Final Groundwater Condition Report

Yankee Nuclear Power Station
Rowe, Massachusetts

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Executive Summary

Quarterly groundwater sampling at YNPS was conducted during 2006 to support NRC License Termination. Groundwater samples were taken all four quarters during 2006 and were analyzed for both routine parameters (gross alpha, gross beta, tritium, gamma emitting radionuclides, and Sr-90) and Hard-To-Detect radionuclides (alpha, beta and X-ray emitting, fission and activation product radionuclides). Boron and general geochemistry parameters (alkalinity, sulfate, chloride, calcium, sodium, potassium, and magnesium) were analyzed in all groundwater samples in the second quarter 2006 only.

Previous studies have provided a Conceptual Site Model that includes four hydrogeologic units at the site:

- a water table aquifer that occurs in stratified drift (glaciofluvial deposits),
- a glacial till unit with multiple water-bearing sand lenses;
- a glaciolacustrine unit with multiple water-bearing sand lenses; and
- a bedrock aquifer.

In these four hydrogeologic units, groundwater occurs under unconfined, semi-confined, and confined conditions. The previous studies have also identified the former spent fuel pit/ion exchange pit as the significant source area for tritium at the YNPS site. This source area was remediated via soil removal in summer and fall 2005.

In summary, tritium was the only radionuclide detected in site groundwater. Tritium concentrations ranged from non-detect values to values in excess of 40,000 pCi/L, and generally exhibited decreasing concentrations through the 2006 quarterly sampling program. The groundwater sampling results were used to develop plan-view plume maps of the glaciofluvial and glacial till aquifers and cross-sections illustrating the vertical distribution of tritium. A plume of tritium-contaminated groundwater occurs within the glaciofluvial aquifer, and is mapped from the former spent fuel pit/ion exchange pit source area across the YNPS site towards the Deerfield River. Tritium concentrations in the plume within the glaciofluvial aquifer range from about 10,000 pCi/L near the source area to values less than 1,000 pCi/L near the Deerfield River.

A deeper plume within sand lenses in the glacial till is also identified. The deeper plume has less aerial extent relative to the plume in the glaciofluvial aquifer, but has tritium concentrations up to 30,000 pCi/L. Migration of tritium in the glacial till is minimized due to the lower hydraulic conductivity measured for the glacial till relative to the glaciofluvial aquifer. The tritium-contoured cross sections demonstrate that tritium has migrated into the deeper portion of the glacial till beneath the former spent fuel pit/ion exchange pit area, but tritium has not moved a significant distance downgradient of the source area in the deeper portions of the till. In contrast, tritium has migrated from the spent fuel pit/ion exchange pit source area downgradient to the Deerfield River within the glaciofluvial unit.

An evaluation of tritium trends was conducted in all monitoring wells included in the LTP monitoring program. A total of 43 monitoring wells had no discernable trends and are characterized as stable, while 10 monitoring locations had statistically-determined downward trends for tritium. One monitoring well had an upward trend, but the tritium concentrations were an order of magnitude below the USEPA MCL of 20,000 pCi/L.

The groundwater laboratory results for radionuclides were non-detect for all radionuclides except for tritium, and as such were below all threshold levels developed in License Amendment No. 158.

A three-dimensional flow and transport groundwater model has been developed to support the decommissioning of the Yankee Nuclear Power Station in Rowe, MA. The modeling work began in July 2006. This model covers a large area on both sides of the Deerfield River so that the model boundaries are naturally located on streams and groundwater divides far from the nuclear plant site. The finite-difference grid cells are discretized with variable spacing from 25 feet near the center of the plant site to as far apart as 400 feet near the outer limits of the model. The model consists of 15 layers: 13 soil layers and two bedrock layers. The model extends 500 feet into bedrock.

The model was used to verify the direction and time of travel from the ion exchange pit to Sherman Spring and then to simulate the May 1963 leak from the ion exchange pit and compare measured Sherman Spring tritium concentrations over time with the simulated results. These results are in good agreement. The model has also been used to simulate the change in tritium concentration from April 2006 through December 2006 at MW-107C, again, with good agreement.

The model reproduces the magnitude of pressure transient responses to the MW-107C pumping tests and a variety of other pressure transient events. Although groundwater gradients between the bedrock and the next higher monitoring wells at several locations were not faithfully reproduced as to direction, most gradient directions were preserved among the 54 pairs tested.

The model was used to evaluate the potential attenuation of tritium in MW-107C, which has been identified as the only portion of the site even close to exceeding LTP dose standards or EPA MCLs. Because the thin sand zone in which MW-107C is located is incapable of supplying the needs of the hypothetical resident farmer well as specified in the LTP, other soil units above and below MW-107C were tried in various combinations that would produce the required well yield, but at the highest dose. This resulted in combining other soil units with lower tritium concentrations but higher flow rates, such that the well concentration would be 8150 pCi/L in April 2007, decreasing to 5100 pCi/L in April 2009.

Based on the model results, a randomly located resident farmer's well at the site would produce water at less than LTP dose limits or EPA MCLs. The model also suggests that the highest point concentrations of tritium (in the glacial till above and below MW-107C) will decrease below the EPA MCL of 20,000 pCi/L about April of 2009. However, the tritium concentration in MW-107C may decrease below the MCL concentration as soon as June 2007 based on the current trend of sampling results.

Based on the results for the 2006 quarterly groundwater sampling, tritium trend analysis, and groundwater modeling, we believe that groundwater at the YNPS site meets the closure requirements specified in the LTP. While one monitoring well exceeds the USEPA MCL of 20,000 pCi/L (as of the fourth quarter sampling results), the modeling results demonstrate that tritium concentration in the resident farmer well will be below the MCL value.

1.0 Introduction

This report documents the groundwater monitoring activities conducted at Yankee Nuclear Power Station (YNPS) for the four quarters of 2006. The purpose of the groundwater monitoring program is to verify that groundwater quality conditions at Yankee Nuclear Power Station (YNPS) meet the closure requirements as defined in the License Termination Plan (LTP) and Nuclear Regulatory Commission (NRC) License Amendment No. 158 (**Reference 1-1**). The LTP specifies quarterly groundwater sampling for tritium and other radionuclides as appropriate, and that groundwater monitoring be conducted after decommissioning is completed but before license termination. The groundwater monitoring program was designed to determine the extent and range of radionuclide groundwater contamination, and to support final status survey (FSS). **Figure 1-1** shows the location of YNPS and the surrounding area, and **Figure 1-2** shows the current 10 CFR part 50 Licensed Site Boundary.

This report summarizes the site geology and hydrogeology in **Section 2** and groundwater sampling and analysis activities and laboratory analytical results are described in **Section 3** and **4**, respectively. Spatial and trend analysis of tritium are presented in **Section 5** and results of groundwater modeling are provided in **Section 6**. Conclusion and recommendations for the groundwater monitoring program are provided in **Section 7**.

1.1 Groundwater Monitoring Program Overview and Site Setting

The Yankee Nuclear Power Station (YNPS) terminated power operation in 1991 and completed physical decommissioning work in the fall of 2006 under an approved Nuclear Regulatory Commission (NRC) license termination plan (LTP) (**Reference 1-1**) As of September 2006, all structures, systems and components planned for removal have been removed; site soils have been surveyed for radiological contamination; impacted soils in the unsaturated zone have been excavated and removed; and imported fill has been placed to achieve the final site grade. Accordingly, all potential primary sources of groundwater contamination have been removed from the site. A site map showing all former site structures and key site features is provided in **Figure 1-3**.

A groundwater monitoring program was initiated in support of decommissioning during the spring of 1993, with installation of ten monitoring wells. Seventy-one additional monitoring wells have been installed since 1993 as part of seven drilling campaigns, the most recent of which was completed summer 2006. A summary of the monitoring well completion details for the monitoring program and a history of surveyed well locations are included in **Tables 1-1 and 1-2.** Monitoring well locations included in the LTP monitoring program are shown in **Figure 1-4**. The results of previous groundwater investigations are documented in **References 1-2, 1-3, 1-4, and 1-5**. **Reference 1-6**, Groundwater Compliance Plan for License Termination for Yankee Nuclear Power Station, details the ongoing groundwater monitoring that was completed in 2006 to demonstrate compliance with the criteria for license termination.

The early monitoring programs in the late 1990s identified a plume of tritium in shallow groundwater, with maximum concentrations of about 5,000 picocuries per liter (pCi/L). A more rigorous investigation began in 2003 and identified a second plume within a deeper, semi-confined geologic formation, with tritium concentrations up to 48,000 pCi/L. Follow-up drilling campaigns were completed in 2004 and again in 2006, to further investigate and bound the groundwater impacts identified by earlier investigations. No plant-related radionuclides other than tritium have been identified in the groundwater. YNPS has completed dose assessments for the existing on-site groundwater in accordance with the LTP and found a dose contribution of less than one millirem per year associated with groundwater at the MCL concentration of 20,000 pCi/L (**Reference 1-1**).

Prior to 2003, groundwater samples had been collected from all site monitoring wells generally three or four times per year, although not on a routine schedule. These samples were analyzed for tritium and gamma-emitting radionuclides. Two sample rounds (November 1997 and February 1998) included analysis for strontium. Beginning in August 2003, groundwater samples were collected from available monitoring wells on a quarterly basis and analyzed for a wider range of radionuclides, including ten gamma emitters, tritium, gross alpha, gross beta, and eleven hard-to-detect nuclides (**Reference 1-3** and **1-4**). Decommissioning activities made safe access to several wells impossible and groundwater sampling was suspended for the second and third quarters of 2005. The quarterly schedule of sampling resumed in the final quarter of 2005 and has continued through 2007. One additional quarterly sampling round is scheduled for spring 2007, and will be used to verify and confirm the trends established through 2006.

1.2 Groundwater Monitoring Program Plans and Procedures

The 2006 groundwater sampling and analysis was conducted in accordance with the Groundwater Compliance Plan for License Termination for Yankee Nuclear Power Station (**Reference 1-6**) and following specific guidance under applicable YNPS procedures. The YNPS procedures utilized for the groundwater monitoring activities include: 1) YNPS Site Characterization and Site Release Quality Assurance Program Plan AP-9601; 2) Ground and Well Water Monitoring Program for YNPS Site AP-8601; and, 3) Groundwater Level Measurement and Sample Collection in Observation Wells DP-9745 (**References 1-7, 1-8, and 1-9**).

A sample event plan was prepared in accordance with AP-8601 and DP-9745 for each quarterly and monthly groundwater sampling round conducted at YNPS (**References 1-8 and 1-9**). The sample event plan specifies the number and type of containers to be filled with sample groundwater from each well, preservation and handling requirements for samples, and analyses to be performed on samples from each well.

The methodology for representative sample collection and field measurements, including groundwater levels, is described in Groundwater Level Measurement and Sample Collection in Observation Wells (DP-9745) (**Reference 1-9**).

2.0 Site Geology and Hydrogeology

2.1 Background

The YNPS site geology has been investigated at intervals throughout the plant design period and operational life. Site hydrogeology was not studied in detail until decommissioning was underway. The most intensive studies have occurred from 2003 to present, culminating in the development of a groundwater fate and transport model that has helped to refine the hydrogeological conceptual site model.

The pre-design exploration of the site consisted of a few borings and some seismic refraction analysis in 1956 (**Reference 2-1**). A somewhat more elaborate investigation was performed as part of the NRC Systematic Evaluation Program (SEP) studies performed in 1979 through 1981 at the site (**References 2-2 and 2-3**). With the decommissioning of the plant, monitoring wells were installed and sampled. In 2003, Framatome (**Reference 2-4**) conducted a review of all prior investigations and groundwater studies. At this point, Radiation Safety and Control Services (RSCS) took charge of site hydrogeologic investigations relating to the Nuclear Regulatory Commission (NRC) License Termination Plan (LTP) (**Reference 1-1**).

On a parallel track, ERM, acting as the Licensed Site Professional (LSP) under the Massachusetts Contingency Plan, 310 CMR 40.0000, began site investigations in 2000 to evaluate the presence of oil and hazardous materials. ERM submitted a series of reports to the Massachusetts Department of Environmental Protection (MADEP) beginning in 2001 continuing to the present that document the presence and remediation of various non-radiological substances on the site. Separate borings were installed, and soil and water sampling were conducted by RSCS and ERM to satisfy the respective requirements of the NRC and the MADEP.

In 2006, Yankee Atomic Electric Company (YAEC) retained Stratex, LLC, to review the existing radiological groundwater investigation program, to model the groundwater at the site, and to predict the fate and transport of radionuclides at the site following license termination. During 2006 a pumping test was conducted on MW-107C, the location of the highest groundwater concentration of tritium at the site. Numerous other short-term drawdown tests (called "pressure transient" tests) were conducted at various monitoring wells with pressure transducers located in surrounding wells in an effort to identify the hydraulic continuity of various sand seams identified in drilling that contained significant tritium concentrations. Also in 2006, all of the previously acquired monitoring well water level data captured by continuously recording dataloggers since 2004 were processed and put into graphs and correlated with various possible influences.

Since 2003, YAEC has provided a series of periodic reports to the NRC documenting new hydrogeologic investigations as they were completed, and provided updates on monitoring well radionuclide concentrations from sampling episodes spread through the decommissioning period. The most recent report, **Reference 1-5**, provided a thorough review of the hydrogeologic conceptual site model and the pumping tests and transient pressure tests done to evaluate the continuity of sand layers within the glacial till and glaciolacustrine units.

2.1.1 Geology and Hydrogeological Conceptual Model

The stratigraphy and hydraulic relationships beneath YNPS comprise a complex, multi-unit groundwater flow system. A hydrogeologic conceptual site model (CSM) has been developed for YNPS based on both the regional geologic setting and on the hydrogeologic and chemical data collected at the site since the first monitoring wells were drilled in 1993 to support decommissioning. Four hydrogeologic units have been identified at the site:

1) a water table aquifer that occurs in stratified drift (glaciofluvial deposits),
2) a glacial till unit with multiple water-bearing sand lenses;
3) a glaciolacustrine unit with multiple water-bearing sand lenses; and
4) a bedrock aquifer.

