

RPD	≡	Relative Percent Difference as %
$S_1$	≡	Initial measurement value
$S_2$	≡	Duplicate or replicate measurement value
$ S_1 - S_2 $	≡	Absolute measurement difference
$(S_1 + S_2)/2$	≡	Average measurement value

A typical acceptable target RPD is 20% for most chemical or radiological constituents in environmental media. For samples that are heterogeneous, an acceptable RPD may be as high as 100 %.

### 5.1.1.2 Absolute Z-Score (AZS)

Another metric to evaluate precision is the Absolute Z-Score (AZS) method. The Absolute Z-Score is determined for a pair of measurements as follows:

$$AZS = \frac{|S_1 - S_2|}{\sqrt{\sigma_{S_1}^2 + \sigma_{S_2}^2}}$$

Where:

AZS	≡	Absolute Z-Score
$S_1$	≡	Initial measurement value
$S_2$	≡	Duplicate or replicate measurement value
$ S_1 - S_2 $	≡	Absolute measurement difference
$\sigma_{S_1}^2$	≡	Initial measurement variance
$\sigma_{S_2}^2$	≡	Duplicate or replicate measurement variance
$(S_1 + S_2)/2$	≡	Quadrature Sum of Square Uncertainties

The AZS metric is a useful method to compare measurement results with large relative uncertainties (i.e., signal-to-noise ratios less than 5). An acceptable target AZS of less than 3, based on the 99% confidence interval of a normal distribution is achievable for most chemical or radiological constituents in environmental media. For samples that are heterogeneous or non-normally distributed, higher AZS results may be expected.

### 5.1.1.3 Relative Difference Method (RDM)

An additional metric to evaluate precision is the Relative Difference Method (RDM) method. The Relative Difference Method is determined for a pair of measurements as follows:

$$RDM = \frac{|S_1 - S_2|}{CRDL}$$

Where:

RDM	≡	Relative Difference Method
S <sub>1</sub>	≡	Initial measurement value
S <sub>2</sub>	≡	Duplicate or replicate measurement value
S <sub>1</sub> - S <sub>2</sub>	≡	Absolute measurement difference
CRDL	≡	Contract Required Detection Limit

The RDM metric is a useful method to compare measurement differences with large uncertainties (i.e., signal-to-noise ratios less than 5) to the required analysis sensitivity (i.e., required detection limit). Analytical labs typically target an RDM of less than 1 as an acceptable metric.

Field duplicate samples were collected during the course of each quarterly sampling event, after considerations for well yield and sample volume requirements.

Approximately 25% of the total number of samples analyzed, for radiochemical and boron constituents were internal lab duplicates or replicates. Approximately 6% of the analyzed samples were analytical blanks.

## 5.1.2 Accuracy

Accuracy refers to the degree to which a measurement can reflect the known or true value. The accuracy of a lab analytical measurement is determined by analyzing known or reference standards or solutions.

### 5.1.2.1 Recovery (R)

A metric used to express accuracy in analytical measurements is the Recovery (R) which is given by the following equation:

$$R = \left[ 1 + \left( \frac{Y - X}{X} \right) \right] \times 100$$

Where:

R	≡	Recovery as %
Y	≡	Measured value
X	≡	Known or reference value

Laboratory performance for accuracy is measured by several indicators, including external programs such as nationally based performance evaluation studies, that may include blind or double-blind standard analyses and internal laboratory QA/QC programs. Another important measure of accuracy is sensitivity. Measurement techniques vary in their ability to detect and quantify chemical or radiochemical constituents. For acceptable sensitivity, a measurement technique must demonstrate the capability to quantify at a level that is no more than 10% of an applicable limit (e.g., a drinking water standard).

Measurement accuracy was evaluated by three methods:

- Calculation of percent recovery of laboratory control samples (e.g., calibration standards, blank spikes, and matrix spikes);
- Comparison of reported minimum detectable concentration (MDC) to selected performance standards (e.g., drinking water standards);
- Comparison of method blank analyses to the MDC.

### 5.1.3 Representativeness

Sample representativeness refers to the degree in which sample data accurately and precisely represent a characteristic of the environmental conditions at that sample point. Sample representativeness is an important PARCC parameter that is difficult to assess quantitatively.

Different measurement techniques may produce dramatically differing results, based on the ability of the technique to represent the system. This is especially true at low-levels at or near the analytical limit of detection. One aspect of analytical representativeness was evaluated quantitatively by evaluation of method blank samples. Equipment or method blank samples that exhibited contamination (i.e., positive detects) were considered analytically non-representative. The presence of statistically significant analyte concentrations at similar levels in measured samples may not be representative of the sampled aquifer.

### 5.1.4 Completeness

Completeness was evaluated by comparison of the number of valid measurements produced to the number of measurements planned. The Completeness (C) metric is given by the following equation:

$$C = \left[ 1 + \left( \frac{Y - X}{X} \right) \right] \times 100$$

Where:

- |   |   |                             |
|---|---|-----------------------------|
| C | ≡ | Completeness as %           |
| Y | ≡ | Number of valid data points |
| X | ≡ | Total number of data points |

The target for completeness of valid measurements for all radionuclides for this sampling event was 100%. This objective was selected because critical sample locations (i.e., locations that define maximum concentration and/or maximum extent of contaminant plumes) have not been established for all radionuclides or geochemical constituents.

### **5.1.5 Comparability**

Comparability was evaluated qualitatively through assessment of sampling and measurement methods and apparent spatial distribution of substances of concern. Comparability was evaluated quantitatively by comparison of the measurement sensitivity to the contract required detection limit (CRDL). Measurements performed to these levels are comparable to previous or historical measurements.

### **5.1.6 Bias**

Bias is defined as a systematic error in a measurement where the measured value displays a consistent positive or negative bias, as compared to the true value. Bias in an analytic method at low levels close to the limit of detection can impact the ability to identify statistically significant levels of an analyte. A false-positive error is an instance when a nuclide or analyte is declared to be present but is, in fact, absent. A false-negative error is an instance when an analyte is declared to be absent but is, in fact, present.

Historically, commercial analytical laboratories used by CYAPCo have exhibited some difficulty with the reporting of false-positive results, attributed to positive analytical bias at the detection limit. Statistical methods were employed to evaluate this analytical bias with regard to the underlying baseline or background distribution.

### **5.1.7 Laboratory Audits/Assessments/Oversight Activities**

Laboratory activities are periodically assessed through surveillance and/or auditing activities to ensure that quality problems are prevented and/or detected. Periodic assessments support the continuous process improvement.

### **5.1.8 Issue Resolution/Case Narrative**

Case narrative documents record detailed documentation of the analyses requested and provide additional documentation regarding problems encountered with sample receipt, sample analysis and data reporting. The forms are generated by the laboratory as required in the SOW and forwarded to the GW monitoring project with all hard copy data packages. The documentation is intended to identify occurrences, deficiencies and/or issues that may potentially have an adverse effect on data integrity.

## 5.2 Data Quality Results

The data quality metrics for radiochemical constituents are summarized as follows:

- Precision                      Relative Percent Difference (RPD) < 25%  
   Absolute Z-Score (AZS) < 3  
   Relative Difference Method (RDM) < 1
- Accuracy                      Laboratory Control Sample Recovery 100% +/- 30  
   Laboratory Blank Analysis Results < MDC
- Representativeness        Qualitative assessment of sample location, sample timing,  
   sample collection method, sample preservation, handling,  
   shipment  
   Laboratory Blank Analysis Results Non-Detect
- Completeness              Valid measurements for critical samples = 100%
- Comparability              Qualitative assessment of sample collection and  
   measurement methods  
   Assignment of sample locations to hydrostratigraphic units.  
   Sample MDC < CRDL in Table 5-1

### 5.2.1 Precision

Results of the data quality assessment for precision are discussed in the following subsections.

#### 5.2.1.1 Field Duplicates

The field duplicate is typically a blind duplicate as submitted to the contract laboratory. The duplicate sample is analyzed for the same constituents as the original sample. Only those reported radiochemical results with a sufficient signal-to-noise ratio (i.e., sample-to-uncertainty concentration ratio greater than 5) are evaluated and summarized. The uncertainty used in this ratio is the 1- $\sigma$  random uncertainty reported with the radiochemical results. Inorganic results that are greater than the CRDL are also included in this evaluation.

The duplicate samples for the third quarter 2005 sampling round were collected from MW-105S, MW-109S and MW-131D. The radioactive analyses included gross alpha, gross beta, H-3, Sr-90, gamma isotopic and the HTDs. Results of the radiochemical field duplicate evaluation are summarized in Table 5-2. All five (5) radiochemical field duplicate results are within acceptance limits (RPD < 20% or AZS < 3).

Results of the inorganic field duplicate evaluation are also summarized in Table 5-2. The inorganic analyses included boron and total uranium. The field duplicate collected at

MW109S was analyzed for boron only. Three (3) of five (5) inorganic field duplicate results are within acceptance limits (RPD < 20% or AZS < 3). Both field duplicate RPDs for total uranium were greater than 49%.

The duplicate samples for the fourth quarter 2005 sampling round were collected from the MW-102D, MW-109D (boron only), MW-118A-4 and MW-133. The blind duplicate sample was analyzed for gross alpha, gross beta, H-3, boron, Sr-90, gamma isotopic, boron and total uranium. Results of the field duplicate evaluation are summarized in Table 5-3. Again, only those radiochemical and inorganic results with a sufficient signal-to-noise ratio are evaluated and summarized. All fifteen (15) duplicate results are within acceptance limits (RPD < 20% or AZS < 3).

Duplicate samples were not collected during the July through November 2005 Westbay MP sample events due to the data quality objectives of these samples. These samples were in general collected for characterization or baseline determination purposes only.

#### 5.2.1.2 Lab Duplicates

Approximately 25% of the samples analyzed by General Engineering Laboratory (GEL) in a quarterly sampling event are internal or lab QC samples. These lab QC samples are comprised of lab control spikes, matrix spikes, method blanks, duplicates and replicates. The reproducibility of lab measurements is evaluated through the use of matrix duplicates. These duplicates are processed at a frequency of one matrix duplicate per batch. Internal acceptance criteria for duplicate samples are summarized as follows:

- Accuracy within 20%
- Absolute difference less than or equal to CRDL

Sample and duplicate analysis results greater than 5 times the CRDL, must fall within  $\pm 20\%$  of the observed value. Sample or duplicate analysis results less than the product of 5 times the CRDL, the difference should be less than or equal to the CRDL.

Results of the lab duplicate evaluation for the third quarter 2005 are summarized in Table 5-4. Three (3) of four (4) radiochemical lab duplicate results are within acceptance limits (RPD < 20% or AZS < 3). Replicate results for Sr-90 at MW130 exhibited an RPD of 58.8%. Results of the inorganic field duplicate evaluation are also summarized in Table 5-4. The inorganic analyses included boron and total uranium. All nine (9) inorganic lab duplicate results are within acceptance limits (RPD < 20% or AZS < 3).

Results of the lab duplicate evaluation for the fourth quarter 2005 are summarized in Table 5-5. All twenty-one (21) lab duplicate results (10 radiochemical and 11 inorganics results) are within acceptance limits (RPD < 20% or AZS < 3).

Results of the lab duplicate evaluation for Westbay MP well samples are summarized in Table 5-6. All lab duplicate results are within acceptance limits (RPD < 20%).

### **5.2.1.3 Reanalysis Duplicates**

During the third quarter 2005 sample event, CYAPCo requested that sixteen (16) samples be reanalyzed to confirm the original analytical results. The reanalyzed sample sensitivity was nominally a factor of 2 to 3 more sensitive than the original analyses (based on the sample MDCs). In some cases the original reported result represented the highest concentration reported to date, in other cases, unexpected statistically positive results were observed in the initial analyses.

During the fourth quarter 2005 sample event, CYAPCo requested that several samples be reanalyzed to confirm the original analytical results. Several samples did not meet the required analysis sensitivity and reanalysis was requested.

## **5.2.2 Accuracy**

Results of the data quality assessment for accuracy are discussed in the following subsections.

### **5.2.2.1 External Laboratory Performance Evaluations**

This section provides a detailed discussion of external performance indicators for the GEL laboratories. The GEL lab took part in the DOE's Mixed Analyte Performance Evaluation Program. The GEL lab also participated in the Environmental Resource Associates (ERA) RadChem™ performance testing program. Results of those studies related to GW monitoring at HNP, are described in this section.

#### **DOE Mixed Analyte Performance Evaluation Program**

DOE's Mixed Analyte Performance Evaluation Program (MAPEP) examines laboratory performance in the analysis of soil, water and particulate filter samples containing metals, volatile and semi-volatile organic compounds and radionuclides. The program is conducted at the Radiological and Environmental Sciences Laboratory (RESL) in Idaho Falls, Idaho, and is similar in operation to DOE's QAP discussed above. DOE evaluates the accuracy of the MAPEP results for radiological and inorganic samples by determining if they fall within a 30% bias of the reference value. Analytical results with a reported bias less than or equal to 20% are flagged as acceptable. Analytical results with a reported bias greater than 20% but less than or equal to 30% are flagged as acceptable with warning. Analytical results for gross alpha and gross beta analyses with an analytical bias less than 100% and 50%, respectively, are acceptable.

RESL provides blind standards that contain specific amounts of one or more radionuclides to participating laboratories. Gamma emitters typically include K-40, Mn-54, Co-57, Co-60, Zn-65, Cs-134 and Cs-137. Alpha emitters typically include U-234, U-238, Pu-238, Pu-239 and Am-241. The beta and hard-to-detect (HTD) radionuclides typically include Fe-55, Ni-63 and Sr-90. Recently, gross alpha and gross beta analysis tests for water and particulate filters have been included.

The MAPEP program also uses false positive testing on a routine basis to identify laboratory results that indicate the presence of a particular radionuclide in a sample, when in fact the actual activity of the radionuclide is far below the required detection limit. False positive test nuclides typically include Sr-90, Fe-55 or Pu-238. Acceptable

performance is indicated when the reported range encompassing the results (i.e., net concentration  $\pm 3\text{-}\sigma$  uncertainty) included zero. Unacceptable performance is indicated when this range does not include zero.

For the twelve (14) MAPEP studies conducted through October 2004 (see References MAPEP-S6, S7, S8, S9, S10, MAPEP-W7, W8, W9, W10, W11 and MAPEP Study-12, 13, 14, 15), the percentages of acceptable or acceptable with warning results are summarized as a function of media in Table 5-7.

Overall, greater than 95% of the GEL data was in the acceptable or acceptable with warning performance category for all media. For gamma isotopic analyses, 100% of the reported lab data was in the acceptable or acceptable with warning category. Approximately 95% of the alpha isotopic results and 87% of the HTD beta results were in the acceptable or acceptable with warning range. GEL has experienced some problems with the low level false positive testing where 75% of the reported results were in the acceptable range.

#### **ERA RadChem™ Proficiency Testing (PT) Program**

Environmental Resource Associates (ERA) RadChem™ PT program is based on the National Standards for Water Proficiency Testing Studies Criteria Document (Reference NSWPT 1998). ERA examines laboratory performance in the analysis of water samples containing gross alpha/beta, naturals including uranium, mixed beta and gamma emitters. The program is conducted by ERA in Arvada, Colorado. ERA evaluates the accuracy of submitted results for radiological samples by determining if they fall within USEPA or National Environmental Laboratory Accreditation Conference (NELAC) control limits.

ERA provides blind standards that contain specific amounts of one or more radionuclides to participating laboratories. Gamma emitters typically include Co-60, Zn-65, I-131, Ba-133, Cs-134, Cs-137 and Ra-226. Alpha and beta analyses typically include gross alpha, gross beta, H-3, Sr-89, Sr-90, Ra-228 and natural uranium.

The GEL lab participated in eleven(11) of the last thirteen (13) ERA studies (see References ERA RAD 52, 53, 54, 55, 57, 58, 60, 61, 62, 63 and 64). The percentages of acceptable or acceptable with warning results for these eight (8) studies are summarized as a function of analysis type in Table 5-8. Overall, 98% of the GEL reported lab data was in the acceptable or acceptable with warning performance category for all media.

#### **5.2.2.2 Internal Lab Performance Evaluations**

Approximately 25% of the samples analyzed by GEL in a quarterly sampling event are QC samples. These lab QC samples are comprised of lab control spikes, matrix spikes, method blanks, duplicates and replicates. Attached in Tables 5-9 through 5-11 is a summary of the number of QC samples processed by the GEL lab during these sample events.

### Internal Performance Criteria

GEL performed a minimum of one laboratory control sample (LCS), one method or reagent blank (MB), and one duplicate sample analysis for each analysis performed in a batch of samples according to References GEL QAP 2005 and CY-ISC-SOW 2003. Batch sizes are composed of one to a maximum of 20 environmental samples. Matrix spike (MS) samples are also analyzed when the analytical method involves chemical or physical separation and does not use an internal standard or carrier, and sufficient sample volume exists.

Internal acceptance criteria for LCS and MS samples are summarized as follows:

- Accuracy within QC acceptance limits (see Table 5-12)
- Results within 2- $\sigma$  TPU of the observed value
- Accuracy within allowed uncertainty and based on CRDL

Matrix Spikes (MS) are first corrected for any ambient test nuclide activity. Samples with ambient activity greater than 4 times the expected value of the spike are not required to fulfill MS acceptance criteria. The activity levels of target analytes in LCS and MS samples are greater than 10 times but less than 100 times the *a priori* lower limit of detection (LLD). Acceptance criteria for LCS and MS samples are 75% to 125%. Additionally, all QC and sample results must have chemical recoveries or chemical yields within the range of 15% to 125%.

### Internal Performance Results for Accuracy

The percentages of acceptable results are summarized as a function of analysis method in Table 5-13. Overall, about 97% of the GEL performance data for LCS and MS samples were acceptable according to performance criteria. For total uranium, alpha isotopic and gamma isotopic analyses, 100% of the internal lab QC data was within acceptance limits. Approximately 98.6% of the LSC results, 96.4% of the boron and 91.7% of the GPC results were within acceptable limits.

### 5.2.3 Representativeness

The extent to which analytical results are representative of the aquifer sampled, can be assessed through a series of qualitative and quantitative evaluations.

A qualitative review of field sample parameters during the first and fourth quarter 2005 sampling events indicated variability in turbidity. The cause of this variability probably results from accumulation of fine geologic material in the wells due to variations in degree of well development as well as variations in the content of fine material at the various locations sampled. Comparison of observed turbidity measurements to analysis of radiochemical constituents in both filtered and unfiltered samples indicates no apparent correlation. Essentially all observed radiochemical constituents appear to be present in a soluble state. Therefore it is concluded that variations in sample turbidity did not affect radiochemical analyses. Boron is expected to be present in groundwater as a soluble oxyanion and, therefore, the measured concentrations are not expected to be affected by variations in sample turbidity. The low-flow sampling method is expected to produce representative samples for boron and radiochemical constituents.

Samples collected from wells MW-106D and MW-122D have historically exhibited elevated pH relative to other wells at the site. These two monitoring wells were abandoned and replaced. The pH values are in the normal range for MWR-106D, but are still somewhat elevated in MWR-122D (see Section 3.2).

Monitoring wells have been assigned to unique hydrostratigraphic units based on the relative placement of screen intervals in each of the wells. The wells retain the designation of shallow or deep as these generally differentiate whether the screens are placed in unconsolidated sediments or bedrock. Three distinct hydrostratigraphic units are recognized, 1) the unconsolidated sediments are those non-indurated, friable materials overlying bedrock, and are the host to the unconfined aquifer, 2) the bedrock unit which is the host to the confined aquifer and generally recognized as a gneissic formation, 3) a silt and peat/organic rich layer has been designated as a perching horizon in the area of the parking lot extending to the north where the perched water table occupies an elevation of about 10 feet AMSL. A glacial till is sporadically present, and locally acts as a confining layer. The assignment of wells to specific units affects the spatial distribution interpretation for the substances of concern.

#### 5.2.3.1 Field Blank Results

A decontamination station is typically established near monitoring wells sampled with non-dedicated equipment to provide for the proper decontamination of dedicated sampling equipment. All non-disposable equipment used during the program was subject to decontamination. These components included the groundwater sampling pump, electrical lead wires and support cable, as well as the flow-through cell in which field parameters were measured. An equipment rinse blank sample was simulated using lab de-ionized water (DI) blank during the third and fourth quarter 2005 sample events since all monitoring wells were sampled using dedicated equipment. Equipment rinse blank samples were collected from each Westbay MP well during the December 2005 sample event.

#### 5.2.3.2 Lab Analytical Blank Results

Method or reagent blank results are evaluated or compared to the CRDL and the lowest sample activity in a batch. Acceptable method blanks are those results that are less than the CRDL or less than 5% of the lowest sample activity in the batch. Method blank results that do not meet the acceptance criteria are critically examined according to the GEL SOPs and documented through GEL's nonconformance reporting (NCR) system. Method blank failures are also documented in the case narrative of the analytical report. Method blank activity levels are not subtracted from sample activity levels.

A total of eighty-nine (89) blank samples were processed and analyzed for radiochemical constituents during the third quarter 2005 sample event. Four (4) of these blank samples or approximately 4.5% of the blanks indicated detectable activity at a concentration greater than the 2- $\sigma$  random uncertainty and these results are summarized in Table 5-14. One would expect a "false positive" rate of 2.5% based on the area under the standard normal distribution around a limiting mean concentration of zero, at the 95% confidence level. A total of eleven (11) blank samples were processed and analyzed for inorganic constituents during the third quarter 2005 sample event. Nine (9)

of these blank samples or approximately 82% indicated detectable levels at a concentration greater than the MDL.

A total of 183 blank samples were processed and analyzed for radiochemical constituents during the fourth quarter 2005 sample event. Ten (10) of these blank samples or approximately 5.5% of the blanks indicated detectable activity at a concentration greater than the 2- $\sigma$  random uncertainty and these results are summarized in Table 5-15. A total of sixteen (16) blank samples were processed and analyzed for boron and total uranium during the fourth quarter 2005 sample event. Fourteen (14) of these blank samples or approximately 87.5% indicated detectable levels at a concentration greater than the MDL.

#### **5.2.4 Completeness**

Valid results were generated for a total of 765 radionuclide tests and 71 inorganic tests in the third quarter of 2005, resulting in completeness of 100%. For the fourth quarter 2005 sampling event valid results were generated for 1294 radionuclide tests and 110 inorganic tests, resulting in a completeness of 100%.

Valid results were generated for a total of 704 radionuclide and geochemical tests performed on groundwater seep samples, resulting in completeness of 100%. For the Westbay MP sampling events, valid results were generated for 235 radionuclide and geochemical tests, resulting in a completeness of 100%.

#### **5.2.5 Comparability**

Comparability was evaluated qualitatively through assessment of sampling and measurement methods and apparent spatial distribution of substances of concern. The analytical methods used for this determination are comparable to methods used to measure dissolved species in natural waters. The sampling method and analytical techniques used in both sampling events were comparable to previous events. These results generally indicate that boron and radiochemical constituents detected in all wells was present in a soluble form and comparable to previous unfiltered measurements.

##### **5.2.5.1 Sample Methods**

Sample collection and control was performed using work processes and trained staff according to References RPM 5.3-0, GW-WPIR 2004, RPM 5.3-1 and RPM 5.2-9. The tasks included sample planning, sample collection, chain-of-custody preparation and sample shipping. GEL in Charleston, SC was used as the primary lab for the radiochemical and inorganic analyses. Methods employed for radiochemical constituents were standard EPA methods or were developed by the vendor laboratory and are recognized as acceptable within the radiochemical industry. All inorganic methods are standard EPA methods. The CRDL, identified in the laboratory Statement of Work (CY-ISC-SOW 2003), are also summarized in Table 5-1.

The GEL lab supplied all sample containers used in the collection of the quarterly groundwater samples. Sample containers were delivered to the site by courier and maintained in a secure manner following use by the sampling team. Samples were packaged for transport to the laboratory with protective packing material in insulated coolers with custody seals.