In these four hydrogeologic units, groundwater occurs under unconfined, semi-confined, and confined conditions. **Section 6-4** of this report summarizes the geology of the site and how it has been conceptualized into a layer structure that can be modeled.

The former reactor site lies relatively low in the Deerfield River valley, which has a great degree of vertical relief with steep sideslopes. The upper slopes of the valley walls are primarily exposed bedrock and thin glacial till. One exception to this is the thick glacial till section extending southward from the former reactor site. The till is over 200 feet thick near the valley floor level and extends up the slope about 700 feet in elevation above the Sherman Reservoir level. Small springs and streams drain the upland area, which sheds most of its precipitation to the local streams and the glaciofluvial terrace deposits. Recharge entering the upland areas seeps deep into the rock and moves laterally toward the Deerfield River, rising in the bottom of the River valley.

At the YNPS site the layered glacial geology is complex. The primary flow path within the glaciofluvial deposits from the Spent Fuel Pool and Ion Exchange Pit (SFP/IXP) was initially north, and then bifurcated to produce a westward path. In the downstream side of Sherman Dam where the dam meets the original land, the glaciofluvial deposit thins and Sherman Spring was created where the phreatic surface daylights. Although most of the leaked tritium from the SFP/IXP flowed northward toward Sherman Reservoir and westward toward the Deerfield River below the dam within the upper glaciofluvial deposits, some of the leaked tritium seeped deeper into the upper glacial till. Within the glacial till there are thin sand seams within which the tritium would collect and be captured in monitoring wells. Beneath some areas of till lies a glaciolacustrine layer with thin sand seams. Almost all the tritium that seeped beneath the glaciofluvial unit was contained within the glacial till and did not enter the glaciolacustrine unit. Earlier versions of the CSM held that the low permeability glacial till was unsaturated between saturated sand layers. However the MW-107C pumping test and pressure transient tests showed that the till layers that vertically separated the sand seams were saturated and transmitted water pressure transients. The water pressure transient tests showed that the sand seams were limited in lateral extent to about 150 feet for the most extensive layers. Because of the relatively short distance between the former reactor site and the Deerfield River, the contamination did not go deep and only minor tritium contamination occurred in the bedrock near the MW-107 area where bedrock was shallower than to the north and west.

2.1.2 Work Completed Since 2006 Interim Groundwater Report

Although the main purpose of this report is to summarize the final status of the groundwater flow system and its radiological content at the YNPS site, a secondary purpose is to complete the documentation of all that has been done to study the groundwater regime at the site. Since the Interim Groundwater Report (**Reference 1-5**), the final site grading has been completed. Final borings have been completed and the logs of borings currently in use on the site that have never been submitted before are included in **Appendix A**. These logs include CB-3R, CW-5R, MW-6R, MW-104D, and MW-112A. The monitoring well hydrographs for both the long-term records and the short-term pressure transient hydrographs have been finalized and analyzed. The 2006 third quarter and 2006 fourth quarter groundwater sampling events have been completed. The groundwater modeling has been completed and the future fate and transport has been simulated. A tritium trend analysis has been completed on each well. Finally, the status of the site is compared with the criteria of the LTP. This documentation is presented and summarized in this report along with its significance.

2.2 Groundwater Elevation and Flow Direction

2.2.1 Site Measurements of Groundwater Elevation

Table 1-1 contains a summary of the details pertaining to all of the monitoring wells used in the 2006 monitoring program. **Table 1-2** contains a history of the surveyed location and reference elevations of the monitoring wells used since 1993. Because some wells were destroyed and then replaced during demolition, or fill was added around certain wells, the reference elevations changed with time and the depth-to-water measurements have to be related to the specific well reference elevation that existed at the time of the measurement.

Many wells had continuous water level recordings made with the use of in-situ pressure transducers and dataloggers. **Table 2-1** shows the period of record for each well for which a credible hydrograph could be obtained from the datalogger record. **Appendix B** contains the hydrographs developed from these records, along with some additional hydrographs that will be explained in more detail below.

Some of the data quality issues that had to be resolved in processing the raw transducer data were the following:

1) Relating the pressure recorded by the transducer to a reference elevation. Some of the transducer cables were vented, but some were not. The latter transducer records had to be corrected by a software program that removed site barometric pressure variations (which were continuously recorded on the site). Some records were not calibrated with any hand measurements and the graphs in **Appendix B** note this on each graph for which no calibration to a reference elevation was available. In other situations, a graph would show a sharp jump in elevation at a point in time and there was only one reference elevation calibration point. A decision had to be made in each case as to how to deal with these sharp jumps. In most cases, the non-calibrated side of the jump was shifted across the board to match the elevation on both sides of the jump. Where multiple readings where taken within the time span of one continuous record, the graph was initially pinned at one elevation, then the differences between the other reference elevations in time and the respective time graph predictions were averaged. Transducer drift, where the error between measured and predicted elevation seems to become larger with time, was only corrected for the monitoring wells involved with the MW-107C pumping test where many hand measurements were taken on each monitoring well used as part of the test.

2) Relating the pressure recorded to a common time standard. An effort was made to bring all measured data that were related to the water level variations of each well to the common time standard of Eastern Standard Time. This meant that the record of Sherman Reservoir elevation fluctuations and flow releases from Sherman Dam had to be corrected in some instances from Daylight Savings Time. Some, but not all, records of MW-107B, MW-107E, and MW-110B had to be corrected for a 4-hour time shift for which no verifiable explanation could be developed.

3) Switching of Well IDs. It became apparent in the course of detailed study of the graphs that certain graphs did not represent the record of the wells they purported to represent. On further examination it was found that some were indeed switched and the records were revised accordingly.

4) Large drops or jumps in data values. Most wells show large drops and/or jumps on days when hand measurements of water levels were made or water quality sampling occurred, due to displacement and/or drawdown by measurement and sampling devices. When pressure transient testing was performed with a submersible pump, the heat of the pump also caused large temporary increases in temperature in the well water as measured by the transducer.

Many hand-measured water levels were recorded over time for the monitoring wells as part of synoptic water level measurements or prior to water sampling. **Table 2-2** summarizes all of the hand-measured data with the exception of a few miscellaneous data that were used to set the reference elevations of the pressure transducers and the hand-measured data taken during the MW-107C pumping test. The miscellaneous reference elevation measurements were used in tying the datum to the respective hydrograph records as recorded by the pressure transducers. The MW-107C data are included in Appendix B of **Reference 1-5**.

2.2.1.1 Vertical Groundwater Gradients

All of the MW-100-series wells except for MW-112 consist of clusters of closely-spaced individual wells with the screened zones separated vertically from one another to sample discrete geologic units. Most, but not all, of these well clusters had a well located in the top of bedrock. CFW-3 and CFW-4 also constituted a well cluster within the fill and underlying assumed glaciofluvial deposits of the Southeast Construction Fill Area (SCFA). For those well clusters for which simultaneous datalogging of pressure transducers was done in multiple wells, the hydrographs have been combined on the same graphs in **Appendix B-3**. For purposes of comparing modeled vertical groundwater elevation differences with measured groundwater elevation differences, **Table 6-8** in the groundwater modeling section lists the head differences within each well cluster. In addition, **Table 2-4** has a column indicating general direction of the vertical groundwater gradient.

All of the wells in the upper soil section have downward gradients. Near the bedrock surface, MW-101, MW-102, MW-106, MW-107, MW-109, and MW-110 showed upward gradients from the bedrock. MW-104D at 40 to 45 feet in a sand layer in glacial till showed an upward gradient compared to the shallow well at MW-104A in the glaciofluvial deposit.

The upward gradients at or near the bedrock surface suggest, based on the modeling as discussed below, that there are relatively permeable zones in the bedrock or just above the bedrock surface that permit this upward flow at these points. In the case of MW-104D, this is probably being driven by seepage through a permeable layer within the till in the south abutment of Sherman Dam.

2.2.2 Groundwater Contour Maps

Contour maps of synoptic hand-measured water elevations have been presented in previous reports submitted to the NRC since 2003. The 2006 Interim Groundwater Report (**Reference 1-5**) contained groundwater contour maps for the main hydrogeologic units for the spring and summer 2006 sampling quarters.

2.2.2.1 Fall Quarter 2006 Groundwater Flow Maps

Figure 2-1 shows the groundwater contours on the surface of the upper sandy phreatic aquifer, the glaciofluvial unit, for September 11, 2006. The contours are relatively evenly-spaced and the inferred flow direction, perpendicular to the contours, is similar to past maps. **Figure 2-2** shows the contour map of the groundwater heads in the "upper till" (identified as "UT" in some tables and figures) soil unit. The contours suggest a general westward flow. The contours are farther apart near the flatter land near the reservoir, then the contours become closer together westward of the axis of the dam, leading down to the River. The gradient westward of the dam is steeper in the upper till than in the glaciofluvial deposit. **Figure 2-3** shows the contours in the lower glacial till and glaciolacustrine unit (identified as "LT-GL"). Because the glaciolacustrine unit is not present everywhere under the YNPS site, it is combined with the somewhat arbitrarily demarcated lower till to represent the lower soil above the bedrock. The gradient is about equal to that in the glaciofluvial layer and the direction of flow is approximately the same. **Figure 2-4** shows the September 2006 groundwater contours in the shallow bedrock under the site. The implied flow pattern is somewhat more complex than the other patterns. Although the overall flow direction is to the west, there is a small divide coming off the rock knob to the east of the former reactor site. The gradient is flatter next to the reservoir than to the west of a line between MW-108 and MW-109, where it is steeper than any of the overlying horizontal gradients.

2.2.2.2 Winter Quarter 2006 Groundwater Flow Maps

Figures 2-5, 2-6, 2-7 and **2-8** represent the same groundwater flow maps as shown in the previous section except that these latter figures are for the groundwater sampling time of December 4, 2006. Implied flow patterns are identical between the September and December sampling periods. Groundwater elevations are slightly higher in December than September, but otherwise the maps are nearly identical between the two sampling periods.

2.2.4 Groundwater Influences

Detailed analysis and cross correlation among the various hydrographs and various forces that can change water levels have yielded an understanding of the factors affecting the various monitoring well water levels. These are discussed in more detail below. **Table 2-4** summarizes the relative strength of the various influences and provides other important data derived from the hydrographs relating to each well.

2.2.4.1 Precipitation

All of the hydrographs after August 1, 2004, presented in **Appendix B-1** and **B-2** have precipitation superimposed on the right-hand Y-axis, in inches per day. The site had a recording precipitation gauge with a tipping bucket that recorded each 0.01 inches with a date and time stamp. This gauge operated from August 1, 2004, through July 2006. Unfortunately, the site data for the period January 1, 2006, through May 31, 2006, were lost and data from Amherst, MA, were used in its place. The daily and cumulative precipitation at the site over the period is discussed in **Section 6** (see **Figure 6-26**).

Most wells at the site show a response to rainfall, although the rise of elevation per inch of rainfall varies among the wells and the delay between the time of rainfall and the occurrence of water rise varies. An example of a quick and large response is a 2.2-foot rise in water level in shallow well CB-1 (**Appendix B-1**) on September 18, 2004, in response to a 3.1-inch rainfall. Most of the bedrock monitoring wells also rose rapidly and with large responses to rainfall. It is the low-yield wells deep in the till or glaciolacustrine deposits that had small and delayed responses such as in MW-101C (**Appendix B-2**) and MW-104C (**Appendix B-1**). **Section 6.6.4.3** contains more information on the response of site wells to precipitation recharge.

2.2.4.2 Recession

Recession is the decline in groundwater elevation following a recharge event. This decline is visually evident on most hydrographs. In low-yielding wells such as MW-103C (Appendix B-1) the rise and fall of the well can only be seen in a seasonal context and not in response to particular precipitation events. In the analysis of the MW-107C pumping test, the recession that was occurring in each well during the test was calculated and added back to neutralize the differing rates of recession on the calculation of drawdown.

2.2.4.3 Barometric

Atmospheric pressure variations cause variations in water well levels. An increase in barometric pressure causes a depression in water level. A decrease in barometric pressure causes an increase in water elevation. The effect on phreatic water levels is very small; it has a larger effect on confined aquifers. The measure of how much barometric pressure variations affect well water levels is called barometric efficiency, which is the ratio of water level change in a well, in, for example, feet, divided by the barometric pressure change, in equivalent feet of water. In the evaluation of the MW-107C pumping test, the barometric efficiencies were calculated for each well in which pressure transducers were installed, and the effects neutralized so that small variations in actual drawdown could be detected. The typical range of barometric efficiency for the wells on this site is 10 to 60%. MW-107B has a barometric efficiency of about 50%, as shown in Appendix B, the "107Bsamplecorr" graph in **Reference 1-5**.

2.2.4.4 Earthtides

Just as the motion of the sun and moon relative to the earth cause ocean tides, they also cause earthtides where the water is compressed in confined aquifers as the earth changes shape ever so slightly in response to expansions and contractions of the crust in response to the changes in gravitational pull of the moon and sun as the earth rotates. As explained in Section 5.1 of **Reference 1-5**, there appear to be two separate earthtide components in the datalogger records at the site. Figure 5-4 of **Reference 1-5** shows a typical breakdown of the earthtide for MW-107B, as programmed with the theoretical parameters for components M2 and O1. Each component has its own repeating frequency and amplitude that changes with the moon phase. When added together, they produce a characteristic signature with an amplitude of about 0.15 feet in MW-107B. The amplitude and frequency of each earthtide component was estimated for each well fitted with pressure transducers during the MW-107C pumping test, then inverted and added back to the record to neutralize the effect of earthtides on the drawdown measurements. The typical range of earthtide effects in water levels on the site is 0.05 feet to 0.2 feet of total amplitude.