### 5.2.5.2 Radiochemical Data Reporting Convention

All reported analytical results include the net concentration, the 1- $\sigma$  or 2- $\sigma$  random uncertainty, 1- $\sigma$  or 2- $\sigma$  total propagated uncertainty concentration (TPU), and the minimum detectable concentration (MDC). Net concentration results greater than the 2- $\sigma$  random uncertainty, generally imply that statistically significant activity is present with a 95% certainty. Net concentration results less than the 2- $\sigma$  random uncertainty indicate zero or statistically insignificant activity. Net concentration results reported as negative values imply that the radioactivity in the sample is less than the average or long-term background.

The reported TPU is a combination of the counting uncertainty and any other factors that contribute to the overall uncertainty including uncertainties in the sample mass, chemical yield and determination of calibration factors. Uncertainty values reported at 2- $\sigma$  allow direct comparison with the net concentration for statistical significance. Uncertainty values reported at 1- $\sigma$  are converted to 2- $\sigma$  for comparison purposes.

Detection limits are essential for evaluating data quality and demonstrating that the desired sample analytical sensitivity was achieved. The LLD is the lower limit at which a measurement can be differentiated from background with some degree of confidence. The LLD for a radionuclide is typically computed from the counting error associated with the instrument background, or blank counting conditions, at the time of analysis and is usually expressed in terms of counts, or count rate. In contrast, the MDC includes conversion factors to relate background count rate to radionuclide activity or concentration. The contractual (or *a priori*) MDCs for these results identified in the Laboratory Statement of Work (CY-ISC-SOW 2003) are summarized in Table 5-1. These CRDL are based on the resident farmer scenario with a 1 millirem per year Total Effective Dose Equivalent (TEDE) annual dose. All reported MDC concentrations are *a posteriori* and include sample specific corrections for radioactive decay, chemical yield and sample mass.

### 5.2.5.3 Radiochemical Data Review

All analytical results in the form of the sample specific MDC were evaluated against the contractual MDCs to ensure that sensitivity requirements were met. The sensitivity requirement is relaxed when statistically significant activity is identified in order to conserve analytical cost and instrument resources. Several instances were identified in the case narrative where required sensitivities were not achieved (i.e., the sample specific MDCs were greater than the CRDL. In some cases this is attributed to a small sample mass or a low chemical recovery resulting in a low recovered sample mass. Ideally, these samples are reanalyzed with a larger sample volume, when available. Results that were statistically significant were tracked and trended with previous results. Results greater than the MCL or the CRDL require continued sampling.

In all cases, the CRDL for Am-241 0.5 pCi/liter was not achieved when analyzed by gamma spectrometry, but it was easily achieved by alpha spectrometry. The analysis for Am-241 by gamma spectrometry is considered a screening analysis and may be a factor of 50 less sensitive than alpha spectrometry.

Simple rules of thumb were used to evaluate analytical results that were not statistically significant with respect to background. Based on the theoretical relationship of the 1- $\sigma$  net concentration uncertainty and the 1- $\sigma$  background concentration uncertainty (which is the basis for the MDC), the MDC-to-uncertainty ratio was evaluated numerically for consistency and reasonableness. In this case, the 2- $\sigma$  TPU uncertainty was used as the estimator for the 1- $\sigma$  net concentration in the evaluation and MDC-to-uncertainty ratios less than 1.5 were flagged for additional review. These thumb rules do not apply to low count rate results typical of alpha isotopic analyses where MDC-to-TPU ratios can span the range from 1 to 25.

### **5.2.6 Issue Resolution/Case Narrative**

Case narratives record detailed documentation of the analyses requested and provide additional documentation regarding problems encountered with sample receipt, sample analysis and data reporting. The forms are generated by the laboratory as required in the SOW and forwarded to the GW monitoring project with all hard copy data packages. The documentation is intended to identify occurrences, deficiencies and/or issues that may potentially have an adverse effect on data integrity. These case narratives are included in Appendixes D with the laboratory analytical data sheets. Specific quality issues identified by the GEL lab during the reporting of third quarter and fourth quarter 2005 sampling event data are summarized in Tables 5-16 and 5-17, respectively. Specific issues identified by the GEL lab during the reporting of Westbay MP sampling event data are included in Table 5-19. In some cases, these occurrences initiated internal non-conformance action on the part of GEL Charleston lab with additional follow-up documentation. We will continue to monitor these case narratives and their impact on lab data quality.

### **5.2.7 Lab Audits**

No onsite audits or assessments were conducted at the GEL facility during this time period.

### **5.2.8 Analytical Bias Assessment**

Historically, commercial analytical laboratories used by CYAPCo have exhibited some difficulty with the reporting of false-positive results, based on MAPEP performance evaluation (PE) data and trend analysis of analytical sample results. These difficulties were generally limited to radioisotopes analyzed via liquid scintillation counting (LSC) and to a lesser extent, gas proportional counting (GPC).

Positive trends and biases have been observed in the past with the following nuclides analyzed via LSC at levels near the reported MDC: Fe-55, Ni-63, Tc-99 and Pu-241. Low-level analytical positive trends have also been observed for Sr-90, gross alpha and gross beta analyses, which are analyzed via gas proportional counting (GPC). Significant trends with gamma or alpha isotopic analysis results are less common.

A positive bias was observed for gross alpha and gross beta results analyzed via GPC during the third quarter sample event. The magnitude of the positive bias was less than

the analysis sensitivity or average MDC. Positive bias was also observed in the Cs-137 and Am-241 results analyzed by gamma spectrometry methods. Negative biases were not observed during the third quarter 2005 round.

A positive bias was observed for gross beta and Sr-90 analyzed via GPC during the fourth quarter sample event. Positive bias was also observed in the C-14 and Tc-99 results analyzed via LSC, Cs-134 by gamma spectrometry, and Cm-242 via alpha spectrometry. The magnitude of the positive bias was less than the analysis sensitivity or average MDC. Negative biases were not observed during the fourth quarter 2005 round.

Statistical and visual methods were employed to evaluate trends in the analytical results as a function of nuclide. Rank order plots for the first and fourth quarter 2005 sample events were prepared as a function of nuclide (see Appendix E). The analytical data were treated as follows:

- Net concentration results at all well locations were arranged in ascending order
- Standard distributional statistics were calculated (i.e., mean, median, minimum, maximum and standard deviation for the net concentration, 2- $\sigma$  random uncertainty and MDC)
- Net concentration results with associated random uncertainty error bars were graphed as a function of rank order
- Expected zero mean concentration and 2- $\sigma$  zero mean concentration control limits graphed as a function of rank order
- Average MDC graphed as a function of rank order

Graphing the expected zero mean and associated 2- $\sigma$  zero mean concentration control limits provides a visual indication of biases in the analytical technique at concentration levels near or below the MDC. The expected  $\pm$  2- $\sigma$  zero mean control limits were based on actual sample data when activity was near or less than the MDC. In most cases, the average 2- $\sigma$  TPU provides restrictive control limits that are more sensitive than the standard deviation of the mean concentration, which is subject to the influence from positive outliers. For analyses that were generally statistically significant with respect to background (i.e., gross alpha, gross beta), analytical blank data were used to estimate the 2- $\sigma$  zero mean control limits.

Statistical methods were used in order to accurately identify and quantify biases in analytical lab data. Some basic statistical parameters for the first and fourth quarter 2005 events are summarized in Tables 5-19 and 5-20, respectively. These methods included segregation of the analytical data into logical subsets, use of outlier detection methodology, and identification of statistical significant bias. Logical data subsets were typically comprised of an individual nuclide by sample event or sample analysis batch. For LSC analysis, a logical subset may consist of samples counted in a single batch. Due to the number of samples collected, multiple batches may be processed for each analyte in a typical sampling event.

A typical groundwater analysis data subset (i.e., by nuclide) was assumed to be comprised of two distributions, an underlying background or zero analyte component randomly distributed around zero, and an unknown spatially or temporal varying distribution characterized by statistically significant or higher analyte concentrations. In most circumstances, the limiting mean value of the underlying background is expected to be a constant with random fluctuations normally distributed around zero, after correcting for instrument background or blank conditions. In the case of a systematic bias in the background, the limiting mean value of the background distribution will be normal and randomly distributed around a non-zero (i.e., positive or negative) value. When the data are sorted in ascending order with regard to analyte concentration, the underlying background will be distributed on the low analyte concentration end while the spatially or temporally varying analyte results (i.e., statistically significant results), will be distributed on the high concentration end of the data sub-set.

Given the rank order of the data set, a modified Z-score method was used starting on the low analyte concentration end, to identify statistical outliers on the high analyte concentration end of the data set. The Z-score test is a standard statistical method to identify outlier data. Positive outliers as identified were assumed to be nonzero or part of the spatially or temporally distributed data. All other results were considered to be part of the zero analyte or baseline distribution. The limiting mean and standard deviation of these baseline mean results were used as an indicator for technique bias at concentrations near the MDC.

The underlying background or baseline data were evaluated for normality based on Filliben's r-statistic, also known as the normal probability plot correlation coefficient. Filliben's r-statistics near unity are characteristic of normally distributed data. Results of the normality testing for the third and fourth quarter 2005 sample events are summarized in Tables 5-21 and 5-22, respectively. Standard hypothesis testing was also used to determine if the limiting mean bias was statistically different from zero. The limiting mean baseline results were evaluated for statistical significance using the Student's t-test. In order to concentrate our efforts on analyses with the most significant bias, we used a 3- $\sigma$  criterion to identify with a high degree of confidence (i.e., at the 99.97 % confidence level) analyses with significant bias with respect to the underlying background or baseline. Our selection of a 3- $\sigma$  criterion in this case is based on conventional control chart theory where the analytical technique is said to be in control (i.e., no apparent bias) when the observed limiting mean value is within  $\pm 3\text{-}\sigma$  of the expected zero analyte concentration. Results of t-testing for the first and fourth quarter 2005 sample events are also included in Tables 5-21 and 5-22, respectively. Some typical examples of the application of these statistical based methods as a function of general analysis type or nuclide-of-interest are as follows.

#### **5.2.8.1 Gamma Emitters**

Manganese-54 is a gamma emitter, determined by photon counting or gamma isotopic analysis. Manganese-54 is produced by neutron reactions with structural stainless steel and has an expected low radionuclide inventory due to a short radioactive half-life of 312.7 days. It has decayed through greater than 7 half-lives since plant shutdown and less than 0.5% of its shutdown activity or inventory remains. Mn-54 is not expected to

be present in detectable quantities in groundwater samples from the HNP and is a good candidate analysis to demonstrate a zero analyte or underlying background distribution.

Figure 5-1 is a rank order plot of Mn-54 concentrations in groundwater for the third quarter 2005 sampling event. The Mn-54 results are graphed with their corresponding 2- $\sigma$  error bars. An average and 1- $\sigma$  standard deviation concentration of  $0.30 \pm 1.06$  pCi/L was observed in this data set while the average MDC was 3.6 pCi/L. The control limits are  $\pm 2.12$  pCi/L based on the 2- $\sigma$  standard deviation of the limiting mean. Approximately half the data points are distributed above or below the zero concentration level. Note that the 2- $\sigma$  error bars generally cross zero except in the extreme positive or negative regions of the data.

The limiting mean value of 0.30 pCi/L is statistically equal to a zero concentration level based on the t-statistic and 47 (n-1) degrees of freedom. The data are also normally distributed around the limiting mean value as illustrated by the frequency distribution in Figure 5-2. As expected, no significant Mn-54 activity is indicated in this trend plot and the data are equally distributed around zero. These results are typical of gamma isotopic analysis where no analyte is present and the background or energy baseline is easily and accurately determined.

Cesium-137 is a gamma emitter, determined by photon counting or gamma isotopic analysis. Cesium-137 is a fission product with a 30.17-year radioactive half-life. Due to a high radionuclide inventory and radioactive half-life, or decay considerations, Cs-137 has been detected in groundwater samples from the HNP.

Figure 5-3 is a rank order plot of Cs-137 concentrations from the third quarter 2005 sampling event. An average and 1- $\sigma$  standard deviation concentration of  $0.26 \pm 1.08$  pCi/L, was observed for the limiting zero mean while the average MDC was 3.6 pCi/L. The control limits are  $\pm 2.16$  pCi/L based on 2- $\sigma$  standard deviations of the limiting mean. The baseline data are normally distributed around the limiting mean value of -0.26 pCi/L in Figure 5-4 and the limiting mean value is not statistically different from zero, based on the t-test. These results are again typical of gamma isotopic analysis with zero analyte data.

Cobalt-60 is a gamma emitter with a high radionuclide inventory at HNP due to its presence in structural material. Cobalt-60 has a radioactive half-life of 5.271-years and about 42% of its shutdown inventory or activity remains. Cobalt is a common impurity in stainless steel and is the dominant external dose producing isotope in reactor interior components on a 10-year time scale.

Figure 5-5 is a rank order plot of Co-60 concentrations in groundwater for the fourth quarter 2005 sampling event. An average and 1- $\sigma$  standard deviation concentration of  $0.26 \pm 1.13$  pCi/L was observed for the limiting zero mean while the average MDC was 3.6 pCi/L. The control limits are  $\pm 2.26$  pCi/L based on 2- $\sigma$  standard deviations. The baseline data are normally distributed around the limiting mean value of 0.26 pCi/L (Figure 5-6). The limiting mean is statistical equal to zero based on the t-test and there were no positive outliers in this Co-60 data set.

It is important to note that Co-60 is also a common trace contaminant in materials used in the construction of high-purity germanium (HPGe) detectors. These HPGe detectors are used for the gamma isotopic analyses. It is not uncommon to observe Co-60 peak background response rates on the order of 0.001 count per second, depending on the HPGe detector size and configuration. Given the sensitivity requirements for these analyses, the ability to accurately distinguish low-level Co-60 (i.e., pCi/L amounts) in groundwater from the detector background contribution is non-trivial. These results are typical of gamma isotopic analysis where the underlying baseline distribution is homogenous and normally distributed. In the past, we have observed positive biases for Co-60, on the order of 0.4 pCi/L.

#### 5.2.8.2 Beta and X-Ray Emitters via LSC

Figure 5-7 is a rank order plot of C-14 concentrations in groundwater for the fourth quarter 2005 sampling event. Carbon-14 is a beta emitter, determined by oxidative distillation and LSC. Carbon-14 has a radioactive half-life of 5730-years, so most of its shutdown inventory is available from a decay perspective. An average and 1- $\sigma$  standard deviation concentration of  $24.6 \pm 21.2$  pCi/L was observed in this data set while the average MDC was 42.4-pCi/L. The control limits are  $\pm 42.4$  pCi/L based on the average 2- $\sigma$  standard deviation. Note that thirty-two (32) of the thirty-six (36) data points are distributed above the zero concentration level.

The limiting mean value of 24.6-pCi/L is statistically greater than the zero concentration level based on the t-statistic and 34 (n-1) degrees of freedom. The data are also normally distributed around the limiting mean value as illustrated by the frequency distribution in Figure 5-8. A significant positive bias is indicated in this trend plot and the data are equally distributed around the limiting mean. These results are typical of LSC analysis where a significant positive systematic bias in the underlying baseline distribution exists. In the case of C-14, this underlying baseline is not attributed to natural background levels of C-14, which are expected to be on the order of 5 to 10, pCi/L.

Figure 5-9 is a rank order plot of Tc-99 in ground water for the December 2005 sampling event. Technetium-99, which decays by beta emission, is determined by LSC analysis. Technetium-99 has a radioactive half-life of xx-years and a significant portion of its shutdown inventory or activity remains. An average and 1- $\sigma$  standard deviation concentration of  $1.65 \pm 2.10$  pCi/L was observed in this sample event data set with an average MDC of 7.8-pCi/L. The Tc-99 data are normally distributed around the limiting mean value of 1.65-pCi/L as indicated in Figure 5-10. The limiting mean value is statistically greater than zero, based on the t-test. These results are typical of LSC analysis where a significant positive systematic bias in the underlying baseline distribution exists. We have observed both positive and negative biases with Tc-99 analytical results. This suggests that the analytical laboratory has some difficulty in determining the appropriate analytical blank contribution for Tc-99 via LSC.

Similar results were obtained for other LSC radionuclides. CYAPCo will continue to statistically evaluate and monitor these data. In the meantime, we will report the data as

is in order to evaluate any dose risk associated with groundwater monitoring in a conservative manner.

#### 5.2.8.3 Beta and Alpha Emitters via GPC

Figure 5-11 is a rank order plot of Sr-90 in water for the third quarter 2005 sampling event. An average and 1- $\sigma$  standard deviation concentration of  $0.13 \pm 0.22$  pCi/L was observed in the limiting mean baseline data set after removing statistically significant or positive outliers and the average MDC was 1.12-pCi/L. The control limits are  $\pm 0.44$  pCi/L based on the average 2- $\sigma$  standard deviation of the limiting mean. Note that fifty-six (56) of the original sixty-nine (69) reported Sr-90 results for this data set were greater than the zero concentration.

The baseline Sr-90 data consisted of 49 data points and were normally distributed around the limiting mean value of 0.13-pCi/L as indicated in Figure 5-12. The baseline limiting mean value was statistically greater than zero based on the t-test. These results are typical of the GPC analysis method, which is not nuclide specific, and a positive systematic bias in the underlying baseline distribution may exist.

Similar results were obtained for gross alpha and gross beta analyses performed via GPC. In the case of gross alpha and gross beta, the positive trends observed in these analyses, are most likely attributed to natural levels of gross alpha and beta radioactivity.

#### 5.2.8.4 HTD Alpha Emitters

Figure 5-13 is a rank order plot of Cm-242 concentrations in groundwater for the fourth quarter 2005 sampling event. Curium-242 is an alpha emitter with an expected low radionuclide inventory at HNP due to radioactive decay. Curium-242 has a radioactive half-life of 163.2 days and has decayed through greater than 14 half-lives since shutdown. Since less than 0.01% of the shutdown activity or inventory remains, Cm-242 is not expected to be present in detectable quantities in groundwater samples from the HNP.

An average and 1- $\sigma$  standard deviation concentration of  $0.008 \pm 0.010$  pCi/L was observed in this data set while the average MDC was 0.05 pCi/L. The control limits are  $\pm 0.02$  pCi/L based on 2- $\sigma$  standard deviations of the limiting mean. The baseline data are not normally distributed around the limiting mean value of, 0.008 pCi/L in Figure 5-14 and the limiting mean value is different from zero, based on the t-test. Low-level counting data are not always expected to be normal, around a limiting mean value. This is a characteristic of low-level alpha counting where the expected shape of the limiting mean distribution is Poisson in nature. The Poisson distribution is asymmetric and representative of a distribution that can be bounded by zero on the low frequency side. In this case, twelve (12) of the thirty-seven (37) reported results exhibited a zero concentration, contributing to the non-normal distribution. As expected, no significant Cm-242 activity is indicated in the trend plot even though the t-test suggests a positive bias. The t-test is not appropriate for non-normal distributions and should be considered qualitative in this case. These results are typical of low-level alpha isotopic analysis where no analyte is present.

#### 5.2.8.5 Radiochemical Bias Summary

Attached in Table 5-23 is a summary of the percentage of positive results detected at concentrations that were greater than 2- $\sigma$  random error and near the MDC level for the third quarter and fourth quarter 2005 sample events. This table provides an indication of the percentage of false positive results as a function of analysis method. Known statistically positive results were removed from these summaries. Only about 5.5% of the gamma isotopic analysis results were greater than the 2- $\sigma$  random error level, which is just slightly higher than the expected rate of 2.5% if there were no significant gamma emitters present. One would expect a "false positive" rate of 2.5% based on the area under the standard normal distribution around a limiting mean concentration of zero, at the 95% confidence level. These results suggest that there is little bias in the gamma isotopic analytical results at levels near the MDC, and there is little gamma isotopic activity in these samples.

Alpha isotopic results for the first and fourth quarter 2005 sample events indicated overall positive activity rates of 0.0%, which also indicates no significant alpha activity present in these samples with minimal bias in the analytical technique at levels near the MDC.

The percentage of HTD beta results determined via LSC and with concentration levels greater than 2- $\sigma$  random error was 5.1%. These results were generally normally distributed around a limiting mean concentration in most cases. Only 1 of the 12 LSC analyses (by nuclide) indicated limiting mean distributions that were positive. Negative limiting mean distributions were not observed for any of the LSC analyses.

Factors that may affect the uncertainty of radiological analyses, and the ability to discern plant-related activity from the natural background activity include; interference from naturally occurring radionuclides due to incomplete radiochemical separation, specificity of radiochemical counting technique, and difficulty in identifying the ambient background or blank contribution. In low-level radiochemical counting, these limitations are imposed by the accurate determination of the systematic and random uncertainty associated with the analytical blank. Generally speaking, gamma isotopic and alpha isotopic analyses are the most specific counting methods with the least amount of systematic bias in the underlying background or blank. GPC and LSC are less specific counting methods and may be subject to systematic and random variability in the underlying blank distribution. CYAPCo will continue to statistically evaluate and trend lab data in order to understand limitations and irregularities in analytical results.

Based upon the work performed during the implementation and development of this Groundwater Monitoring Report for the first and fourth quarter 2005 quarterly sampling events, the following conclusions and recommendations have been developed for the radiochemical analyses presented in this report:

- A systematic bias was observed for Sr-90 based on statistical and graphical evaluations of the reported analytical data. Negative biases, which have been

observed in the past for radionuclides analyzed by LSC, were not observed in any of the sample event data sets.

- Positive systematic biases were also observed for H-3 (analyzed via LSC) and gross alpha/beta (analyzed via GPC). An overall false positive rate on the order of 6.7% was observed for the LSC analyses results. This is higher than the expected false positive rate of 2.5%.
- Systematic bias was not identified for gamma emitters, based on the statistical and graphical evaluations, but an overall false positive rate of 5.5% was observed in the data set. CYAPCo will continue to statistically evaluate and trend the biases identified within this report.
- Field collected and laboratory completed QA/QC sample results were within acceptable protocol ranges for all analyses.
- External laboratory performance evaluation data was excellent for all gamma emitters and good to average for the alpha and beta HTD analysis. About 73% of the false positive test results were in the acceptable or acceptable with warning range.
- Internal laboratory performance evaluation data was excellent for all analyses. Greater than 98% of the results met the acceptance criteria.

### **5.3 Data Quality Summary**

Analysis of boron, total uranium and radiochemical constituents was performed on unfiltered water samples collected from groundwater monitoring wells at HNP during the third and fourth quarter of 2005.

Overall, assessments of QA/QC information indicate that groundwater monitoring data are acceptable for groundwater characterization and monitoring efforts. Groundwater sampling was performed in accordance with sample plans and work processes. No contamination or other sampling-related problems were identified that affected data integrity in the field. Laboratory external performance data was good to excellent for all constituents. MAPEP performance results for false positive testing requires some improvement. Laboratory internal performance data was good to excellent for all constituents. Measurement of boron, total uranium and radiochemical constituents in samples collected from HNP met the identified data quality metrics for these sampling events as summarized in Table 5-24.

## 6 Spatial and Trend Analysis

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### 6.1 Spatial Distribution of SOCs

The spatial distribution of detected SOCs (boron, tritium, Sr-90) have been mapped for the perched, unconfined and confined aquifers for the third and fourth quarter 2005 sampling events, and are summarized below.

There is uncertainty in mapping groundwater flow and contaminant distribution in fractured rock. The maps of contaminants and the text discussing spatial distribution is intended to show general distribution of contaminants; actual flow through the fractured rock may vary significantly from that depicted and discussed. The inferred distribution of SOCs represents interpretations of site conditions.

#### 6.1.1 Spatial Distribution of SOCs from Third Quarter 2005

The concentrations of boron, tritium, Sr-90, Cs-137, and total uranium for the third quarter 2005 sampling results for the industrial area and peninsula area are displayed on Figures 6-1 and 6-2. A discussion of the distribution of the SOCs in each aquifer is presented in the following sections.

##### 6.1.1.1 Boron

Boron is detected in the three aquifers at concentrations ranging from 16 µg/L to 565 µg/L. This range of boron concentration includes both naturally occurring background boron and plant-related boron. Although no statistical assessment of background boron concentrations in groundwater at HNP has been performed, concentrations of up to 100 µg/L in unconsolidated and shallow bedrock formations are generally considered to be natural background; concentrations greater than 100 µg/L are generally considered to be elevated due to plant-related contributions. Furthermore, groundwater samples collected from the deeper zones of the multi-level bedrock wells exhibit boron in excess of 200 µg/L that may well be naturally occurring.