2.2.4.5 On-site Water Supply Well

Through the analysis of the various well hydrographs it became apparent that there was an occasional source of drawdown that affected some of the wells on the site, particularly the bedrock monitoring wells in the vicinity of the former reactor. The only water well known within a large radius of the site is the well that supplies the site with water, identified as "Plant Well" on **Figure 1-4**. This well was drilled in July 1999 and had a reported yield of 60 gallons per minute at 21 feet below the top of bedrock. Based on the location of site bedrock monitoring wells that appear to respond to the use of the well, this high yield zone appears to extend north from the plant well through the former reactor area (see more discussion in **Section 6.7.2**). There is a water meter somewhere in the site water supply system that is read once per week. **Table 2-3** records the weekly water use on the site between December 2005 and July 2007. Water use has decreased over this time period as site construction activities decreased. There is a large storage tank that is part of the water system, so the well is not used every day.

The response in monitoring wells from plant well use is most prominent in the bedrock wells, but other wells in till, such as MW-107D, also respond. It is hypothesized that some of the deeper soil monitoring wells in the former reactor area respond to the plant well through the pressure being transmitted from areas where sand seams in which the monitoring wells are located are in contact with the rising bedrock to the east of the former reactor site. The magnitude of response in monitoring wells would be affected by a number of site hydrogeologic parameters in addition to the pumping rate and the length of the pumping period. The installed pump is rated as 5 gallons per minute and the drawdown in the pumping well would not be great if the yield is 60 gallons per minute. The typical magnitude of drawdown for wells that respond in a significant way to the plant water well is a few feet.

2.2.4.6 Reservoir and Tailwater Elevations

Sherman Reservoir elevation is manipulated daily as part of a hydropower production system. The typical range of fluctuation across a day is about two feet. A typical pattern of Reservoir elevation change is shown in Appendix B, the "107Bsamplecorr" graph, in **Reference 1-5**. As shown in **Table 2-4,** not many wells responded to the rise and fall of the Reservoir. Some of the best responses are wells in bedrock, particularly CW-10, which is located close to the edge of the Reservoir. CW-10 has a directly linked response, but other monitoring wells respond in different ways, as described in **Table 2-4**. MW-108A, another well located close to the Reservoir, shows small responses to the daily rise and fall of the Reservoir, but when the Reservoir tends to rise in average level over a week, that rise in average level is more directly translated to the well. In some of the more distant bedrock wells that respond, the effects are delayed, are diffuse, or are more related to the level of the average position of the reservoir over a period of days. More detail on the response to Reservoir levels is included in **Section 6.7.4**.

While evaluating the shorter hydrograph records for MW-113C, a periodic drawdown and recovery effect was noticed that could not be tied to either the Reservoir fluctuation, the onsite well, nor any other offsite well. After further investigation and comparison of flow releases from Sherman Dam, a good correlation was found between Dam discharge rates and changes in level in MW-113C. This effect was first described in the 2006 Interim Groundwater Report (**Reference 1-5**). The analysis of this effect was refined some as part of the groundwater model development as described in **Section 6.7.3**. The 5-day graph of MW-113C presented in **Appendix B-4** of this report is slightly revised from that provided in **Reference 1-5**, as the graph in the earlier report did not correct the times of discharge for the fact they were recorded on a Daylight Savings Time basis, whereas the well hydrograph is on Eastern Standard Time. Notice that maximum range of change due to release rate fluctuation is about one foot. It is interesting to note that MW-113C is located about 130 feet below ground surface in the second significant sand seam in glacial till at that location; the River elevation next to the well is 1025 feet, and the average water elevation in MW-113C is 1031 feet. The only other wells that show a tailwater elevation response are MW-106B, C, &D, which are located close to the tailwater area, but do not show the magnitude of response seen in MW-113C. The hypothesis is that the sand seams in which the deeper soil wells reside may butt up against the bedrock wall that forms the northwest side of the Deerfield River in this area.

2.2.4.7 Freeze-Thaw and Snow Melt

Although the winter of 2006 did not have much snow, the winter of 2005 did and a large snow melt event is recorded near the end of March when temperatures warmed above freezing (**Figure 2-9**) and many wells such as CB-2 (**Appendix B-1**) rose on the order of 5 feet or more. As shown in **Table 2-4**, only a few wells (deep ones) do not respond to a snow melt event. One low-yield well, MW-103C, showed a peculiar pressure spike when temperatures rose above freezing on March 7, 2006.

2.2.4.8 Stormwater Basin Management

To control sediment discharge on the site during major earthwork in the spring and summer of 2006, a series of stormwater basins were created in the ground that provided both for temporary holding of precipitation runoff and for ground infiltration of runoff. **Figure 2-10** shows the location of the temporary stormwater basins and an area on the rock knob east of the former reactor site where stormwater was pumped to discharge on the ground there. The three identified East Side Stormwater Basins were sometimes pumped in series from the north to the south, and then up to the discharge area on the side of the rock knob.

The effect of filling these basins became apparent during the analysis of the MW-107C pumping tests (**Reference 1-5**). During the recovery period of the 24-hour test, many monitoring well water elevations rose significantly above elevations at which they began. Field notes indicate that stormwater was being moved around the site and basins near MW-107C were being filled by pumping from other areas. The PAB Alleyway Basin and the East Side Basin both had portions of the basins that are near areas of shallow bedrock. The hypothesis is that infiltration from the basins moved down the soil/bedrock interface and moved laterally through sand lenses in the till that butted up against the rock.

2.3 Groundwater Influences During and After Demolition

During plant operations, the main restricted area of the site was primarily covered with buildings or asphalt and had a stormwater management system with catch basins and underground stormwater piping that removed potential groundwater recharge from the plant area. Site grading activities related to decommissioning are now complete. Stormwater catch basins have been removed and underground stormwater piping has been removed or abandoned in place. All runoff is now controlled by site grading and surface swales and ditches. Some concrete slabs, foundation walls, and piping have been left in place and they are shown on **Figure 2-11**. The final site grading is shown on **Figure 2-12**. **Figure 2-10** shows the locations of the major excavations that were completed on the site, either for soil remediation or for creation of temporary stormwater basins. The surface precipitation infiltration capacity of the site has been changed significantly from what it was in the operational state, as impervious surfaces have been removed and excavations in a sandy glaciofluvial deposit have been filled with more silty, till-like material. The changes in effective recharge rate as a consequence of adding the fill and removing impervious surfaces are discussed in **Section 6.4**.

3.0 Groundwater Sampling and Analysis

This groundwater condition report includes the laboratory analytical results for four quarterly groundwater-sampling events Q1 through Q4 2006 and several monthly sampling events. The monthly sampling activities were conducted in the same fashion as the quarterly sampling.

The first quarter (2006 Q1) sampling event occurred between April 18 and May 3, 2006. The second quarter (2006 Q2) sampling event occurred between June 26 and July 12, 2006. The third (2006 Q3) and fourth (2006 Q4) quarter sampling events occurred between September 12 and September 21, 2006 and December 4 and December 14, 2006, respectively. The analytical results from Q1 2006 and Q2 2006 and monthly results for January, February and May were presented previously (**Reference 1-5**). Results for Q3 and Q4 2006 and monthly sampling results for August, October and November 2006 are discussed in **Sections 4 and 5**.

The groundwater samples were forwarded to an offsite laboratory for radiochemical and inorganic analyses. The sample results for each quarter and monthly sampling event were assessed and validated, and a Data Assessment Report was developed for each sampling episode (**References 3-1 through 3-7**).

Measurements of field parameters were included as components of the groundwater sampling and are discussed in **Section 3.1** and **Section 3.2**.

Groundwater samples were collected by low-flow sampling methodology utilizing either a peristaltic pump or a bladder pump with dedicated polyethylene tubing. Peristaltic pumps were typically utilized in shallow monitoring wells screened in the glaciofluvial aquifer, while the bladder pumps were used in deeper monitoring wells.

Prior to Q2 2006 groundwater samples at YNPS were typically filtered before analysis. The groundwater sampling procedure required that all groundwater samples with turbidity greater than five (5) NTU be filtered. The 5-NTU criterion typically was exceeded, and filtering was conducted at the analytical laboratory following preservation in the field.

Beginning with Q2 2006, groundwater samples were not filtered. Using a non-filtered approach minimizes any potential bias associated with filtering. For comparison to the filtered Q1 2006 samples and previous groundwater samples that were filtered, a subset of the analyses conducted in Q2 2006 was analyzed using both filtered and unfiltered aliquots of samples. Filtered and unfiltered aliquots were analyzed for gamma-emitting radionuclides (Cs-134, Cs-137, Co-60, Nb-94, Sb-125, Eu-152, Eu-154, Eu-155, and Ag-108), tritium, and Sr-90.

No gamma-emitting radionuclides or Sr-90 were detected in either filtered or unfiltered groundwater samples, as all values were below detection (**Reference 3-5**). Accordingly, the filtered and unfiltered results demonstrate no statistically significant differences for these radionuclides (**Reference 3-5**).

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 YNPS.

Depth-to-water 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 meet the stability requirements of the low flow sampling methodology promulgated by EPA. 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 Q1 through Q4 2006 sampling events are included in groundwater field sampling logs. The field sampling logs are field notes that document the sampling of each well, and are provided in **Appendix C**. As recorded in the field logs, the field parameters typically stabilized within an acceptable range.

3.3 Sample Locations

The horizontal and vertical coordinates of each monitoring well were surveyed. The horizontal location of each well is referenced to the Massachusetts Mainland State Plane Coordinate System (NAD 83 in feet) and its vertical elevation is referenced to the 1988 North American Vertical Datum (NAVD) in feet. A summary of the coordinates and elevations for all monitoring wells is provided in **Table 1-2.** Monitoring well locations for wells included in the YNPS monitoring plan are shown in **Figure 1-4**.

3.4 Laboratory Analysis

Groundwater samples for Q1 through Q3 2006 were analyzed for both routine parameters (gross alpha, gross beta, tritium, gamma emitting radionuclides, and Sr-90) and Hard-To-Detect (HTD) radionuclides (alpha, beta and X-ray emitting, fission and activation product radionuclides). Boron and general geochemistry parameters (alkalinity, sulfate, chloride, calcium, sodium, potassium, and magnesium) were analyzed in all groundwater samples in Q2 2006 only. The analytical program for YNPS groundwater samples is summarized in **Table 3-1.**

The complete suite of radionuclides included in **Table 3-1** was analyzed for all groundwater samples in Q1, Q2, and Q3 2006. As anticipated in the Groundwater Compliance Plan (**Reference 1-6**), tritium continued to be the only plant-related radionuclide identified in groundwater through Q3. Based on the tritium-only detections through 2006, Yankee proposed a reduced set of analyses for the Q4 2006 sampling campaign. Based on the results through Q3, YAEC proposed to discontinue gross alpha and gross beta analyses and to select radionuclides for which analyses are to be performed, based on the following graded approach:

- Wells that have consistently shown tritium levels below 5,000 pCi/l would undergo analysis for tritium only;

- Wells that have shown tritium levels above 5,000 pCi/l but less than 10,000 pCi/l would undergo tritium analysis, gamma spec analysis, and analysis for C-14, Sr-90, and Tc-99; and

- Wells that have shown tritium levels consistently greater than 10,000 pCi/l would undergo tritium analysis, gamma spec analysis, and analysis for C-14, Sr-90, Tc-99, Am-241, Pu-238, Pu-239/240, Pu-241, Cm-242, and Cm-243/244.

A summary of the groundwater sampling program for Q4 2006 is included in **Table 3-2**. Several monitoring wells were sampled for the complete suite of radionuclides even though the recent results did not fall into the full suite category due to either being a replacement well (CB-3) or a relatively recent monitoring well in the YNPS groundwater monitoring program (MW-102D, MW-104D, and MW-107E) (**Table 3-2**).

The laboratory analytical results are discussed in **Section 4.0**.

4.0 Laboratory Analytical Results

A total of 53 monitoring wells and Sherman Spring are included in the YNPS monitoring program (the remaining wells have been abandoned in place by backfilling with grout, consistent with MADEP guidelines). The 53 monitoring wells were sampled each quarter during 2006, with minor exceptions. Monitoring well MW-101C was obstructed during the first two quarters and was only sampled in Q3 and Q4. Several monitoring wells (MW-104D, MW-107E, MW-107F, MW-113A, and MW-113C) were installed during 2006, and were included in the sampling program as they were completed.

Quarterly groundwater samples were taken from all available monitoring wells during 2006, and selected monitoring wells were analyzed monthly. A complete suite of radionuclides was analyzed in groundwater samples taken in Q1, Q2, and Q3 2006 sampling rounds, while only tritium was analyzed in the monthly samples. As discussed in **Section 3.4**, radionuclides other than tritium were analyzed in selected monitoring wells for Q4 2006 groundwater analyses (**Table 3-2**).

A total of 49 monitoring wells and Sherman Spring were sampled in Q1 2006. The laboratory program included three field duplicates and three matrix/matrix spike duplicate (MS/MSD) samples in support of the quality control/quality assurance (QA/QC) program.

The Q2 sampling included 52 monitoring wells and Sherman Spring, three field duplicate samples and three MS samples. A total of 51 monitoring wells and Sherman Spring were sampled in Q3, and QA/QC samples included four duplicates and four MS samples. The Q4 sampling included 53 monitoring wells and Sherman Spring, and QA/QC for Q4 was supported by three duplicate and three MS samples. Complete laboratory analytical results for all four quarters are included as **Appendix D**.

In addition to the four quarterly sampling rounds conducted in 2006, monthly sampling for tritium was conducted on selected monitoring wells. The monthly sampling criteria included evaluation of significant changes in tritium concentrations in a monitoring well(s) and additional samples from newly installed and replacement monitoring wells. The complete laboratory results for the monthly samples are included in **Appendix D**. A summary of the laboratory results is provided in the following sections.

4.1 Tritium

During the first quarter 2006 sampling event, tritium was detected in 18 of the 49 wells sampled at concentrations greater than the sample MDCs. The highest concentration of tritium (41,300 pCi/L) was detected at monitoring well MW-107C which is screened in a sandy zone of the upper till. Tritium results for Q1 2006 sampling event are summarized in **Table 4-1**.