There is no MCL or CTDEP RSR established for boron, however the CTDEP, as part of the ongoing RCRA CAP and Property Transfer program, has recently established an RSR of 1,400 µg/L for boron. Boron will be assessed against RSR criteria as part of the RCRA CAP/Property Transfer program. In the context of this report boron is used as an indication of plant-related contamination and also as an effective tracer of potentially contaminated groundwater. A discussion of the boron distribution in groundwater for the three aquifers is presented in the following sections.

##### Perched Aquifer

The only well currently monitored in the perched aquifer is MW-508S, and the boron concentration in MW-508S was 50.2 µg/L. Boron concentrations in the perched aquifer in previous quarters have been interpreted as background, with no impacts from plant activities observed. The boron detected in MW-508S in the third quarter 2005 is consistent with historic results for MW-508S.

### **Unconfined Aquifer**

A large area of elevated boron is observed in the unconfined aquifer from upgradient portions of the site (MW-101S) to downgradient areas of the site (MW-110S) (Figure 6-3). In the unconfined aquifer boron concentrations appear highest around the southern perimeter of the RCB in MW-106S (565 µg/L), with plume concentration decreasing to the south and southeast, consistent with groundwater flow in the unconfined aquifer (Figures 6-3 and 2-3).

While the source of the highest boron concentrations is focused on the RCB area, elevated boron is also observed in the northern and western portion of the industrial area (MW-101S; 371 µg/L, MW-135; 152 µg/L, and MW-131D; 158 µg/L) and upgradient of the RCB area (MW-102S; 282 µg/L) (Figure 6-3).

Elevated boron is also detected in MW-113S (99.1 µg/L) located south of the discharge canal in the southeastern portion of the site (Figure 6-3). This location is well south and east of the mapped boron plume, but is adjacent to septic leaching beds that may be releasing boron to the shallow groundwater in that area.

### **Confined Aquifer**

In the confined aquifer boron is detected in both the western and eastern portions of the industrial area (Figure 6-4). Elevated boron is detected in MW-109D (195 µg/L) and MW-133 (222 µg/L) located in the western portion of the industrial area (Figure 6-4). Boron is also detected extending south from MW-102D (84 µg/L), past MWR-122D (227 µg/L) and MW-106D (389 µg/L), and on to MW-110D (182 µg/L) in the eastern portion of the industrial area (Figure 6-4). Both areas of detected boron appear to flow from north to south towards the Connecticut River, with the highest concentrations adjacent to and downgradient of the RCB (Figure 6-4). Elevated Boron is also detected in the shallow ports of Westbay wells MW-118A (217 µg/L to 287 µg/L and MW-119 (135 µg/L to 363 µg/L) within the plume identified for the confined aquifer (Figure 6-4).

#### **6.1.1.2 Tritium**

Tritium is detected in the three aquifers at concentrations ranging from non-detect up to 7,170 pCi/L. Tritium did not exceed the DCGL or the single-nuclide MCL (20,000 pCi/L) equivalent concentration at any location. Although there is known to be contribution of tritium to groundwater at HNP (and other locations in North America) from historical deposition of tritium from atmospheric fallout, no statistical assessment of that contribution has been performed at HNP. Detection of tritium at, or near, the detection limits generally achieved by the analytical laboratory may actually be due to background tritium, however, that level is substantially below levels of concern at HNP.

### **Perched Aquifer**

Tritium was non-detect in MW-508S (Figure 6-1), consistent with the historic non-detect values observed perched aquifer monitoring wells. In addition to the low, background boron detections, the tritium distribution also indicates no impacts from plant activities in this portion of the site.

### **Unconfined Aquifer**

In the unconfined aquifer (Figure 6-6), tritium was detected above activity concentrations of 1,000 pCi/L in two locations. The highest tritium levels in the unconfined aquifer occur in MW-102S (3,750 pCi/L) and 1,290 pCi/L is detected in MW-131D (Figure 6-5). The elevated tritium values are located south of the former tank farm (MW-131D) and north of the fuel building (MW-102S). All other tritium values are below 1,000 pCi/L or non-detect (Figure 6-5).

Previous groundwater sampling results had detected a second plume of tritium that flowed from the RCB and PAB area to the southwest, but it was not observed during the first, second, and third quarters of 2005. The absence of tritium-contaminated groundwater in the southwestern portion of the industrial area is most likely related to the source removal activities completed in the PAB and tank farm removal areas.

### **Confined Aquifer**

In the confined aquifer, tritium is detected in a broad portion of the industrial area. The highest tritium is reported in MW-105D (7,170 pCi/L) adjacent to the southwest side of the RCB (Figure 6-6). It appears that groundwater flows from the RCB area, and then continues south toward the Connecticut River, passing through the area of MWR-106D (4,980 pCi/L), MW-110D (5,350 pCi/L) and MW-109D (4,350 pCi/L) (Figure 6-6). The monitoring wells downgradient of the RCB area in the confined aquifer appear to be part of the tritium plume that is sourced in the RCB area. Based on the tritium distribution in the confined aquifer, the general groundwater flow direction in the confined aquifer is interpreted to be to the south and southeast towards the Connecticut River (Figure 6-6).

#### **6.1.1.3 Strontium-90**

Sr-90 is detected in both the unconfined and confined aquifers at concentrations ranging from non-detect up to 3.18 pCi/L. The MCL concentration for Sr-90 is 8 pCi/L and all reported Sr-90 values in the monitoring wells are below the MCL value. One exception to the MCL is Sr-90 in MW-130. MW-130 represents a unique monitoring well construction, as the well was built to monitor seep water flowing from bedrock fractures exposed as part of dewatering and soil remediation activity in the PAB area. A french drain was built on the exposed bedrock to collect seep water, and MW-130 was constructed and screened within the seep collection area. The french drain and monitoring well were subsequently covered with low permeability fill material as part of the remediation activity in the PAB area, and groundwater was allowed to rise to ambient levels within the fill. MW-130 was sampled as part of the third quarter sampling program and the initial sample had 16.2 pCi/L. Recognizing the unique design of MW-130, the elevated Sr-90 initially detected was believed to correspond to an Sr-90 reservoir collected by the french drain and was not representative of the unconfined aquifer as a whole. To further assess MW-130, approximately 1,331 gallons of water was purged from the well to remove any accumulated and or stored seep water, and a second sample was collected and analyzed for Sr-90. The post-purge sample had 1.52 pCi/L of Sr-90 and is believed to accurately represent Sr-90 in that portion of the unconfined aquifer.

### **Perched Aquifer**

Consistent with the historic tritium and boron results in the perched aquifer, Sr-90 has also historically been non-detect in all monitoring wells screened within the perched aquifer. The results for MW-508S for the third quarter were not clear. The initial Sr-90 result for MW-508S was non-detect, however the sample was re-analyzed and the laboratory reported 2.52 pCi/L Sr-90. The re-analysis is not consistent with the historic results or the fourth quarter 2005 results (see Section 6.1.2.3) that was also non-detect. Additional groundwater monitoring will be necessary to resolve this uncertainty.

### **Unconfined Aquifer**

In the unconfined aquifer the highest Sr-90 is detected in MW-134 (2.52 pCi/L) located south of the RCB (Figure 6-7). Additional detected Sr-90 occurs in MW-131D (1.94 pCi/L), MW-135 (1.93 pCi/L), MW-130 (1.52 pCi/L), and MW-106 (1.23 pCi/L). The highest Sr-90 concentration is located downgradient of the RCB and tank farm, which appears to be the source area(s) for the Sr-90 detections. Based on the groundwater flow map developed for the unconfined aquifer, and its similarity to the plumes mapped for tritium and boron in the unconfined aquifer, it appears that the Sr-90 plume is flowing south and southeast toward the Connecticut River (Figures 6-7 and 2-4).

### **Confined Aquifer**

In the confined aquifer Sr-90 was detected in MWR-106D (2.37 pCi/L) and the initial sample from MW-508D (3.18 pCi/L) (Figure 6-8). MWR-106D is located southeast of the RCB and MW-508D is located in the southeast corner of the parking lot, well south and west of the RCB. MW-508D had historically had non-detect values for Sr-90 and is well south and west of historic Sr-90 detections in the confined aquifer. To further assess the detected Sr-90 in MW-508D, the sample was re-analyzed at the laboratory and the re-analysis for Sr-90 was non-detect. Additional monitoring will be necessary to resolve this uncertainty for Sr-90 in MW-508D.

Based on the limited data available in the vicinity of the RCB in this aquifer and the non-detect values in all of the other monitoring wells, no distinct plume can be mapped in the confined aquifer.

## **6.1.2 Spatial Distribution of SOCs from Fourth Quarter 2005**

The concentrations of boron, tritium, Sr-90, Cs-137, and total uranium for the fourth quarter 2005 sampling results for the industrial area and peninsula area are displayed on Figures 6-9 and 6-10. A discussion of the distribution of the SOCs in each aquifer is presented in the following sections.

### **6.1.2.1 Boron**

Boron is detected in the three aquifers at concentrations ranging from 17.2 µg/L up to 1,180 µg/L. This range of boron concentration includes both naturally occurring background and plant-related boron. Although no statistical assessment of background boron concentrations in groundwater at HNP has been performed, concentrations up to 100 µg/L in unconsolidated and shallow bedrock formations are generally considered

natural background; concentrations greater than 100 µg/L are generally considered to be elevated due to plant-related contributions. Furthermore, groundwater samples collected from the deeper zones of the multi-level bedrock wells exhibit boron in excess of 200-µg/L that may well be naturally occurring.

There is no MCL or CTDEP Remediation Standard Regulation (RSR) established for boron, however the CTDEP as part of the ongoing RCRA CAP and Property Transfer program has recently established an RSR of 1,400-µg/L for boron. Boron will be assessed against RSR criteria as part of the RCRA CAP/Property Transfer program. In the context of this report boron is used as an indication of plant-related contamination and also as an effective tracer of potentially contaminated groundwater. A discussion of boron in the three aquifers follows.

#### **Perched Aquifer**

The only well currently monitored in the perched aquifer is MW-508S, and the boron concentration in MW-508S for the fourth quarter was 61.5 µg/L. Boron concentrations in the perched aquifer in previous quarters have been interpreted as background, with no impacts from plant activities observed. The boron detected in MW-508S in the fourth quarter 2005 is consistent with historic results for MW-508S.

#### **Unconfined Aquifer**

In the unconfined aquifer (Figure 6-11), boron concentrations appear highest around the eastern perimeter of the RCB, adjacent to the fuel building, and in the northeastern portion of the industrial area. The highest boron concentration occurs in MW-137 (1,180 µg/L) located northeast of the RCB and adjacent to the southern side of the fuel building (Figure 6-11). Consistent with the groundwater flow contours in the unconfined aquifer, a plume of boron occurs to the south and east of the RCB with concentration decreasing to the south toward the Connecticut River (Figures 2-7 and 6-11). The boron distribution in the southern, downgradient portion of the plume is characterized by MW-109S (109 µg/L) and MW-110S (127 µg/L).

Similar to that observed in the third quarter 2005, elevated boron is also detected in MW-113S (103 µg/L) located south of the discharge canal in the southeastern portion of the site (Figure 6-11). This location is well south and east of the mapped boron plume, but is adjacent to septic leaching beds, that may be releasing boron to the shallow groundwater in that area.

#### **Confined Aquifer**

The distribution of boron in the confined aquifer unit defined by the fourth quarter 2005 data show a broad plume of boron concentrations greater than 100 µg/L, with a higher central plume with boron in excess of 350 µg/L (Figure 6-12). The area of elevated boron extends south from the RCB and east of the RCB down to the Connecticut River, and appears to be sourced in the RCB area (Figure 6-12).

The elevated boron in the wells in the western portion of the plume (MW-123S; 121 µg/L) is not associated with other SOCs, suggesting a source other than borated water from the power plant process (Figure 6-12).

### **6.1.2.2 Tritium**

All detections in the three aquifers are below the MCL concentration for tritium of 20,000 pCi/L, and range from non-detect to 16,000 pCi/L. Elevated tritium concentrations are observed in both the unconfined and confined aquifers, with the highest concentration observed in the confined aquifer. Although there is known to be contribution of tritium to groundwater at HNP (and other locations in North America) from historical deposition of tritium from atmospheric fallout, no statistical assessment of that contribution has been performed at HNP. Detection of tritium at, or near, the detection limits (250 pCi/L to 500 pCi/L) generally achieved by the analytical laboratory may actually be due to background tritium, however, that level is substantially below levels of concern at HNP.

#### **Perched Aquifer**

Tritium was non-detect in MW-508S (Figure 6-9), consistent with the historic non-detect values observed in the perched aquifer monitoring wells. In addition to the low, background boron detections, the tritium distribution also indicates no impacts from plant activities in this portion of the site.

#### **Unconfined Aquifer**

Similar to the tritium distribution mapped from the third quarter 2005 results, the highest tritium concentrations are observed northeast and adjacent to the RCB in MW-137 (7,760 pCi/L) and MW-132S (7,720 pCi/L) (Figure 6-13). MW-137 and MW-132S are directly adjacent to the Fuel Building where the fuel pool is located. The elevated tritium in the RCB and Fuel Building area flows south of the RCB towards the discharge tunnel and the Connecticut River (Figures 6-13 and 2-7).

#### **Confined Aquifer**

The tritium distribution in the confined aquifer defined by the fourth quarter 2005 data is very similar to that identified in the third quarter 2005 results (Figures 6-6 and 6-14). Elevated tritium concentrations are observed south of the RCB in MWR-106D (4,630 pCi/L) and MW-105D (5,930 pCi/L), and the highest tritium values occur in MW-110D (3,010 pCi/L) located further to the south near the Connecticut River. These wells define a plume of tritium that is flowing towards the Connecticut River, consistent with the mapped groundwater flow for the confined aquifer (Figures 6-14 and 2-8). Elevated tritium also occurs in the deeper portion of the confined aquifer as defined by the Westbay monitoring wells. Tritium concentrations in the Westbay monitoring wells range from 1,570 pCi/L in MW-120 on the western edge of the plume to 16,000 pCi/L in central portion of the plume (Figure 6-14)

### **6.1.2.3 Strontium 90**

Sr-90 is detected in both the unconfined and confined aquifers, with concentrations ranging from non-detect to 5.19 pCi/L. All Sr-90 concentrations reported for the fourth quarter 2005 are below the MCL concentration for Sr-90 of 8 pCi/L. The Sr-90 distribution in the three aquifers is discussed in the following sections.

#### **Perched Aquifer**

Sr-90 was not detected in MW-508S, consistent with historic analyses prior to third quarter 2005. The third quarter 2005 results were not clear, as the initial analysis was non-detect while a re-analysis detected a low concentration (2.52 pCi/L) of Sr-90. The

non-detect value reported in the fourth quarter is consistent with results received prior to third quarter 2005. Additional monitoring will be necessary to finalize interpretation of potential impacts to the perched aquifer.

#### **Unconfined Aquifer**

In the unconfined aquifer the highest Sr-90 is detected in MW-106S (2.4 pCi/L) and MW-125 (2.51 pCi/L) located adjacent to southern side of the RCB and downgradient to the southeast of the RCB, respectively (Figure 6-15). Additional detected Sr-90 occurs in MW-131S (1.99 pCi/L), MW-137 (1.28 pCi/L), MW-136D (0.864 pCi/L), and MW-110S (0.361 pCi/L). Based on the groundwater flow map developed for the unconfined aquifer and similar to the plumes mapped for tritium and boron in the unconfined aquifer, it appears that the Sr-90 is migrating south toward the Connecticut River (Figures 6-15 and 2-5).

Sr-90 was also detected in MW-117 (1.25 pCi/L) located in the eastern portion of the lower peninsula. Low Sr-90 detections (0.8 to 1.5 pCi/L) similar to those reported in the fourth quarter 2005 have been observed in this monitoring well in previous quarterly sampling.

#### **Confined Aquifer**

Sr-90 was detected in two areas in the confined aquifer. The highest Sr-90 value was reported in MW-103A (5.19 pCi/L) located adjacent to the tank farm northwest of the RCB. Sr-90 was also present in MWR-103S (0.98 pCi/L) located in the same general area (Figure 6-16). A second area of Sr-90 is present on the southeast side of the RCB. The Sr-90 plume interpreted from the two areas where Sr-90 is detected is interpreted to flow south towards the Connecticut River (Figure 6-16). The highest concentration in the southern portion of the plume is 2.18 pCi/L detected in MWR-106D located southeast of the RCB.

### **6.1.3 Distribution of Cs-137 in Third and Fourth Quarter 2005**

Cs-137 was not detected above the MDC in the third quarter 2005, but was detected in several monitoring wells in fourth quarter 2005. Three monitoring wells had detected concentrations of Cs-137 in fourth quarter 2005 including MW-137 (16.7 pCi/L), MW-103S (12.8 pCi/L), and MWR-122D (6.21 pCi/L). All of these detected values are well below the MCL of 200 pCi/L established for Cs-137. Cs-137 has been detected sporadically in monitoring wells at HNP, but at concentrations well below regulatory limits. Monitoring wells at HNP will continue to be monitored for Cs-137.

### **6.1.4 Distribution of Uranium in Third and Fourth Quarter 2005**

Uranium, quantified as total uranium, has been consistently detected in deep bedrock monitoring wells across the site. Total uranium concentration has typically been higher in deep wells completed in bedrock than in shallow wells completed in unconsolidated soil, with concentrations ranging from non-detect to less than 15 µg/L. Over the last several quarters total uranium has increased in several bedrock monitoring wells, most notably MW-106D and MW-101D. Total uranium increased to values in excess of the MCL (30 µg/L) in both monitoring wells during the first and second quarters 2005 with

concentrations ranging from 58 µg/L to 67.8 µg/L (MW-106D) and 8.95 µg/L to 40.3 µg/L (MW-101D). Total uranium has decreased to values below the MCL in both MW-101D (0.16 µg/L to 20.9 µg/L) and MWR-106D (13.7 µg/L to 21.1 µg/L) monitoring wells in both the third and fourth quarter 2005.

Two additional wells had total uranium exceedences during the third and fourth quarter 2005. In the third quarter 2005, MWR-105D had 69.6 µg/L and 68.4 µg/L was reported in the fourth quarter 2005, while MW-103B reported 57.5 µg/L in the fourth quarter. Both of these monitoring well were newly installed during fall 2005.

The presence of uranium in groundwater at HNP is consistent with the known presence of natural uranium-bearing minerals in the metamorphic rocks underlying the site. Uranium-bearing minerals, including uraninite, have been identified in pegmatite deposits on Haddam Neck (Cook, 2004). Likewise, the isotopic signature of the uranium is also consistent with a natural, background uranium source (see Section 4.10). The increase in uranium is consistent with the transient increase in aeration of the aquifer systems underlying the central portion of the HNP during groundwater depression to support soil removal and structure demolition. Aeration of the aquifer increases the oxidation potential of the groundwater, which will, in turn, increase the solubility of natural uranium species (Yu, et. al., 2001). The oxidation process may also be significant for newly installed bedrock wells like MWR-105D and MW-103A where uranium-bearing minerals may be exposed to oxidized water. Total uranium concentrations are expected to decline following discontinuation of dewatering activities and return to natural water levels and flow regimes.

### **6.1.5 Distribution of SOCs in Multilevel Monitoring Wells**

A total of four Westbay multi-level monitoring wells (MW-118A, MW-119, MW-120, and MW-121A) have been installed at CYAPCo. The multi-port monitoring wells include up to six sampling zones and are screened to depths up to 465 feet below ground surface. The multi-port monitoring well locations are shown on Figure 2-1 and well details for the multi-level monitoring wells are summarized in Table 2-1. MW120 and MW119 are located along the Connecticut River, south of the Former Turbine Hall (Figure 2-1). MW118A is located between the former Turbine Hall and the Discharge Canal, and MW121A is sited south of the western end of the Discharge Canal (Figure 2-1). These monitoring locations are downgradient of potential source areas and are sited within and near potential bedrock fractures that control groundwater pathways within the confined aquifer.

The multi-level monitoring wells were sampled during the third and fourth quarter 2005 and analyzed for SOCs including Sr-90, Cs-137, tritium and boron. Cs-137 results were non-detect for both third and fourth quarters 2005. Sr-90 was non-detect during third quarter 2005 in all Westbay multilevel wells, but low Sr-90 concentrations were reported in MW-119-4 (1.75 pCi/L), MW-119-6 (2.02 pCi/L), and MW-121A-4 (1.58 pCi/L). The results for both third and fourth quarters for tritium and boron are summarized in

Figures 6-17 through 6-24. The concentration versus depth profiles for tritium and boron are very similar for each in both the third and fourth quarters.

Boron concentrations in the multi-level wells ranged from 28.8  $\mu\text{g/L}$  to 363  $\mu\text{g/L}$ , while tritium concentrations varied from non-detect to 16,500 pCi/L.

The distribution of tritium with sampling depth in the four multi-level monitoring wells is shown in Figures 6-17 through 6-20. Tritium has a maximum activity concentration between 50 and 100 feet BGS in MW-118A, MW-119, and MW-120, while the maximum value in MW-121A occurs between 150 and 200 feet BGS (Figure 6-16 through 6-19). Tritium concentrations decrease from the maximum value to background levels in all four wells. The tritium concentrations in MW-120 are much lower than those in the other three Westbay wells (Figures 6-16 through 6-19). MW-120 is located near the western limit of the mapped confined aquifer plume and defines the edge of the tritium plume in the deeper portions of the confined aquifer (6-18 and 6-13). All tritium concentrations in the four Westbay wells are consistent with background levels below 250 feet BGS (Figure 6-17 through 6-20).

The boron distribution with sampling depth is different than that observed for tritium. While a maximum boron concentration for MW-119 and MW-118A is observed between 50 and 100 feet BGS, boron levels increase with sampling depths below 150 feet BGS (Figures 6-21 and 6-22). Similarly, boron concentrations increase with sampling depth in both MW-120 and MW-121A (Figures 6-23 and 6-24). The observed concentrations (100  $\mu\text{g/L}$  to 350  $\mu\text{g/L}$ ) are well above typical background levels detected in shallow groundwater samples (less than 100  $\mu\text{g/L}$ ) across the facility, but well below the CTDEP RSR of 1,400  $\mu\text{g/L}$ .

The decrease in tritium concentrations with sampling depth below 250 feet BGS indicates that minimal plant-related groundwater contamination occurs at depth in the confined aquifer. The presence of elevated boron in the deep confined aquifer may indicate that the background distribution of boron in the deeper bedrock is different than that observed in the shallow portions of the confined aquifer and in the unconfined aquifer.

## 6.2 Trend Analysis of SOCs

### 6.2.1 Boron Trend Analysis

There has been a general decrease in the observed maximum boron concentration at HNP since September 1999. Boron concentrations have generally fluctuated over the time-frame of the GWMP without discernable temporal or spatial trends. The boron quarterly monitoring analytical results from December 2001 through December 2005 are compiled in Appendix D. Time series plots of the boron concentrations from March 2002 to December 2005 are provided in Appendix F.

The higher boron concentrations have generally been detected in the shallow wells, typically those wells screened in the unconfined aquifer. Boron levels in bedrock or confined aquifer wells have typically been relatively low compared to wells completed in shallower intervals, probably reflective of background concentrations. This generalization is well illustrated by the time series plot of well pair MW-100S and 100D. Boron concentrations that have fluctuated greatly in MW-100S, screened in the unconfined aquifer, ranging as high as 1,145  $\mu\text{g}/\text{L}$  as recently as December 2003, to a stable trend of non-detections exhibited in MW-100D, a deep bedrock or confined aquifer well. A different type of trends are also shown in the MW-105S/D and MW-106S/D well pairs, both of which have shown greatly elevated boron concentrations in the shallow unconfined aquifer wells and low boron levels in the deep bedrock wells probably near background concentrations prior to RCA soil remediation efforts. Results for October and December 2005 exhibited near background levels at MW-105S (45.3 and 39.5-pCi/L) and MWR-105D (106 and 100-pCi/L). Results were consistently higher at MW-106S (565 and 401-pCi/L) and MW-106D (389 and 356-pCi/L).