Tritium was detected in 22 of the 53 groundwater samples during the second quarter 2006 sampling event at concentrations greater than the sample MDC. The highest tritium concentration was again measured in well MW-107C at a concentration of 36,000 pCi/L. Tritium results for the second quarter 2006 sampling event are summarized in **Table 4-1**.

Tritium concentrations ranged from non-detect to 32,500 pCi/L during Q3 2006, and the greatest concentration was present in MW-107C. Tritium was detected in 31 of 52 samples in Q3 and laboratory results are summarized in **Table 4-1**.

During the Q4 2006 sampling event, tritium was detected in 27 of 54 groundwater samples. Similar to the first three quarters, the highest tritium concentration was reported in MW-107C. Tritium results for the fourth quarter 2006 sampling event are summarized in **Table 4-1**.

The results for the monthly tritium samples are also included in **Table 4-1**. The total number of tritium samples in the monthly sampling efforts ranged from three samples in October to 18 samples in May. The tritium concentrations detected in the monthly samples are generally consistent with that observed in the quarterly samples (**Table 4-1**)

Two monitoring wells were replaced during 2006 (CB-3 and CW-10) and the replacement monitoring wells (CB-3R and CW-10R) were sampled and analyzed for tritium. The tritium results for both original and replacement monitoring wells are summarized in **Table 4-2**, and demonstrate that the results for the replacement wells are consistent with the previous results for the original monitoring wells.

All tritium results are below the US Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 20,000 pCi/L except at MW-107C. Monitoring well MW-107C has consistently had tritium concentrations above 30,000 pCi/L, with historic levels in excess of 40,000 pCi/L (**References 1-3 and 1-4**). In general during 2006, tritium concentrations have decreased from Q1 through Q4. Many monitoring wells have had significant decreases including MW-107C (41,300 pCi/L to 29,100 pCi/L) and MW-101A (16,900 pCi/L to 3,880 pCi/L) in the upgradient portion of the site, and MW-106A (10,300 pCi/L to 3,010 pCi/L) and CB-6 (7,680 pCi/L to 869 pCi/L) in the downgradient portion of the site. The consistent decreases in both the upgradient and downgradient portions of the site suggest that the source concentration is decreasing at the site.

4.2 Boron

Boron was used as a neutron moderator in the primary cooling water during plant operation, and when detected above background levels in environmental samples at YNPS is a potential indication of plant-related contamination. Boron, like tritium, is conservative and does not partition significantly to soil or bedrock and may also be an effective tracer of potentially contaminated groundwater.

Boron was analyzed in all groundwater samples collected during Q2 2006. The boron results are summarized in **Table 4-3**. Boron concentrations ranged from not detectable at 4 micrograms per liter (μg/L) to 258 μg/L in monitoring well CW-10. The highest boron concentrations are generally associated with monitoring wells located in the former SFP/IXP source area that are screened within the upper sand lenses in the till (i.e., MW-107C (214 μg/L) and MW-107D (168 μg/L)) and glaciofluvial aquifers (i.e., MW-102D

(134 μg/L) and MW-107A (116 μg/L)), similar to the location of the highest tritium concentrations (**Tables 4-1 and 4-3**). Lower boron concentrations are observed in the glaciofluvial, till, glaciolacustrine, and bedrock aquifers downgradient of the SFP/IXP source area.

The distribution of boron in the glaciofluvial aquifer is presented in the 2006 Interim Groundwater report (**Reference 1-5**). The boron plume in the glaciofluvial aquifer is very similar to the tritium plumes mapped there for Q1 and Q2 2006 (**Reference 1-5,** Figures 7-3, 7-4, and 7-12). The highest boron concentrations are located in the former SFP/IXP source area, with decreasing concentrations observed in the downgradient monitoring wells. Similar to the tritium plumes for Q1 and Q2, the boron distribution is also consistent with groundwater contours and flow directions mapped for the glaciofluvial aquifer (**Reference 1-5,** Figures 6-4 and 7-12). The elevated boron concentrations and the similarity of the tritium and boron plumes indicate a plant-related source for the boron. Since the fate and transport properties for boron and tritium are relatively similar, as both contaminants are minimally retarded in the aquifer, the similarity of the boron and tritium plumes further indicates that the plume distribution at YNPS is well characterized.

There are no state or EPA standards for boron. All boron concentrations currently and historically identified at the site are well below 1 mg/L. Boron in groundwater was evaluated at the site in 2003 and 2004 and detected concentrations ranged up to 490 μg/L. The laboratory detection limits were higher then (100 μg/L), and many groundwater samples had boron concentrations in excess of 100 μg/L (**Reference 4-1**). The historic results indicate that the boron plume is slowly decreasing due to natural attenuation.

4.3 Other Radionuclides in Groundwater

Groundwater samples from each of the existing monitoring wells have now been analyzed during at least three quarterly rounds for the full suite of 10 gamma-emitting radionuclides, tritium, gross alpha, gross beta and 11 hard-to-detect radionuclides. The results of these analyses are included in **Appendix D**, and show that no gamma-emitting or hard-to-detect radionuclides have been detected in any well. Low levels of a few radionuclides have been reported sporadically at concentrations near the critical level (1.645 times the standard deviation of the total counts), but these values fall within the statistically expected five percent of false positive values at the 95% confidence level. The wells in which these values above the critical values are observed are evenly distributed among the wells and radionuclides. That is, there is no common plant-related radionuclide consistently identified in a single well (except for tritium).

The absence of radionuclides other than tritium in groundwater samples is consistent with soil-water partition coefficients (K_ds) determined for these radionuclides (**Reference 4-2**). The partition coefficients control the distribution of radionuclides in groundwater, as compounds with low K_d values are strongly partitioned to groundwater relative to soil, concrete and geologic material, while compounds with higher K_d values are more readily partitioned to the solid phase. Tritium has an effective K_d value of approximately zero, and Sr-90, Cs-137, and Co-60 typically have increasingly larger K_d values (**Reference 4-2**). Thus, the presence of tritium and absence of other radionuclides in site groundwater is consistent with the K_d values for these radionuclides. Although use of a linear isotherm to represent partitioning is usually modeled as a reversible process, many radionuclides including Cs-137 and Co-60 are partitioned to soil as an irreversible process (**Reference 4-2**).

4.4 General Geochemistry

As part of the general groundwater characterization at Yankee Rowe, all monitoring wells listed in the NRC Groundwater Compliance Plan (**Reference 1-6**) were sampled and analyzed for anions and cations during the Q2 2006 groundwater sampling round. Anions included in the laboratory analysis were sulfate, chloride and bicarbonate/carbonate. The cation analysis included magnesium, calcium, potassium, and sodium. The laboratory results for both anions and cations are summarized in **Table 4-3**.

Calcium and magnesium concentrations ranged from 2.32 to 223 milligrams per liter (mg/L) and 0.085 to 68.4 mg/L, respectively, while sodium and potassium concentrations varied from 1.85 to 184 mg/L and 1.31 to 25.2 mg/L, respectively. Sulfate concentrations (0.63 to 102 mg/L) were the lowest of the anions, with generally greater values for chloride (0.46 to 780 mg/L), bicarbonate (3.1 to 320 mg/L), and carbonate (non-detect to 234 mg/L). Carbonate was typically much lower relative to bicarbonate, as bicarbonate is the dominant carbonate species when pH is below 9.0 (**Reference 1-7,** Table 7-3). The two monitoring wells with pH values in excess of 11 (MW-107A and MW-110A) contained elevated carbonate concentrations (66 and 234 mg/L, respectively), and groundwater in that area is probably impacted by concrete in the nearby subsurface.

5.0 Spatial Trend Analysis

The spatial distribution of tritium has been mapped for the glaciofluvial, till, and bedrock aquifers for all four quarters of 2006. Plume maps and discussion of the tritium distribution for Q1 and Q2 2006 are included in **Reference 1-5**. A summary of the conceptual site model developed for YNPS along with the spatial distribution of tritium in Q3 and Q4 2006 is presented in the following sections.

The CSM identifies the former SFP/IXP as the significant source area for tritium at YNPS. Tritium migrated from the SFP/IXP into the glaciofluvial aquifer and downward into the till in the period 1963-1965. Additionally, YAEC believes the SFP may have leaked periodically before a steel liner was installed in the period 1978-1981, based upon cracks observed in the concrete pool walls. However, the amount of SFP leakage in the 1970s was small and not discernable based on water-level changes and make-up rates. The 1963-65 tritium release(s) created a significant plume of tritium-contaminated groundwater in the glaciofluvial aquifer as evidenced by concentrations of tritium in excess of 2,000,000 pCi/L measured in Sherman Spring in 1965 (**Reference 1-2**). Since the initial release in the 1960s, tritium concentrations in the glaciofluvial aquifer have decreased to less than 5,000 pCi/L in the downgradient portion of the glaciofluvial aquifer.

In addition to the impact to the glaciofluvial aquifer, tritium released from the former SFP/IXP has migrated downward into the till and sand layers within the till. This is a function of the downward hydraulic gradient that occurs between the glaciofluvial and glacial till aquifers. This process resulted in significant tritium contamination in the till, as over 40,000 pCi/L of tritium has been detected in MW-107C screened in the upper till adjacent to the SFP/IXP as recently as April 2006.

Soil excavation during 2005 removed a significant portion of tritium-contaminated soil from the former SFP/IXP area. During the soil excavation activities, a slug of tritium-contaminated groundwater was released from the former SFP/IXP area into the glaciofluvial aquifer and has migrated through the downgradient portion of the YNPS site. This slug of elevated tritium has passed through the glaciofluvial aquifer during 2005 and 2006 as documented in the downgradient monitoring wells MW-104A, CB-6, MW-106A, and Sherman Spring (**Figure 5-1**). As shown in **Figure 5-1**, tritium concentrations (up to 14,000 pCi/L) in these downgradient monitoring wells had maximum concentrations in the late 2005 and early 2006 time period, followed by sharply decreasing tritium concentrations. These observations are consistent with a slug of tritium-contaminated groundwater migrating through the shallow, glaciofluvial aquifer.

Prior to the excavation activities in 2005, a plume of tritium-contaminated groundwater was established across the YNPS site in the glaciofluvial aquifer with tritium concentrations ranging from 5,000 to 10,000 pCi/L in the area adjacent to and directly downgradient of the former SFP/IXP area to concentrations less than 1,000 pCi/L in downgradient monitoring wells (**References 1-3, 1-4, and 1-5**).

The tritium plume characterized for the Q1 and Q2 2006 for the glaciofluvial aquifer identified the slug of tritium-contaminated groundwater in the downgradient portions of the site, and demonstrated that the plume characteristics in the glaciofluvial aquifer established prior to the 2005 soil excavation were in the process of being re-established across the site (i.e., highest concentrations in the upgradient portion of the site adjacent to the SFP/IXP, with lower concentrations downgradient of the SFP/IXP) (**Reference 1-5,** Figures 7-3 and 7-4). The tritium concentrations in the glacial till during Q1 and Q2 2006 were higher than those reported in the glaciofluvial aquifer, but with limited downgradient migration, consistent with the results of the pressure-transient and pumping tests conducted in summer 2006 (**Reference 1-5,** Figure 7-5).

5.1 Spatial Distribution of Tritium Third and Fourth Quarters 2006

The spatial distribution of detected tritium has been mapped for the glaciofluvial and upper till aquifers for the third and fourth quarter 2006 sampling events, and is summarized below.

5.1.1 Spatial Distribution of Tritium from Third Quarter 2006

The tritium plume in the glaciofluvial unit mapped for Q3 2006 is shown in **Figure 5-2**. The downgradient slug of elevated tritium identified in Q1 and Q2 2006 is present in Q3 2006, and is part of a large plume of elevated tritium whose source is the former SFP/IXP area (**Figure 5-2**). Tritium concentrations up to 10,100 pCi/L (MW-101A) are present in the shallow glaciofluvial aquifer in the vicinity of the former SFP/IXP, with decreasing concentrations observed in the downgradient monitoring wells (**Figure 5-2**). The downgradient slug of elevated tritium (up to 5,280 pCi/L) has somewhat higher tritium values relative to the more intermediate downgradient monitoring wells (i.e., MW-104A, 1,430 pCi/L), and the distribution of tritium is consistent with the groundwater flow direction identified in the glaciofluvial aquifer (**Figure 2-1**).

In addition to the broad tritium distribution within the shallow glaciofluvial aquifer, tritium is also detected more locally in the till, glaciolacustrine, and bedrock aquifers. While tritium in the bedrock and glaciolacustrine aquifers is limited to one location in each aquifer (MW-105B and MW-113C, respectively), sand lenses within the till contain a local tritium distribution downgradient of the SFP/IXP source area. This deeper zone of impact is smaller than the shallow plume but more concentrated in the vicinity of MW-107C because of the restricted groundwater flow within the discontinuous, low-yielding sand lenses within the till.

Figure 5-3 shows the detected tritium concentrations within sand lenses in the upper portion of the till for Q3 2006 in plan view. Tritium concentrations observed in Q2 2006 within the till are generally a little higher those detected in Q3 2006 (**Table 4-1**). The tritium plume in the upper sand lenses within the till is focused in the area immediately downgradient of the SFP/IXP source area and extends to MW-105C (1,650 pCi/L) but the non-detect value for MW-104D indicates that this plume has not migrated to the MW-104 well cluster. The highest tritium concentration is detected in MW-107C (32,500 pCi/L), but the Q3 2006 concentration is significantly lower than the 36,000 pCi/L reported for Q2 2006. This limited distribution is generally consistent with groundwater contours and flow direction interpreted for the upper sand lenses within the till (**Figures 2-2 and 2-6**) and the tritium plume characterized in the upper sand lenses during Q2 2006 (**Reference 1-5,** Figure 7-5).

The vertical distribution of tritium is summarized in cross-sections A-A' through E-E' and the locations of the cross-sections are shown in **Figure 5-4**. **Figures 5-5 through 5-9** are Geologic Cross-Section A-A' through E-E' showing contoured tritium concentrations during Q3 2006. Geologic Cross-Section A-A' is aligned generally in the direction of groundwater flow, toward the Deerfield River. Similar to **Figure 5-3**, which shows the horizontal tritium distribution, **Figure 5-5** illustrates the vertical distribution of tritium impacts on cross-section A-A' during Q3 2006. This figure also shows that impacts within the deeper glacial till appear to originate adjacent to the SFP/IXP source area and extend downgradient in the direction of ground water flow inferred in **Figure 2-2** to a point midway between the SPF/IXP source area and CB-6 (**Figure 5-5**).

Tritium concentrations in the upper portions of the till for Q3 2006 range from 1,650 pCi/L in the downgradient portion of the plume (MW-105C) to 32,500 pCi/L in MW-107C, located adjacent to the SFP/IXP source area. As shown in **Figures 5-3 and 5-5**, the tritium distribution in the till is limited to the area directly downgradient of SFP/IXP, and in contrast to the tritium distribution in the shallow glaciofluvial aquifer, does not have a significant downgradient component. The 20,000 pCi/L MCL for tritium is exceeded in MW-107C, but sampling results for all other monitorng wells screened in the till, glaciolacustrine, and bedrock aquifers have tritium concentrations, where detected, consistently well below the MCL.

The limited distribution of tritium observed in the glacial till is further illustrated in cross-sections B-B', C-C', D-D' and E-E' (**Figures 5-6 through 5-9**). The absence of a wide-spread plume within this unit is generally consistent with the results from the pumping test of MW-107C and the multiple pressure transient tests conducted during summer 2006 (**Reference 1-5,** Figures 5-23 through 5-29). The pumping test and the pressure transient tests demonstrated that the connectivity of the sand lenses in the till is highest in the area of the former SFP/IXP source area, with limited connectivity at distances greater than 100 feet. MW-105C was shown to have hydraulic connection with sand lenses in the till located in the SFP/IXP source area, consistent with the ongoing detection of tritium in MW-105C. The combination of the tritium analytical results, pumping test, and pressure transient data suggest that the tritium plume in the glacial till sand lenses extends no further downgradient than the MW-104 and MW-105 well clusters and has established equilibrium with the source area (**Figure 5-3 and Figures 5-5 through 5-9**).

Tritium is typically not detected in bedrock monitoring wells and during Q2 2006 has only been detected in MW-105B (3,290 pCi/L). The lack of tritium in most of the monitoring wells is consistent with upward gradients established between the bedrock and overlying glacial till or glaciolacustrine aquifers. The presence of tritium in MW-105B is is function of the relatively shallow bedrock in this area. Likewise, the pressure transient testing identified a connection of MW-105B and sand lenses within the upper glacial till.

5.1.2 Spatial Distribution of Tritium from Fourth Quarter 2006

The tritium distribution in the glaciofluvial aquifer for Q4 2006 is shown in **Figure 5-10**. The plume is very similar to the tritium distribution observed for Q3 2006, except tritium concentrations are lower. The downgradient slug of tritium is still observed, however the highest concentration is located farther downgradient, and the tritium concentration within the slug is significantly lower (**Figures 5-2 and 5-10**). These observations are consistent with the mapped groundwater flow direction and the continued migration of the slug towards the Deerfield River (**Figure 2-5**). Tritium concentrations in Q4 2006 are typically lower than those reported for Q3 2006 (**Table 4-1 and Figures 5-2 and 5-10**)

Figure 5-11 depicts the tritium plume in the upper glacial till sand layers for Q4 2006. Similar to the distribution identified for Q3 2006, the highest concentration was reported in MW-107C (29,100 pCi/L), with the downgradient plume distribution including MW-105C (2,750 pCi/L). The non-detect concentration reported for MW-104D continues to limit the downgradient extent of the plume to an area upgradient of the MW-104 well cluster (**Figure 5-11**). The Q4 2006 distribution of tritium is consistent with the results for Q1 through Q3 2006, where the plume in the upper sand layers of the glacial till is limited to the area downgradient of the former SFP/IXP source area including MW-105C, but upgradient of the MW-104 well cluster (**Figures 5-3 and 5-11 and Reference 1-5,** Figure 7-5).

The vertical distribution of tritium is shown in **Figures 5-12 through 5-16** where contours or isocons of tritium in cross section are depicted. Similar to the cross sections developed for Q3 2006, the Q4 2006 results indicate a deep tritium distribution beneath the former SFP/IXP area and an extensive downgradient tritium distribution in the shallow glaciofluvial aquifer (**Figures 5-12 through 5-16**).

Consistent with Q3 2006 results, tritium was only detected in one bedrock monitoring well, MW-105B (2,900 pCi/L). During 2006, tritium has been consistently reported in MW-105B ranging from 4,780 pCi/L in the May monthly sample to 2,900 pCi/L in Q4 2006 (**Figure 5-17**). As shown in **Figure 5-17**, the tritium concentration in MW-105B is decreasing, and has a statistically validated downward trend (see **Section 5.3**)

5.2 General Geochemistry of Site Groundwater

The general geochemistry data for all Q2 2006 groundwater samples were presented in a Piper diagram (**Reference 1-5,** Figure 7-7). The YNPS groundwater samples were shown to have low magnesium and sulfate, with a wide range of bicarbonate+carbonate to chloride and calcium to sodium+potassium ratios. For all of the YNPS groundwater samples there is no cluster of data or specific chemical signature.

When the groundwater samples were separated into their specific hydrogeologic units: glaciofluvial, till, glaciolacustrine and bedrock, some specific geochemical signatures were apparent (**Reference 1-5,** Figures 7-8 through 7-11). The anion-cation data for the groundwater samples from the glaciofluvial aquifer indicated that the geochemistry of that unit was generally distinct from that of the till, glaciolacustrine, and bedrock units, all three of which are very similar. The glaciofluvial groundwater has a more chloride-dominated anion component relative to the till, glaciolacustrine and bedrock, which are more bicarbonate/carbonate dominant. All hydrogeologic units were shown to have low sulfate.

The similarity of the till, glaciolacustrine and bedrock groundwater chemistry was interpreted as the result of glacial erosion of the bedrock and the subsequent glacial deposition of the derived material into glaciolacustrine and till soils. The glaciofluvial unit is also a result of glacial deposition, but the active agent in this process was melt water rather than ice and the resulting difference in grain-size distribution may affect its geochemical signature. Alternatively, the use of deicing salt on the roadways throughout the YNPS may be evident in the geochemical signature of the shallow aquifer.

The glaciofluvial aquifer is closest to ground surface and most permeable of the four units, allowing relatively more mixing with meteoric water. Although not tested for this study, meteoric (atmospheric) water likely has a different geochemical signature from groundwater derived from any of the stratigraphic units at YNPS and mixing with this water would likely result in a more distinct groundwater type. Regardless of the cause of the relative uniqueness of the geochemistry of groundwater from the glaciofluvial aquifer, the results of the anion-cation analyses tend to corroborate the conceptual model of the site, which presumes that groundwater flow in the glaciofluvial aquifer is largely isolated from flow in the deeper units.

5.3 Trend Analysis of Tritium

To evaluate the long-term trend for tritium in groundwater, YNPS has completed a trend analysis for all monitoring wells included in the quarterly groundwater monitoring plan. The trend analysis was conducted for tritium, as tritium is the only radionuclide identified in groundwater at YNPS. The trend analysis included all sample results from 2006 (including the monthly sampling) for all monitoring wells that are part of the quarterly sampling program. The analysis utilized Sens Slope Trend analysis, and all results indicating an upward or downward trend were confirmed using Kendall-Mann Upward Trend analysis (USEPA, 1989 and 1992). The two sigma value was used for all non-detect concentrations, and the results of the trend analysis are summarized in **Table 5-1**. The complete trend analysis data and results are included in **Appendix E**. The trend analysis results are presented in terms of identifying either an upward trend, downward trend or no trend. The no trend result indicates that neither an upward nor downward trend is present, and is generally indicative of a stable trend. Time series plots of the tritium concentrations for the 2006 results for each monitoring well are also provided in **Appendix E**.

The trend analysis was conducted on all 53 monitoring wells and Sherman Spring and a total of 272 tritium results were included in the analysis. Of the 272 total tritium results, 133 or 49% represent non-detect tritium concentrations. A summary of the tritium results utilized in the trend analysis for each monitoring well is also included in **Appendix E**.

Of the 54 monitoring locations, nine monitoring wells (CB-6, MW-101A, MW-105B, MW-106A, MW-107A, MW-107D, MW-107E, MW-110A, and MW-111A) and Sherman Spring have a defined downward trend (**Figures 5-18 and 5-19**). A total of 43 monitoring wells have no trend and one monitoring well (MW-110C) displays an upward trend. The upward trend determined for MW-110C is based on the four quarterly 2006 results, as this monitoring well was not installed prior to 2006. The tritium concentration in MW-110C is relatively low ranging from 1,160 pCi/L in Q1 2006 to 2,590 pCi/L in Q4 2006 (**Figure 5-20**). While the tritium concentration has clearly increased in MW-110C during 2006, the maximum concentration is still an order of magnitude below the tritium MCL of 20,000 pCi/L and significant increases are not expected in this portion of the site. MW-110C is downgradient of the former SFP/IXP area where significant soil remediation was conducted, and all other monitoring wells in this portion of the site have stable or decreasing tritium trends. The result for the first quarter 2007 will allow further evaluation of this upward trend determined for MW-110C.

5.4 Fate and Transport of Tritium

The processes of natural attenuation, including dilution, dispersion and radioactive decay, have significantly reduced the tritium levels in groundwater at YNPS since the 1960s. The tritium concentrations are lower in the shallow aquifer because the higher hydraulic conductivity and more homogeneous flow domain in that unit have allowed more flushing and dilution compared to the deeper, discontinuous sand lenses where flow is more restricted because the sands are interlayered within a low permeability glacial till.

With a groundwater plume in equilibrium, a source area will release a contaminant to the aquifer at a relatively constant rate, and the dissolved contamination will attenuate in the downgradient aquifer as a function of processes including dilution, dispersion and radioactive decay. Continuation of these processes will slowly decrease the size of the plume as the contaminant mass in the source area decreases. Important characteristics of a plume in equilibrium are: 1) consistent plume shape over time, 2) relatively constant or slowly decreasing contaminant concentrations in groundwater, and 3) no increases in downgradient distance of contaminant migration.

The tritium plumes at YNPS appear to be in equilibrium with the source area. The plumes characterized for Q1 through Q4 2006 have similar distributions, are slowly decreasing in concentration, and are not increasing in the downgradient direction. Of significance is the decrease in MW-107C that has occurred following soil remediation in the former SFP/IXP area. Soil removal in the former SFP/IXP was conducted from June 2005 through fall 2005. Prior to the soil remediation activity, tritium levels in MW-107C were fairly constant, varying between 48,000 pCi/L and 41,800 pCi/L from 2003 through 2005 (**Figure 5-21**). Lower tritium concentrations were reported in March and May

2004, however these lower concentrations were related to a damaged road box that allowed infiltration of surface water into the well, diluting the groundwater in MW-107C (**References 5-1 and 5-2**). Following completion of soil remediation in the former SFP/IXP, tritium levels in MW-107C began to decrease, and by Q4 2006 had decreased to 29,100 pCi/L.

MW-107C is directly adjacent to the former SFP/IXP and is believed to be very near to the tritium source area. The high, constant tritium concentrations observed in MW-107C over the 2003 to late 2005 time period indicate that a significant source of tritium was degrading groundwater, and that the rate limiting process was most likely the contact time that groundwater had with the source. The high, relatively constant value of tritium detected in MW-107C was a function of relatively constant groundwater flow through the source area, and a large source that acted to maximize tritium concentrations in groundwater.

The decrease in tritium levels observed in MW-107C in 2006 has followed significant soil remediation and indicates that the rate limiting process for groundwater contaminant concentration is no longer the contact time of groundwater with the source area, but is a function of a continous decrease in the source mass. Prior to soil remediation in the SFP/IXP, the size and strength of the source area was most likely large relative to the contact zone for groundwater, and resulted in a high and relatively constant level of tritium groundwater contamination. Following the soil removal and associated source mass reduction, the rate limiting process for groundwater degradation no longer appears to be the contact time of a large source with a constant groundwater flux, but a constantly decreasing mass in the source area. Prior to the soil remediation the source mass was large enough that the amount of tritium removed via groundwater flow through the area was small relative to the mass of source contamination. The soil removal in the source area significantly reduced the source mass to the level where continued source reduction of tritium via precipitation recharge flushing and groundwater flow through the contaminated source soils is acting to continuously reduce the contaminant mass in the source area, resulting in a continuous decrease in groundwater tritium levels. The decreasing tritium concentrations may also be related to the slow diffusion of tritium from the low permeability glacial till into the adjacent more permeable sand lenses.

While most monitoring wells with elevated tritium experienced a decrease in concentration during 2006, CFW-6 located upgradient of the former SFP/IXP had a significant increase in tritium during 2006 (**Figure 5-22**). CFW-6 is located upgradient of the industrial area, adjacent to the drainage for Wheeler Brook (**Figure 1-3**). Prior to Q1 2006, tritium levels in CFW-6 were typically non-detect. During 2006, tritium rapidly increased from the non-detect concentration to 2,650 pCi/L in Q3 2006, followed by a decrease to near non-detect values in Q4 (**Figure 5-22**). Other monitoring wells in this area (CFW-5 and CFW-1) and nearby monitoring wells in the upgradient portion of the industrial area (CB-8 and CB-3) did not experience a similar increase in tritium during 2006 (**Table 4-1**).