Attached in Figure 6-25 is a box plot for boron concentrations as a function of time ranging from September 1999, through December 2005. Box plots provide a mechanism to graphically compare 2 or more sets of data, in this case, temporal or seasonal groundwater monitoring results from multiple quarterly sampling events. In particular, trends with respect to the median, extreme values and data dispersion over time are visually evident. The median value provides an unbiased central tendency of the data that is not affected by extreme outliers. The position of the median value in the vertical box provides information regarding the symmetry of the inter-quartile range when viewed on a linear scale. The inter-quartile range describes the spread of the central 50% of the data. The length of the vertical boxes shows the extent of the inter-quartile range. The length of the vertical lines or whiskers shows the overall extent of the data above and below the inter-quartile range. We have selected a log concentration scale since the detectable concentrations ranged over 2 or more orders of magnitude.

The box plot displays a quartile summary of quarterly sample event data with some key statistics. The quarterly sample event results are sorted in increasing numerical order and divided into 2 groups at the median or second quartile ( $Q_2$ ). The median of the lower group is the first quartile ( $Q_1$ ) and the median of the upper group is the third quartile ( $Q_3$ ). The difference between  $Q_3$  and  $Q_1$  is the inter-quartile range and is represented by the central vertical box or rectangle in the box plot diagram. The horizontal line dividing the central vertical box is the second quartile ( $Q_2$ ) or median value of the data set. The two lines extending out from the center box are the whiskers and the end points in this case represent the minimum or zero quartile ( $Q_0$ ) and maximum or fourth quartile ( $Q_4$ ) values.

The plotted values in Figure 6-25 display results for all wells sampled during the sampling event with concentrations greater than the method detection limit (MDL). There has been a general decrease in the observed maximum boron concentration since September 1999. Median results have fluctuated from a low of about 45  $\mu\text{g}/\text{L}$  in December 2001 to a high of 188  $\mu\text{g}/\text{L}$  during September of 2002 with no apparent temporal or seasonal trend.

### 6.2.2 Gross Alpha Trend Analysis

Gross alpha concentrations for the past 14 sample events for unconfined and confined aquifer wells (conventional wells only) are plotted in Figures 6-26 through 6-27. Higher gross alpha levels were generally detected in the deeper wells completed in bedrock during these sampling events (Figure 6-27). The source of most of the activity is erosion of naturally occurring alpha-emitting nuclides that are likely present in the granite-gneiss bedrock. Natural levels of gross alpha activity can range as high as a few hundred pCi/L, when special sampling techniques designed to capture the volatile and short-lived natural alpha emitters are observed. Plant-related alpha radionuclides are not believed to contribute to the gross alpha activity since alpha isotopic analysis generally results in non-detects with nominal detection sensitivities on the order of 0.3 pCi/L or less, which is a factor of 10 lower than the gross alpha MDC.

Figure 6-28 is a box plot for site-wide gross alpha concentrations as a function of time ranging from December 2001, through December 2005. Plotted values in this case represent statistically significant results with concentrations greater than the 2- $\sigma$  TPU. The maximum gross alpha concentration has ranged from 7.8 to 45.7 pCi/L since December of 2001. Median results have fluctuated from a low of 1.3 pCi/L to a high of 5.1 pCi/L. There were no apparent temporal or seasonal trends.

### 6.2.3 Gross Beta Trend Analysis

Gross beta results since 1999 are compiled in Appendix D. Gross beta results ranged from 1.6 to 490 pCi/L. The CT Public Drinking Water Quality Standard screening level for gross beta radioactivity is 50 pCi/L, though natural levels may range as high as a few hundred pCi/L.

Gross beta activity at high levels has been correlated with Sr-90 (a beta emitter) Another beta emitter which contributes to gross beta activity is Cs-137. Gross beta concentrations from the past 14 sample events for the unconfined and confined aquifer wells are plotted in Figures 6-29 through 6-30. All third quarter and fourth quarter 2005 gross beta results from conventional wells are less than the CT Public Drinking Water Quality Standard screening level of 50 pCi/L.

Figure 6-31 is a box plot for site-wide gross beta concentration as a function of time ranging from December 2001, through December 2005. The maximum gross beta concentration has ranged from 142 to 490 pCi/L, since December of 2001. Median results have fluctuated from a low of 5.4 pCi/L, to a high of 10.0 pCi/L. There are no apparent temporal trends associated with gross beta results.

### 6.2.4 Tritium Trend Analysis

There has been a general decrease in tritium activity concentrations at HNP since the quarterly GWMP sampling was implemented in September 1999. A summary of tritium results from the GWMP is provided in Appendix D. The higher tritium activity concentrations have typically been exhibited in the confined aquifer wells, notably deep bedrock wells MW-102D and MW-103D, and shallow bedrock well MW-110D. MW-105S, a well screened in the unconfined aquifer, has historically displayed the highest

tritium activity concentrations at the facility. None of these confined aquifer wells detected tritium above the USEPA MCL of 20,000 pCi/L during the October and December 2005 sampling events. Time series plots showing tritium activity concentrations from the GWMP quarterly sampling events are shown in Appendix F.

Historically, the highest tritium activity concentration observed at MW-102D was 28,630 pCi/L during the June 2003 sample event (see Figure 6-32). Tritium results for MW-102D ranged from 2,860 to 3,070 pCi/L, in October and December 2005, respectively, suggesting consistent concentrations at this well over the last 9 sample events. This well is a confined aquifer or deep bedrock well, which has exhibited fairly stable tritium concentrations in the 20,000 pCi/L range over the sampling events prior to December 2001.

Since December 2001, tritium levels in MW-103D have consistently ranged from 8,100 pCi/L to 12,900 pCi/L (see Figure 6-33). Analytical results for MW-103D ranged from 8,950 pCi/L during the September 2004 event to 10,800 pCi/L during the December 2004 event. This well was not sampled during the October 2005 sample events due to its removal as part of the PAB excavation. Sampling has resumed at this location in December 2005 (7,170-pCi/L) after the installation of MWR-103D.

Tritium levels in well MW110D have decreased substantially from the 27,630 pCi/L detected when quarterly monitoring commenced in September 1999. In December 2002, tritium levels decreased to 11,100-pCi/L (see Figure 6-34). Results have ranged from 5,350-pCi/L in October 2005, to 8,010-pCi/L, during the December 2005 sampling event.

The highest tritium concentration recorded to date was 138,700-pCi/L at well MW-105S during the September 1999 sampling event. There has been a significant downward trend in tritium concentrations at this well with results ranging from 5,520 to 3,280 pCi/L during the March and June sampling events (see Figure 6-35). This well was physically removed from the monitoring network in August 2004 as part of the PAB excavation. Sampling proceeded again with a replacement well designated as MWR-105S at this location in September 2005. Results for September (< 307-pCi/L) and December 2005 (< 280-pCi/L) were non-detects.

There has been an upward trend in tritium concentrations at MW-114S with results ranging from 1,350 to 6,730 pCi/L during the March and June 2004 sampling events (see Figure 6-36). No samples were collected at this location in 2005 due to site dewatering activities and existing natural water levels.

Tritium concentrations from the past 14 sample events for the unconfined and confined aquifer wells are plotted in Figures 6-37 and 6-38. With the exception of well MW-102D and MW-103S, all H-3 results during these sample events were less than the USEPA MCL of 20,000, pCi/L.

Figure 6-39 is a box plot for site-wide H-3 concentrations as a function of time ranging from September 1999, through December 2005. Maximum H-3 concentrations have ranged from 13,900 to 31,270 pCi/L since September of 1999. Median results from have fluctuated from a low of about 900 pCi/L to a high of 4430 pCi/L during this same period. There were no apparent seasonal trends in the median results.

## 6.2.5 Strontium-90 Trend Analysis

Historically, monitoring well MW-105S has exhibited the highest activity concentration of Sr-90 (see Figure 6-40) before this well was removed from service due to PAB excavation activities. Results for replacement MWR-105S were non-detects in October and December 2005 reflecting the extensive soil remediation efforts. Elevated Sr-90 concentrations have also been noted at MW-106S (see Figure 6-41). Other wells where Sr-90 concentrations greater than the CRDL of 2 pCi/L included MW-103S and MW-104S (see Figures 6-42 and 6-43).

Strontium-90 concentrations from the past 14 sample events for unconfined and confined aquifer wells are plotted in Figures 6-44 through 6-46. With the exception of well MW-103S, MWR-105S and MW-106S, all Sr-90 results for unconfined aquifer wells were less than the USEPA MCL of 8.0 pCi/L. All results for confined or deep bedrock wells were less than the CRDL of 2 pCi/L and no result to date has exceeded this level.

Figure 6-47 presents a box plot for site-wide Sr-90 concentration as a function of time ranging from December 2001, through December 2005. The maximum Sr-90 concentration has ranged from 69.7 to 197 pCi/L, at MW-105S, since December of 2001. Median results have fluctuated from a low of about 0.8 pCi/L to a high of 4.6 pCi/L. There were no apparent temporal or seasonal trends in the median values. There appears to be a seasonal trend in the highest values which all occur in MW-105S. These maximum values levels tend to coincide with September and December sampling events, which are typically characterized by peak groundwater elevation levels.

## 6.2.6 Cesium-137 Trend Analysis

Appendix D summarizes Cs-137 analytical results in all wells since December 2001. Prior to the September and December 2004 sampling events, Cs-137 has been consistently identified in groundwater at location MW-103S between a minimum of 8.39 pCi/L and a maximum of 87.6 pCi/L (Figure 6-48). MW-103S was a shallow monitoring well in the cluster located in the vicinity of the former RWST. Cesium-137 was identified in the replacement MWR-103S at a concentration of 12.8-pCi/L during the December 2005 sample event.

Cesium-137 has also been consistently detected at two other monitoring wells, MW-115S and MW-102D. Cesium-137 has been detected in MW-115S in concentrations ranging from 1.6 to 7.59 pCi/L (Figure 6-49). Cesium-137 concentrations have ranged from 2.0 to 12.7 pCi/L in MW-102D (Figure 6-50).

Cesium-137 concentrations from the past 14 sample events for unconfined and confined aquifer wells are plotted in Figures 6-51 through 6-52. With the exception of well MW-103S and MW-137, all Cs-137 results during these sample events were less than the CRDL of 15 pCi/L. The USEPA MCL for Cs-137 is 200 pCi/L and no result to date has exceeded this level. Time series plots for Cs-137 are provided in Appendix F.

## 6.2.7 Alpha Isotopic Analyses

Americium-241 concentrations from the past 14 sample events for unconsolidated, shallow and deep bedrock wells are plotted in Figures 6-53 through 6-54. With the exception of well MW-103D, all Am-241 results during these sample events were less than the CRDL of 0.5 pCi/L. The USEPA MCL for alpha emitters is 15 pCi/L and no result to date has exceeded this level.

## 6.3 Linear Regression Analysis

### 6.3.1 Sr/Y-90 + Cs-137 vs Gross Beta

Figure 6-55 is a correlation plot of gross beta activity versus total Sr/Y-90 and Cs-137 concentration in conventional wells. Only sample results with detectable Sr-90 or Cs-137 were used in this comparison. Yttrium-90 (Y-90) is the radioactive decay product of Sr-90. Since the half-life of Sr-90 is significantly longer than Y-90, secular equilibrium is observed where both nuclides are characterized by the same concentration levels and the total concentration, denoted as Sr/Y-90, is doubled. A slope of 0.87 with a positive correlation coefficient (R) of 0.96 was observed (see Figure 6-54). The squared correlation term ( $R^2$ ) was 0.93. These results suggest that Sr-90 and/or Cs-137 comprise at least 93% of the gross beta response at higher levels (i.e. greater than 25 pCi/L gross beta activity) and can be used to obtain screening or reasonable estimates of total Sr/Y-90 and Cs-137 in groundwater.

### 6.3.2 Total Uranium vs Gross Alpha Regression Analysis

Figure 6-56 is a correlation plot of the total uranium concentration ( $\mu\text{g/L}$ ) versus gross alpha concentration (pCi/L) in groundwater. Only sample results with detectable total uranium and gross alpha activity were used in this comparison. A positive correlation coefficient (R) of 0.95 was observed for the data set. The squared correlation term ( $R^2$ ) suggests that at least 90% of the gross alpha response can be attributed to the total uranium results.