The sharp increase, followed by the rapid decrease in tritium concentration observed in CFW-6 suggests that a slug of tritium-contaminated groundwater migrated through the shallow groundwater in the CFW-6 area. The most likely source of tritium for this slug of tritium-contaminated groundwater is concrete rubble from the reactor support structure that was temporarily stored east of the industrial area (**Figure 5-23**). The concrete rubble had up to 100 pCi/gram of tritium and was located in that area from fall 2005 through early 2006. Following removal of the concrete rubble, final status survey results identified up to 40 pCi/g of tritium in surface soils within the area of concrete rubble storage (**Figure 5-23**). Tritium is readily leachable into the subsurface and would quickly migrate via infiltration to the shallow groundwater, creating the slug of tritium-contaminated groundwater observed in CFW-6. Based on the groundwater flow determined for this portion of the site, the slug of elevated tritium would flow from the CFW-6 area to the north and discharge to the Sherman Reservoir (**Figures 2-1 and 2-5**).

The monitoring network established at YNPS has provided a strong understanding of the horizontal and vertical extent of tritium contamination in site groundwater. The plumes defined in 2006 are all below the EPA MCL established for tritium except for MW-107C located adjacent to the source area. Based on the source removal completed in the former SFP/IXP area, tritium groundwater concentrations are expected to continue the general decrease in concentration observed in 2006.

6.0 Groundwater Model

6.1 Introduction

A three-dimensional flow and transport groundwater model has been developed to support the decommissioning of the Yankee Nuclear Power Station in Rowe, MA (YNPS). The modeling work began in July 2006. The model has been used to assist in the interpretation of the MW-107C pumping test in June 2006 and in the interpretation of the various pressure transient tests performed in onsite monitoring wells during June and July 2006. A number of other features of the detailed groundwater hydrographs of the site monitoring wells have been evaluated with the model, with the goal of gaining a better understanding of the conceptual site model. The model has also been used to simulate the movement of tritium from the IXP area from May 1963 onward and to predict the maximum concentration of tritium in a hypothetical "resident farmer" well if one were to be installed beginning as early as spring of 2007.

6.1.1 Scope and Objectives

Although not required by any regulatory order or agreement, the development of a numerical simulation tool for YNPS was undertaken to assist in the evaluation of the complex layering of thick glacial till, interbedded sand seams, and glaciolacustrine deposits found under and downgradient of the area of the site with the highest residual radioactivity in groundwater. The model parameters have been highly refined in specific portions of the site where the residual tritium concentrations in groundwater have exceeded the EPA MCL of 20,000 pCi/L. The main questions have been how long the groundwater will continue to exceed the MCL and what would be the maximum concentration of tritium in a hypothetical resident farmer's well on the site.

The scope of this modeling exercise has been broad, covering the YNPS site in three dimensions and large areas of watershed above and below the site. Although the primary focus is the industrial area formerly occupied by the reactor and generating station, the overall model domain has to be sufficiently large to define reasonable boundary conditions. Because the Deerfield River acts as a discharge boundary and YNPS is located near that boundary, the model domain was extended to encompass surface water drainage basins on both the west and east sides of the Deerfield River. The scope of the modeling activity is summarized in the following bullets:

- Physical Scope of the Model
  - The area known to have been the primary radioactive water release site (i.e., the Spent Fuel Pool (SFP) and Ion Exchange Pit (IXP)) westward to Sherman Spring is modeled in detail.
  - The major drainages on the west and east sides of the Deerfield River, with YNPS in the approximate middle, are included for completeness.
  - In the vertical dimension, the model incorporates saturated hydrogeologic units from the ground surface to as much as 800 feet below ground

surface. Total bedrock thickness from top of rock to model bottom is 500 feet.
    - The thick valley fill deposits are represented by subdivision into as many as 13 individual layers to represent the glaciofluvial deposits on top, the thick glacial till with as many as three primary, nearly horizontal sand seams and a locally thick glaciolacustrine deposit on bottom with as many as two distinct primary sand seams.
- Temporal Scope of the Model
    - Historical Operating Conditions (pre-closure), including simulation of the spread of the May 1963 Spent Fuel Pool/IXP leak.
    - Post Closure Conditions (after completion of demolition activities), reflecting changes to recharge conditions in the industrial areas and changes to soil permeability in the areas of deep soil remediation.

The physical scope of the modeling exercise is intended to be sufficiently robust to incorporate hydrologic boundary conditions in all three dimensions. The temporal scope is intended to provide an indication of the effects of long-term and short-term hydrologic transient events over the course of plant operation and closure. The modeling activity has assisted in refining the hydrogeologic conceptual site model, which is described in more detail in Sections 4 and 6 of **Reference 1-5**.

Several general and specific objectives were defined for the modeling activity. These objectives support data needs identified for groundwater monitoring and for strategic evaluation of the post-closure conditions at YNPS and are listed below:

- General Objectives
    - Produce a numerical simulation tool that is generally representative of observed site conditions at YNPS.
    - Produce a numerical simulation tool that can be used to illustrate groundwater flow regimes within the hydrogeologic formations identified at YNPS.
    - Produce a simulation tool that can support assessment of fate and transport of tritium originating within the former industrial area of the site.
    - Assess the potential impacts of changing conditions related to termination of plant operations and performance of decommissioning activities at YNPS.
- Specific Objectives
  1) to create a tool to confirm or refute the conceptual site model (e.g., testing various degrees of continuity of sand layers between wells with known intermediate-depth tritium contamination);
  2) to predict how the tritium plume will migrate with time and change in concentration with time;
  3) to determine where the deep tritium plume will discharge to the River and at what concentration; and,
  4) to predict the concentration of tritium entering the "resident farmer" well.

6.1.2 Modeling Software

MODFLOW and MT3DMS are porous media models, but can be adapted to model flow and transport in fractured media. Although bedrock has been included in the YNPS model, it is only of minor importance to the fate and transport of radionuclide releases at the site. For the purposes of this model, the issues revolving around use of porous media models for fractured bedrock are not important due to the low importance of bedrock to the problems at hand. Most of the model development has been done with a regional model covering a large area on both sides of the Deerfield River valley. The flow models are constructed using the 1996 version of MODFLOW as developed by the US Geological Survey (USGS). Groundwater Vistas (GWV), GWV4, Version 4.25, has been used as the pre- and post-processor, as developed by Environmental Simulations, Inc. (ESI). Particle tracking used the USGS MODPATH program with pre- and post-processing by Groundwater Vistas. Solute transport was implemented using MT3DMS developed by the US Army Corps of Engineers (COE) with pre- and post-processing by Groundwater Vistas.

ArcView 9.1 was used to prepare data sets and present the final model results. Rockworks was used to develop the geologic database and create gridded surficial unit surfaces and cross sections to aid in the 3-dimensional design of the model. Surfer was used to grid and contour some of the data.

Detailed individual "run logs" were created and saved in accordance with ASTM D5718.

6.1.3 Base Map Preparation and Spatial Location of Data

The model base maps were constructed in ArcView, utilizing data available from the State of Massachusetts GIS web site and from site base maps and surveys prepared by YNPS or its contractors. These data were projected in Massachusetts Mainland NAD83 State Plane. The vertical datum of site-specific data is referenced in this work to NAVD88 in feet. Some data were available for the site in NAD 1927 datum and the original "NEPCO" (New England Power Co.) arbitrary vertical datum which was 106.66 feet below 1929 NGVD. Add 0.45 feet to NAVD88 to obtain 1929 NGVD on the site. YNPS provided a recent bathymetric survey map of Sherman Reservoir, which was digitized and projected in ArcView to match the reservoir outline.

Base map work has been aided by color orthophotos at 1:5000 scale taken April 2001, USGS topographic contour maps at 3-meter contour interval, a detailed YNPS property contour map at a 5-foot interval, and other Arc "shape files" including streams, and sand and gravel aquifer maps. Results from **Reference 2-2** include the most comprehensive geologic mapping of the site. Figures from that report were scanned and fit to the base map. Other miscellaneous reports, such as the report of the 1956 geophysics survey (**Reference 2-1**), which contained important data for model development such as depth to rock, were also scanned and fit to the base map where data needed to be geo-referenced.

6.1.4 Rockworks Database and Surfer used for Geologic Data and Layer Elevations

Site-specific boring and monitoring well data were used to develop the onsite model parameters, the locations of which are shown in **Figure 6-2**. Table 1 in **Reference 2-4** summarizes monitoring wells placed on the site prior to 2003, only two of which were installed prior to plant shutdown in 1993. Since 2003, many additional supplemental investigations have been performed and reported to the Nuclear Regulatory Commission (NRC) by YNPS and to the State of Massachusetts by ERM.

All borings and monitoring well data for the site, along with simplified stratigraphic descriptions, were entered into a RockWorks database and geo-referenced. In addition, all points at which bedrock elevations were known or inferred from field mapping, seismic refraction work, or drilling, were compiled in RockWorks. No offsite well data within the model area were found in our research.

Geologic inference from inspection of topographic maps was used to estimate bottom elevations of the glaciofluvial deposit adjacent to the Deerfield River. The aerial distribution of the sand and gravel unit is available from the Massachusetts GIS website. Experience (**Reference 2-3**) in mapping landslides along the Deerfield River Valley gave insight into the likely thickness of the sand and gravel unit away from the plant site where its thickness has been documented by borings. The detailed site bedrock topography map in the vicinity of the plant (IA) was made using the data points in **Figure 6-1** to create a contour map through the minimum curvature algorithm, as shown on Figure 4-10 of **Reference 1-5**. An estimated depth to bedrock derived from a downhole camera shot at the Furlon House well provided a data point there, and the remainder of the bedrock elevations were derived from geologic inference from topographic map analysis. Most of the upland areas were assumed to have thin or no soil over bedrock.

Reference 1-5 contains numerous detailed geologic cross-sections along with groundwater head profiles and tritium concentration profiles. **Reference 1-5** also contains detailed maps of the thickness of the glaciofluvial unit, the top elevation of the underlying till layer, and the top elevation of the underlying glaciolacustrine layer in the main industrial area of the site.

6.2 Model Discretization

A large regional model was constructed to encompass the YNPS site. It is apparent from looking at the topographic map of the area that groundwater that flows through the plant site could begin from as far away as several miles. Rather than estimate the flux of groundwater flow entering the site from the east and using constant flux boundaries to represent that flux contribution, the modelers elected to include a large naturally-bounded area (the watershed boundary) that would, by its nature, determine the flux. This was particularly important in light of the transient modeling that was performed where determining the flux under variable stress conditions would have been quite difficult.

Although it is obvious that the discharge of any contaminants carried in groundwater from the site would enter the Deerfield River, it has not been established how far downstream that discharge could occur. Again, rather than trying to apply constant flux boundary conditions downstream of the area of interest on the River, the model boundaries have been extended out to the natural watershed divides and far enough downstream so these natural boundaries would allow the model to distribute the flux appropriately along the River.

The model was discretized into the standard rectangular finite-difference grid, but with irregular spacing. The model has 80 columns, 57 rows and 15 layers and a variable grid size that varies from 25-foot square finite-difference cells in the former plant area to 400-foot square cells at the model boundaries. **Figure 6-3** shows the finite-difference grid overlain on the USGS base map. The model extends 21,000 feet east to west and 14,000 feet south to north. The origin is at Massachusetts NAD83 State Plane Coordinates, Mainland Division, x = 261,000 feet and y = 3,085,800 feet.

The top thirteen layers of the model consist of soil. In the upland areas, the layers are of equal thickness (0.5 feet) except where the soil is known to be thick, such as in the till slope southeast of the plant where seismic refraction was used to establish the soil thickness. In the immediate plant area where sufficient data were available to define specific geologic units such as the glaciofluvial layer, the till layer, and the glaciolacustrine layer, these surfaces were contoured in Rockworks and used to define individual layer elevations. In an effort to study the transport potentials of particular signature sand seams encountered during deep drilling in overburden that reaches up to 300 feet thick, 5 thin layers were created within the surficial section that were parameterized to represent through-going sand seams where data suggested those sand seams were significant, as from the studies reported in **Reference 1-5**. **Table 6-1** gives a vertical cross-section description of how the model was discretized in the vertical plane. **Figures 6-6A** and **6-6B** show vertical cross sections through MW-107, east to west and south to north, respectively. The YNPS Interim Groundwater Report (**Reference 1-5)** contains figures showing the contours on the tops of the major surficial units and the thickness of the glaciofluvial stratum.

6.3 Boundary Condition Specification

There are a variety of boundary conditions used in the modeling. No-flow boundaries (a special case of constant flux boundaries where flux is constant at zero--also called Neumann or Type 2 boundaries) are placed around the outside of the naturally-defined limits of the model, and under the bottom of the model. As calibration proceeded, areas of the uplands that were predicted by the model (most of the top 13 layers of Zone 9, which are defined as soil layers, each 0.5 feet thick) to become "dry" were then fixed as no-flow cells in order to improve the convergence of the regional model, which is highly non-linear as all layers including 14 and above were allowed to be simulated as "unconfined" if the layers above were not predicted to be saturated. There are a total of 23,878 active cells in the flow model. The area of transport in the MT3DMS model was limited to the immediate site area and downstream along the Deerfield River lower valley area.

The Deerfield River and Sherman Reservoir within the model area are treated as constant head cells (also called Dirichlet or Type 1 boundaries). During pre-demo times (prior to 2006), Sherman Reservoir elevation was set at elevation 1106 feet NAVD88 for steady-state runs with average annual recharge-based simulations. There are a total of 171 constant head cells in the flow model. They are defined primarily in layer 1 of the model. Several constant head cells in areas downstream of Sherman Dam occur in lower layers because there are some large finite-difference cells there that span the River and adjacent steep banks and the layering constraints forced the constant head cell to the layer where the cell bottom was just below River level in that cell.

Streams and upland rivers were defined as "drains" (also called Cauchy or Type 3 boundaries). This is a condition that allows discharge from the modeled groundwater system into the drain, but when the water table is predicted by the model to drop below the defined drain bottom elevation, there is no water contributed by the stream to the model. The resistance to discharge into the drain is controlled by the "conductance" value assigned to each drain cell. The conductance was relatively small, set at 100 cubic feet per day per square foot per foot of head difference between the defined stream elevation and the predicted water table. The drains were digitized in segments based on the USGS map elevations along streams defined on the State shape file of "streams" and in obvious large wetlands. Because some of the cells in the periphery of the model are large and the slopes are steep in many areas, the linear interpolation routine caused some "drain" cells to be defined below the top layer of the model where soil thickness was very thin. There are a total of 582 drains in the model.

A number of concrete slabs and foundations have been left in place on the site, but few, if any, of them are barriers to groundwater flow. Most foundations do not even extend through the top layer of the model.

Boundary conditions for the model are shown on **Figure 6-4**. The contours on the top of bedrock for the area near the site are shown on **Figure 6-5**.

6.4 Hydraulic Conductivity and Recharge Parameterization

The conceptual site model forms the basic framework for parameterizing the computerized groundwater model. During the last continental glaciation, the Deerfield River valley was first scoured, then had glacial till plastered on the sideslopes. A glacial lake formed in the valley during deglaciation, leaving thick, localized silty thinly-bedded glaciolacustrine deposits with some interbedded sand seams. A late glacial pulse in the valley apparently overrode the glaciolacustrine deposits, and laid more till over the glacial lake deposits while periodic melting resulted in some significant sand seams interbedded in the till. In the final stages of deglaciation, glacial meltwaters deposited kames, kame terraces and outwash over the top of the till left in place in the valley.

The bedrock underlying the site is well-bedded albite gneiss with a foliation that strikes northeast and a 20 to 35-degree dip to the southeast. Joints in the area are predominately high angle, but well distributed in strike. There is a slight preference for a northwest-southeast joint strike. Given the lack of strong evidence for a preferred bedrock fracture orientation throughout the model area, the grid is located north-south with no anisotropy imparted to the bedrock. Although there have been no bedrock pumping tests or rigorous photolineament studies, site monitoring well response to the new "plant" well southeast of the ISFSI suggests a north-south linear from the well through the MW-107 area. Terrain analysis and contours on the bedrock surface, such as shown on **Figure 6-5**, suggest a northwest-southeast linear parallel to and just downstream of Sherman Dam. Other bedrock fracture zones may occur throughout the model area but they are unlikely to be important to the transport of any contaminants that might have been released at the site.

The soils to the west of the former Vapor Containment (VC) area and in the area of the Plant well are quite thick. A large area of thick glacial till extends up the slope for several thousand feet southeast of the former industrial area. There is thick soil (up to 300 feet thick in places--for example, at the Furlon House well) at other locations under or next to the Deerfield River and down to approximately elevation 800 feet or even lower. Whether this is the thalweg of the river valley and whether this is continuous along the bottom of the river valley are not known. The model honors all bedrock data points, but not all the points of lowest elevation have been connected to create a thalweg at the lowest measured elevation, due to lack of data points in between and beyond MW-106B and the Furlon House well.

The vertical conceptualization of the model is given in **Table 6-1**. **Table 6-2** summarizes the defined hydraulic conductivity zones and **Figures 6-6** through **6-17** display the distribution of these hydraulic conductivity zones within the various layers of the model. Initial hydraulic conductivity estimates for rock and soil came from Table 2 of **Reference 2-3**. The values for the glacial till were measured by high quality laboratory testing on undisturbed samples. Additional data on the hydraulic conductivity of the glaciofluvial deposit were taken from **Reference 6-1**. The Executive Summary of **Reference 6-1** states that the mean hydraulic conductivity value of the glaciofluvial unit is 1.1E-3 centimeters per second or 3.1 feet per day (with a range of 1.7E-7 to 6.5E-3 centimeters per second). The two hydraulic conductivity values used for layer 1 glaciofluvial were 5 and 10 feet per day. Calibration started from these initial values to obtain a set of heads that were generally the right order of magnitude based on the calibration wells using average annual recharge estimates.

Values were varied within reasonable ranges to calibrate the model to observed water elevations in monitoring wells. Recharge and the main hydraulic conductivity values were tested within Groundwater Vista's parameter estimation routine to get the first approximation. Once the heads in the upper glaciofluvial deposit were close to observed average annual values, the pumping test on MW-107C was simulated and parameters were refined. Next, the head differences observed at vertically-separated nested monitoring wells on the site were used to refine parameters. Then the results of the June and July 2006 pressure transient testing were used to refine the location and hydraulic conductivity of individual sandy (permeable) layers. Finally, a variety of other special simulations were run (see below) to refine parameters in localized areas.

Layer 1 of the model is the most important because most of the leaked mass of radionuclides passed through this layer on its way to discharge in Sherman Reservoir and the Deerfield River. Below layer 1, transport also occurred, but at much lower rates and with much less total mass involved. **Figure 6-6** can also be interpreted as a surficial geology map of the site. Zone 9, in yellow, represents the thin soil and exposed rock on the upland areas; Zone 2, in gray, represents the known areas of thick glacial till; Zones 1 and 3 represent the glaciofluvial deposits along the valley floor. In the following figures, there are changes only in the site area where the results of calibration to various pressure transient events dictated the location and magnitude of the local hydraulic conductivity values.

Average annual recharge distribution for the steady-state operational history modeling is shown in **Figure 6-18** and described more fully in **Table 6-3**. Recharge was applied to the top active layer of the model. There is no published Natural Resources Conservation Service (NRCS) soil map for this area, nor published USGS nor State surficial geology map with any detail. The upland areas (where rock is shallow) and the steep sideslopes are represented by Zone 1 with a very low applied recharge rate. The sand and gravel areas in the valley floor are represented by Zone 2 with a much higher average rate. The valley floor sand and gravel deposits also receive a lot of runoff from the adjacent steep uplands. This runoff seeps into the soil and increases the apparent recharge rate. The application of runoff from upland areas was combined with the recharge rate of the valley floor deposits, rather than attempting to assign a constant flux boundary along the upland edge of the valley floor deposits. The effective average annual recharge rate on the upland areas is significantly lower than would typically be assigned to that soil type, but parameter estimation runs made during calibration essentially dictated the values of the recharge rate that were necessary to match measured average annual heads and vertical gradients. The overall average annual recharge rate for the calibrated model was, however, 5.3% of average annual precipitation (49.1 inches per year), which is reasonable for shallow bedrock and silty glacial till.

During plant operation, the Industrial Area (IA) was primarily impervious area served by catch basins that essentially prevented infiltration in the area shown in **Figure 6-18** as having zero recharge. In the post-demolition state the recharge rates in the industrial area are set at 0.0025 feet per day for most areas, but zero in areas where significant areas of concrete slab have been left in place. The post-demo soil recharge rate for the IA is an estimate based on experience, since not even sieve analyses are available for most of the fill that has been placed on the site as part of soil remediation and final grading. Based on discussions with the site contractor that placed the fill, the fill was silty in nature and is probably a reworked till. Therefore, it is likely to have a lower infiltration capacity than the surrounding glaciofluvial deposits.

6.5 Transient and Solute Transport Parameters

Although transient simulations are not really necessary for long-term fate and transport analysis, a number of transient simulations were performed as part of calibration. Calibration of the model can be greatly refined through attempting to match transient events. Because transient simulations were performed, it was necessary to estimate and then calibrate storativity or storage coefficient and specific yield (Sy). Because of the high topographic relief in the area encompassed by the model, specific storage (Ss) was specified rather than the storage coefficient (specific storage is equal to storage coefficient per foot of aquifer thickness). Specific storage works more accurately with unconfined model layers.

Storativity was initially calculated based on the results of the June MW-107C pumping test, as shown in Table 5-1 of **Reference 1-5.** Simulation of the pumping test resulted in some localized zonation. Some special simulations of response to pressure transient testing, to reservoir fluctuation, to dam tailwater fluctuation, and to response to the on-off cycles of the plant water well were used to refine values locally. **Figures 6-19** through **6-25** show the final zone distribution, and **Table 6-4** describes the values assigned to each zone.

Table 6-4 also shows the porosity of the zones defined on **Figures 6-19** through **6-25**. Porosity of the glacial till was calculated from standard geotechnical equations using the values of specific gravity, water content, and total unit weight in Table 2 of **Reference 2-3**. The porosity of the glaciofluvial deposit of 0.3 was taken from **Reference 6-1**, which states in the Executive Summary that the effective porosity falls in the range of 0.24 to 0.37. The porosity of the bedrock zones was estimated from experience.

Tritium transport simulations required the specification of dispersivity and radioactive half-life. Several ranges of dispersivity values were tried during the initial simulation of transport of the IXP leak to Sherman Spring. The most reasonable spread of the leak in the longitudinal and transverse direction was obtained with the following values: longitudinal dispersivity (D_L) = 10 feet; transverse dispersivity (D_T) = 1 foot; and vertical dispersivity (D_V) = 0.1 foot. The vertical dispersivity was taken from experience as 10% of the transverse dispersivity. These values were applied throughout the entire model domain.

The radioactive half-life of tritium was set at 4540 days, **Reference 1-1**.

Since no fate and transport runs were made with a sorbing solute, it was not necessary to define K_D values that would create a retardation effect.

6.6 Model Calibration and Verification

The calibration of the model was based primarily on a comparison of "observed" and "predicted" heads and on observed versus calculated vertical gradients for the 100-series monitoring wells on a pre-demo, long-term average annual basis. The pumping test on

MW-107C was used to refine values in the vicinity of that well. Some other localized changes were made in response to specialized simulations as described below. A "verification" data set made up on the non-100-series monitoring wells was run with the calibrated model. Although traditional trial-and-error changes of parameters were used in calibrating to local conditions, the initial modeling approach was to use a parameter estimation procedure provided by Groundwater Vistas. Groundwater Vista's parameter estimation procedure employs Marquardt's modification to the Gauss-Newton nonlinear least-squares parameter estimation technique.

The average annual groundwater elevations for each monitoring well were calculated by simply averaging all available hand-measured readings for each well. The length of record and number of measurements varies from well to well. There were no directly applicable USGS long-term monitoring well records available to correlate individual records to average long-term averages. Most of the 100-series wells have been monitored since July 2003, whereas the CB and CW series have been monitored since 1993. As shown in **Figure 6-26**, at least the last two years of precipitation have been somewhat above the long term average at Readsboro, VT (5 miles to the north), of 49.08" per year (p. 6A-8 of Appendix 6-A of **Reference 1-1**). Therefore, the pre-demo calibrated model, which was calibrated with the 100-series monitoring well data sets, may over-predict the heads for the longer term wells, which is what the verification statistics show. The 100-series monitoring wells were chosen for calibration, however, because of the detailed hydrographs available for most of these wells and because multi-level wells exist at each cluster, enabling calibration by vertical gradients.

Calibration residuals (observed values minus predicted values) for the steady-state regional model are calculated by multiplying the difference between observed and predicted head by the weighting factor for each "target" or observation point. Weights for all observed data were assigned as 1.0 since all monitoring wells were accurately surveyed and a reasonable number of data points exist for each monitoring well through time.

The model is highly nonlinear due to the large variability in elevation across the model, thin soil layers over much of the model domain, and the choice of running the model as unconfined. The model would only run using the PCG2 solver (pre-conditioned conjugate gradient method of solving the matrix) with highly damped parameters. Initial solutions that converged required the use of a "rewet" algorithm that is rather crude, but kept the bouncing of predicted head elevations between iterations from causing the model to crash. After obtaining an approximate solution, upland areas of the model were successively turned to no-flow cells where they are predicted to go dry. This damps the solution process further. Eventually the rewet algorithm was turned off and the mass balance error came under control, although not so low as can usually be achieved (see **Table 6-5**). Once a steady-state solution was obtained, the model was run as a transient solution (but with constant recharge and all other conditions constant) for 600 days using the calibrated Ss and Sy and average annual precipitation recharge to further minimize the flow mass balance errors to something on the order of 0.1%.

Chemical mass balance errors for the 20-year tritium fate and transport simulation discussed below were variable by layer, as shown in **Table 6-6**. Most of the layer chemical mass balance errors were in the normal range for this type of simulation. Several layers had very localized high errors in one or two cells near constant heads, but it did not affect the mass distribution in the rest of the model area. The third-order total-variation-diminishing (TVD) scheme was used to solve the advective term with a Courant number of 1, which reduces numerical dispersion and artificial oscillation, but still creates some negative concentrations in upgradient directions. However, all of the Method of Characteristics (MOC) methods produced very large dispersion in the upgradient direction. Although the generalized conjugate gradient solver with full dispersion tensor helps to remove stability constraints on the transport time step size, the maximum time step was still only 0.5 days.

6.6.1 Single Head Calibration

The model was calibrated for steady-state average annual heads and for steady-state average annual vertical gradients. **Table 6-7** and **Figures 6-27** and **6-28** summarize the individual head calibration statistics for the pre-demo steady-state condition. The residual mean is 0.34 feet with a standard deviation of residuals divided by the range of measured heads of 0.065 which is within normal criteria. Two of the largest residual errors were at MW-113C and MW-110D. MW-113C is near the top of the high steep bank near the Deerfield River. That well is located in a grid cell that is 100 feet east-west and 50 feet north-south. Repeated attempts to improve the calibration in that area suggested the need to improve the horizontal cell size discretization, but that was not deemed necessary because of the relative unimportance of this area to the main focus of the model. It has been difficult to calibrate MW-110D. This well is located quite close to the MW-107 cluster and responded to the MW-107C pumping test, but has a measured head about 9 feet lower than MW-107C, E, or F. In order to produce a reasonable connection that permitted the MW-110D well to respond in the right magnitude to pumping in MW-107C, the predicted head is much higher than would be the case if a much more muted connection was simulated. Fortunately, MW-110D is upgradient of the main area of interest in simulating future tritium concentrations.