Figure 6-57 is a similar correlation plot of the total uranium concentration (pCi/L) versus gross alpha concentration (pCi/L). Total uranium concentrations were estimated as the product of the total uranium ( $\mu\text{g/L}$ ) and the specific activity of natural uranium (pCi/ $\mu\text{g}$ ). Total uranium was assumed to be comprised of a natural mix of U-234, U-235 and U-238, with a U-234/U-238 ratio of 1.03, and a specific activity of 0.698 pCi/ $\mu\text{g}$ . The natural uranium radionuclides all decay by alpha emission with radioactive half-lives greater than  $2.44 \times 10^5$  years. Only sample results with calculated total uranium concentrations greater than the average MDC of 1.7 pCi/L and detectable gross alpha activity were used in this comparison. Screening for gross alpha activity in the presence of high concentrations of salts and dissolved solids can result in erratic and anomalous results. For this reason, filtered samples with high concentrations of dissolved solids and unfiltered samples, which exhibited high concentrations of suspended solids or turbidity, were removed from this evaluation. A slope near unity of 0.94 and a positive correlation coefficient (R) of 0.97 was observed for the data set (see Figure 6-58). The squared correlation term ( $R^2$ ) was 0.96. These results suggest that at least 96% of the

gross alpha response can be attributed to the total uranium results. These results suggest that gross alpha activity can be used to estimate levels of non-volatile, long-lived alpha emitters such as total uranium in groundwater, provided the necessary precautions for solids and dissolved solids are taken.

## 7 Conclusions and Recommendations

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### 7.1 Groundwater Quality Status

The GWMP at the HNP provides the framework for data collection, quality assurance, and reporting groundwater quality status at the facility. Analytical results from the quarterly sampling program implemented at the plant provide the data for comparing to standards, regulatory limits, and developing metrics for evaluating overall groundwater quality and potentially, plume status at the HNP.

Groundwater contamination by plant-related SOCs has been observed in both the unconfined and confined aquifer units currently described at the facility. Consistent with the CSM for HNP, the general configuration of contaminant plumes extend from the area immediately upgradient of the reactor containment building to the Connecticut River. The mapped plumes are well defined both horizontally and vertically, and the observed groundwater contamination at the plant appears to have originated from unplanned releases of contaminated process and wastewaters within the general vicinity of the reactor containment building, primary auxiliary building, tank farm, and other facilities immediately surrounding the reactor containment building.

Tritium, Sr-90, and boron account for the majority of the observed SOCs with less-frequent detections of Cs-137. Cs-137 was not detected above the MDC in the third quarter 2005 sampling results, but was detected in three wells ranging from 6.21 pCi/L to 16.7 pCi/L in the fourth quarter 2005. The three Cs-137 detected values in the fourth quarter 2005 are well below the MCL of 200 pCi/L established for Cs-137.

Tritium, boron and Sr-90 are broadly distributed across the HNP industrial area, with tritium and boron having the widest distribution in both the unconfined and confined aquifers relative to Sr-90. Although plant-related tritium concentrations in groundwater have declined substantially below the MCL in recent years, localized areas of other constituents (e.g., Sr-90) have remained elevated relative to the respective drinking water standard. While the maximum observed Sr-90 concentration currently is below the drinking water standard of 8 pCi/L, groundwater consistently exhibits detectable concentrations of Sr-90 near the 8 pCi/L standard. Sr-90 and tritium groundwater concentrations have declined substantially in the industrial area of the HNP since quarterly sampling for Sr-90 and tritium began in 2001 and 1998, respectively (Appendix F). Boron will be evaluated as part of the ongoing RCRA CAP under regulatory oversight of both USEPA and CTDEP.

Uranium, quantified as total uranium, is consistently detected in deep bedrock monitoring wells across the site. Total uranium concentration has consistently been higher in deep bedrock wells than in shallow wells completed in unconsolidated soils. Total uranium in two wells exceeded the uranium MCL of 30 µg/L in the third and fourth quarter sampling events. Uranium in groundwater at HNP is attributed to naturally occurring sources.

The presence of uranium in groundwater at HNP is consistent with the known presence of natural uranium-bearing minerals in the metamorphic and intrusive rocks underlying the site. Uranium-bearing minerals, including uraninite, have been identified in pegmatite dikes on Haddam Neck (Cook, 2004). Uranium concentrations have generally increased over the past year. This is consistent with the transient increase in aeration of the aquifer systems underlying the central portion of the HNP during groundwater depression to support soil removal and structure demolition and the installation of new bedrock wells. Aeration of the aquifer increases the oxidation potential of the groundwater, which will increase the solubility of natural uranium species (Yu, et. al., 2001). Total uranium concentrations are expected to decline following discontinuation of dewatering activities and return to natural water levels and flow regimes.

The deep multi-level monitoring wells show non-detect concentrations of Cs-137 at all sampling depths, and limited detections of Sr-90 in the shallow sampling intervals. Tritium concentrations decrease with sampling depth below 150 feet BGS and are consistent with background concentrations in the deeper samples. In contrast to the decrease in tritium concentration with sample depth, boron concentrations increase with sample depth below 150 feet BGS suggesting that background concentrations in the deep bedrock are greater than those characterized in shallow bedrock.

## **7.2 Contaminant Source Removal Effects**

Soil excavation from the vicinity of the PAB, tank farm, and service alley has effectively removed a substantial portion of the previously identified contaminated soil and bedrock fractures that served as a secondary source of groundwater contamination. This is evidenced by removal of the entire unconsolidated sediments section in the vicinity of the former well MW-105S, which historically exhibited the highest Sr-90 concentration on site. Removal activities during fall 2005 were focused on soil and shallow bedrock in the tank farm area. Other identified soil contamination areas are yet to be removed (e.g., tritium-contaminated soil underlying the fuel building and tritium-contaminated soil in the eastern portion of the RA). The tritium contamination occurs in shallow soils above the water table and beneath a building or asphalt paving. Due to the shallow location above the water table and the presence of structures above, little contribution to tritium in groundwater is believed to be occurring. These soils will be removed as decommissioning activities allow access to the specific areas.

Excavation in the PAB service alleyway and tank farm has been completed and the excavations were filled with clean fill material. During the excavation activities numerous seeps within the excavations were monitored. Seep concentrations decrease over time, and monitoring terminated when backfilling began.

## **7.3 Subsequent Sampling Recommendations**

Based on the review of the results of the third and fourth quarter 2005 quarterly sampling and observed long-term trends in some wells, several recommendations concerning subsequent groundwater monitoring sampling events are as follows:

- The recommended analytical suite for the upcoming first quarter 2006 GWMP quarterly sampling event should be the same as the one implemented for fourth quarter 2005.
- Results from previous sampling rounds have demonstrated that filtered and unfiltered samples provide equivalent results. Based on that understanding, unfiltered groundwater samples should be collected from all of the wells in the industrial area and analyzed for all constituents during the first and second quarter 2006 quarterly sampling events.
- Newly installed monitoring wells and multi-level wells that are included in the HNP monitoring network should be sampled for a standard analytical suite of analytes in future sampling rounds.

Otherwise, the wells sampled should remain the same as previous sampling rounds.

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## 9 Definitions

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C<sub>1</sub> Concentration (C<sub>1</sub>) - The concentration level for a single analyte that will result in a 4-mrem per year total effective dose equivalent (TEDE) based on target organ dose methodology.

Contract Required Detection Limit (CRDL) - Analysis sensitivity requirements required by contract or SOW. Compliance is determined by comparison with sample specific MDCs or MDLs.

False Negative Rate ( $\beta$ ,  $\beta^*$ ) - The rate at which the statistical procedure does not indicate possible contamination, when contamination is present at some level ( $\beta$  denotes one sample and one constituent,  $\beta^*$  denotes multiple samples and one constituent).

False Positive Rate ( $\alpha$ ,  $\alpha^*$ ) - The rate at which the statistical procedure indicates possible contamination, when contamination is not present ( $\alpha$  denotes one sample and one constituent,  $\alpha^*$  denotes multiple samples and one constituent).

Freshet - A rapidly rising flood of minor severity and short duration, attributed to heavy rains or rapidly melting snow.

Instrument Detection Limit (IDL) - The level at which a measurement can be differentiated from background with some degree of confidence. Computed from the counting error associated with the instrument background or blank counting conditions usually expressed in terms of counts or count rate.

Lab Control Sample (LCS) - A sample prepared by adding a known amount of target analyte to deionized distilled water. Used to assess the method accuracy and long-term analytical precision.

Lower Limit of Detection (LLD) - The level at which a measurement can be differentiated from background with some degree of confidence. Computed from the counting error associated with the analytical blank counting conditions usually expressed in terms of counts or count rate.

Matrix Spike (MS) - A sample prepared by adding a known amount of target analyte to a specified amount of matrix sample for which an independent estimate of the target analyte concentration is available. Used to determine the effect of matrix on a method's recovery efficiency.

## 9 Definitions

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Matrix Spike Duplicate (MSD) - A known amount of target analyte added to two samples taken from and representative of the same population and carried through all steps of the analytical procedures in an identical manner. Used to assess variance of the sample analysis.

Maximum Contaminant Level (MCL) - The average concentration level for a single analyte that will result in a 4-mrem per year total effective dose equivalent (TEDE) based on target organ dose methodology.

Method Detection Limit (MDL) - The concentration of a substance that can be measured and reported at the 99% confidence level to be greater than zero.

Minimum Detectable Activity (MDA) - Analogous to the LLD but includes conversion factors to relate background count rate to analyte activity.

Minimum Detectable Concentration (MDC) - A level analogous to the LLD but includes conversion factors to relate background count rate to analyte concentration.

Relative Percent Difference (RPD) - A measure of the precision of two results, defined as the absolute difference divided by the average of the two results multiplied by 100.

Required Detection Limit (RDL) - Analysis sensitivity requirements required by contract or SOW. Compliance is determined by comparison with sample specific MDCs or MDLs.

Total Propagated Uncertainty (TPU) - Includes all factors that contribute to the overall uncertainty including counting statistics, sample mass, chemical yield and calibration factors.

## 10 Acronyms

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ASTM	American Society for Testing and Materials
CAP	Corrective Action Program
CRDL	Contract required Detection Limit
CMS	Containment Mat Sump
CSM	Conceptual Site Model
CTDEP	Connecticut Department of Environmental Protection
CYAPCo	Connecticut Yankee Atomic Power Company
DI	De-ionized
DOE	Department of Energy
EOF	Emergency Operations Facility
EPA	Environmental Protection Agency
ERA	Environmental Resource Associates
FDR	Field Daily Reports
GEL	General Engineering Laboratory
GMP	Groundwater Monitoring Program
GPC	Gas Proportional Counting
GWMP	Groundwater Monitoring Program
HPGe	High-Purity Germanium
HNP	Haddam Neck Plant
HTD	Hard-to-detect
KPA	Kinetic Phosphorescence Analyzer
LCS	Laboratory Control Sample
LLD	Lower Limit of Detection
LSC	Liquid Scintillation Counting
LTP	License Termination Plan
MAPEP	Mixed Analyte Performance Evaluation Program

MCL	Maximum Contaminant Level
MDC	Minimum Detection Concentration
MDL	Method Detection Limit
MS	Matrix Spike
MSL	Mean Sea Level
MP	Multi-port
NCR	Nonconformance Reporting
NELAC	National Environmental Laboratory Accreditation Conference
NSWPT	National Standards for Water Proficiency Testing Studies Criteria
NRC	Nuclear Regulatory Commission
NTU	Nephelometric Turbidity Unit
FAB	Primary Auxiliary Building
PARCC	Precision, Accuracy, Representativeness, Comparability and Completeness
pCi/L	picocurie per liter
QAP	Quality Assurance Program
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RCB	Reactor Containment Building
RCRA	Resource Conservation and Recovery Act
RDM	Relative Difference Method
RESL	Radiological and Environmental Sciences Laboratory
RPD	Relative Percent Difference
RSR	Remediation Standard Regulation
SOC	Substance of Concern
SOP	Standard Operation Procedure
TEDE	Total Effective Dose Equivalent
TPU	Total Propagated Uncertainty
µg/L	microgram per Liter
USEPA	United States Environmental Protection Agency
WP&IR	Work Plan and Inspection Record