6.6.2 Vertical Gradient Calibration

Table 6-8 and **Figure 6-29** show the calibration statistics for the pre-demo, vertical gradient predictions under average annual recharge. Vertical gradients are notoriously difficult to match, but the model does a reasonable job in this case. In this highly layered geologic environment, measured vertical head differences were as high as 54.5 feet. The standard deviation of the residuals divided by the range of head differences was 0.096, which is respectable for this model. Measured gradients between the bedrock and the next higher monitoring well show both positive and negative values in the data set. A major objective in the calibration of vertical gradients is to get the direction correct, although the magnitude is often hard to match. As shown on **Table 6-8**, there are 5 pairs where the direction was not simulated correctly: MW-102C to B; MW-106D to B; MW-107B to D; MW-109B to D; and MW-110D to B. With the exception of the MW-109 pair, the other predicted gradients are very close to neutral, at least. It was very difficult to produce upward gradients in the bedrock in this model. It required putting in small high transmissivity zones that led from the upland area into the area of the well of interest. With the lack of data on where these linears might lie, it made such placement speculative. Fortunately, there are no areas of bedrock with high concentrations of tritium that would make it necessary to have a better understanding of the nature of bedrock flow.

6.6.3 Verification Data Set Calibration

A "verification" data set was run with the same model that was used for the pre-demo calibration. The objective of using a verification data set is to test a separate set of points at which heads were measured to see how much the calibrated model was biased by adjusting local parameter values to achieve local head calibration. The more this localized parameter adjustment is needed and done, the less likely the verification data set will achieve good calibration. The verification data set was comprised of wells that were not in the 100-series designations. Many of the wells shown on the calibration statistics table in **Table 6-9** have been monitored since 1993.

Although the verification data set standard deviation of residuals divided by the range of measured heads is 0.084 and in an acceptable range, the residual mean is -4.81 feet, which suggests the model over-predicts the heads (which, as discussed above, may be due in part to differences in recharge over the long term versus the short term with the two calibration data sets). Also, five of the residuals are fairly large: CB-4; CFW-2; CFW-3; CFW-4; and CW-10. CB-4 is in an area where the groundwater gradient on the bank of the River is very large and calibration is made more difficult by large grid cell sizes. CW-10 is in bedrock in an area where no particular attention was paid to bedrock well calibration and, as stated above, bedrock well calibration is difficult at best since less attention has been paid to characterizing the bedrock groundwater regime since it is not important to fate and transport issues at the site. CFW-2, 3, and 4 are in the Southeast Construction Fill Area. No attempt was made to calibrate wells in this area as it was outside of the main area of modeling interest. CFW-3 and CFW-4 are clustered wells with no drilling logs available so the assumed properties of the fill and soil in this area are apparently in error; however, not enough data exist to develop an accurate layering in this fill area. It is apparent from this that the fill is thicker and more permeable than assumed in the model development. Fortunately, in the main area of interest, the area from MW-107 down to Sherman Spring, the residual errors are quite small.

6.6.4 Discussion of Sensitivity Analyses

Even very good calibration of a groundwater model does not mean that all of the properties are correctly spatially defined as there are many combinations of variables that can produce similar point predictions. The sparser the data set, the less unique the solution if it is based on water level matches alone. The systematic variation of individual parameter values above and below the calibrated value gives a good indication of which variables are the most important to the calibration. Sensitivity analyses have been performed on horizontal hydraulic conductivity, vertical hydraulic conductivity, and recharge rates.

Parameter zones were chosen for sensitivity analysis if the zones covered a large area of the model or the zone had multiple site monitoring wells. The sum of squared residuals (SSR) is graphed on the Y-axis as it usually is the most sensitive calibration statistic with the widest range in this type of analysis. The parameter multiplier is given on the X-axis. The parameter multiplier is what is multiplied by the value used in the calibrated model: 1.0 equates to the value used in the calibrated model. Ideally, the SSR would be lowest at a parameter multiplier of 1.0 and be higher for parameter multipliers that would be either higher or lower.

Many of the sensitivity analyses show Type I Sensitivity as defined by ASTM D 5611, meaning that variation of an input causes insignificant changes in calibration residuals as well as the model's conclusions. During the calibration process parameters were modified if Type II Sensitivity was indicated, even though changes may have produced little change in model conclusions. Some of the sensitivity analyses show Type III Sensitivity where variation of an input causes significant changes to both the calibration residuals and to the conclusions derived from the model and parameters were generally modified, unless otherwise noted, to minimize error. Type IV Sensitivity was not formally investigated where the change in calibration residuals is insignificant but the change in the model's conclusions would be significant. However, the extensive trial and error process used to build this model provided the opportunity to try many individual changes and combinations of changes of parameters and Type IV Sensitivity of at least the flow model parameters has been vetted fairly thoroughly.

6.6.4.1 Horizontal Hydraulic Conductivity Sensitivity

The horizontal hydraulic conductivity was simultaneously increased in the same proportion in both the X- and Y-directions. The first eight graphs on **Figure 31** show the sensitivity of Zones 1, 3, 6, 7, 8, 9, 10, and 14. Zones 1, 3, 6, and 9 are the most sensitive to perturbation of the Kxy value. With only a couple of minor exceptions where the parameter is not sensitive to change, the analyses show that a slight change in parameter could improve calibration slightly. Although an important portion of the model has Zone 2 silty till soils, only one of the calibration wells was in this zone. Notice that Zone 6, which is an implied high permeability zone in the valley bottom, is a very sensitive parameter. Although no direct evidence exists for the choice of permeability for Zone 6, the calibration of the model is quite dependent on it having a relatively high permeability.

6.6.4.2 Vertical Hydraulic Conductivity Sensitivity

As often found in regional models, the vertical hydraulic conductivity is not a very sensitive parameter. As shown on **Figure 6-31**, the two most sensitive zones are the deep bedrock and the glaciofluvial deposits, where the model appears to be optimized. For some of the less sensitive zones, there is a suggestion that model calibration could be improved slightly by decreasing the Kz (except for Zone 3), but the effect would be minor and the model has been constrained to normal ranges of ratios between Kxy and Kz.

6.6.4.3 Precipitation Recharge Rate Sensitivity

The next to the last two sensitivity analyses graphs on **Figure 6-31** are focused on the two primary recharge zones. The graphs suggest that Zone 1, over the upland areas of thin soils, is moderately sensitive, but the model seems to have an optimum value. Zone 2 covers the glaciofluvial deposit area and is the area within which the most monitoring wells occur. It is very sensitive to recharge rate, but again, the model appears to be optimized.

6.6.4.4 Drain Conductance Sensitivity

The last sensitivity analysis in **Figure 6-31** is on drain conductance. Notice that the parameter is sensitive, but the parameter used of 100 cubic feet per day per square foot per foot of head difference is very close to optimum. The analysis suggests that one could multiply the parameter by three to get a slightly better fit, which would also allow a slightly higher recharge rate to be used, but this has not been done because of the relatively minor impact on the model.

6.7 Discussion of Various Model Test Runs

The pumping test on MW-107C was simulated early in the model development to assist in defining model parameters in the critical areas of tritium release on the site. Since there was no attempt to recreate the antecedent groundwater positions prior to the start of the pumping test, this does not classify as a calibration. The main interest was to reproduce the general magnitude and range of drawdown as measured in monitoring wells from the pumping of MW-107C. Similarly, a number of model test runs were made to evaluate the capability of the model to reproduce the effects of various pressure transients inferred from the hydrograph analyses. The recharge that occurs during any particular time frame is a complex function of antecedent moisture conditions, temperature conditions, snow cover, rainfall intensity and other factors that were not recreated before each of the specific test runs described in this subsection. The site history over the period 2003-2006 is very complicated in terms of when impervious cover (like asphalt and concrete slabs) was removed from certain areas, when certain drains were created or discontinued, and when certain excavations were created and backfilled. The starting point for all these test runs was the model-predicted average annual heads under pre-demo conditions.

6.7.1 MW-107C Pumping Test Simulation

This complex pumping test and the corrected water levels for each monitoring well are described in **Reference 1-5**. **Figure 6-32** shows the individual graph comparisons of the measured and predicted conditions during a 2.3-day test period that started about half a day before the step drawdown test. The model was not set up to simulate the step drawdown test, but rather the main 24-hour constant rate test. As one can see from the graphs, the "computed" heads all declined during the test period, but not necessarily in response to the pumping test. Starting from a set of initial heads, a transient simulation with small time steps with otherwise steady-state parameters will often produce small adjustments to heads in various model cells. The main thing to look for is the incremental change in the computed curve starting at about 1.2 days.

Although one might not infer it from looking at these graphs, the "computed" response to the pumping test was quite sensitive to the selection and arrangement of permeability and specific storage in the multiple layers of the model in the vicinity of MW-107. Many (meaning on the order of 100) different trial combinations of the parameters were tried to achieve the computer-simulated responses that were in the right order of magnitude of response as shown on these graphs. For those wells that had obvious measured responses such as MW-102A, 107C, 107E, 107F, 110C, and 111C, the computed responses are quite close in magnitude. For the special case of MW-107C, a special correction is needed for estimating the actual drawdown in a well simulated to be pumping in a finite-difference cell in which the drawdown is averaged over the size of the model cell containing the well. The correction formula can be found in **Reference 6-2**. Applying the correction for this particular case, the predicted drawdown would be 8.5 feet in the well itself beyond that predicted for the finite-difference cell. So the corrected computer-simulated drawdown in MW-107C would be 1101.3 feet, which are 3.6 feet more than measured, rather than 4.9 feet less than the measured drawdown shown on **Figure 6-32**.

6.7.2 Simulating the Effect of Plant Well Pumping

Inspection of hydrographs indicated an occasional significant drawdown in some monitoring wells on the site. The hydrographs showed a typical form of well drawdown and recovery. Since there are no water wells within several miles of the site except for the plant well that now serves the ISFSI, the ISFSI well is assumed to be the source of the pressure transient. Information from Cushing & Sons well driller indicates that the well has a five gallon per minute capacity pump. March 17, 2006, monitoring well hydrographs suggested that the well was pumped for 4 hours in the morning. By adjusting the length, depth, and permeability of a bedrock linear extending from the plant well northward through the MW-107 area, the following drawdowns were obtained as part of a 4.2-day simulation:

Mon. Well	Measured head change, ft.	Simulated head change, ft.
Plant Well	No data	7.8
MW-101B	No data	2.1
MW-102B	3.1	1.4
MW-104B	<0.1	.03
MW-105B	0.25	0.2
MW-107B	5.2	1.4

6.7.3 Simulating the Effect of Tailwater Elevation Fluctuation on MW-113C

As shown on Figures 5-22A and 5-22B of **Reference 1-5**, MW-113C rose and fell in concert with Sherman Dam releases, which was translated into rise and fall of tailwater. A crude rating curve was developed for the River cross section below the dam using the traditional Manning formula, which translated documented flow releases in cubic feet per second into river rise and fall. This was further translated into transient elevation changes in the constant heads defined for the River elevation with time steps of one hour, which is the recording interval for flow releases from the dam. The results of the simulation for 4.5 days showed the following results:

Mon. Well	Measured head change, ft.	Simulated head change, ft.
113C	0.8	0.6
106B	0.15	0.25
106D	0.2	0.3
106C	<0.1	0.1

6.7.4 Effect of rise and fall of Sherman Reservoir

Three monitoring wells appeared from the hydrographs to show closely-linked effects of the rise and fall of Sherman Reservoir: MW-108, MW-105, and MW-113C. Transient constant head conditions were defined in Sherman Reservoir to simulate the change in Reservoir elevation in the early morning of March 14, 2006, using a one-hour time step, which is the recording interval for Reservoir elevation. Using a 3-day simulation, the following results were obtained:

Mon. Well	Measured head change, ft.	Simulated head change, ft.
105B	0.1	0.01
108A	no change discernible	0.01
108C	0.5	1.0
113C	no hydrograph	no effect predicted

The last entry in the table for MW-113C is significant because it appears from Figures 5-22A and 5-22B of **Reference 1-5** that when the Reservoir fell 0.4 feet, MW-113C elevation decreased about 0.2 feet. It is not certain, at this time, how that pressure transient is transmitted.

6.7.5 Response to heavy rainfall events

Simulating response to rainfall is a complicated task and usually requires the use of an unsaturated-saturated flow model if the unsaturated zone is much over a few feet thick. However, model runs were made to simulate response to rainfall to gain some insight into the response capabilities of the model and the behavior of the recharge system.

The period 11/20/04 through 12/3/04 was simulated when there were several multi-day heavy precipitation events during a relatively normal pattern of one- to two-foot variation in Sherman Reservoir level. If a daily rainfall event exceeded the average daily recharge rate, then that proportion was used to increase the recharge for that day.

Mon. Well	Measured head change, ft.	Simulated head change, ft.
CB-2	4.5	1.2
CW-6	3.5	1.9
CB-6	1.0	5.2
MW-107B	2.2	16.5
MW-105B	2.8	14.4
MW-105C	2.7	7.3
MW-104B	2.0	4.6

Several things are apparent from the above comparison table. The model over-predicts the bedrock well measured responses. The model shows a very fast response, whereas the measured response is slower and more diffuse. This is undoubtedly due to the lag time between the fall of the precipitation and its infiltration through unsaturated till and bedrock to reach the water table. In the glaciofluvial deposit represented by CW-6 and CB-6, one is overpredicted and one is underpredicted. In the till well in layer 2, CB-2, there is an underprediction. In the layer 3 sand layer represented by MW-105C there is an overprediction. The local infiltration of rainfall depends greatly on thickness of the unsaturated zone, the proximity to natural drainage features or even underground piping that might tend to act as a drain, and local runoff coefficients. Focusing on such micro-detail was beyond the scope of this model, which was more focused on large scale groundwater patterns over long periods of time where local surface variations in infiltration are not so important.

6.8 Groundwater Head Distributions, pre- and post-Demo Conditions

Figures 6-33 through **6-40** show the pre-demo average annual simulated head equipotentials for all of the layers where sand lenses are simulated, plus the two bedrock layers. Since all layers of the model are treated as isotropic in the horizontal plane, flow would be perpendicular to the contours, except where two zones of different permeability were juxtaposed. In this latter case, flowlines are refracted according to Snell's Law in passing from one permeability zone into another. **Figure 6-33** shows the phreatic surface, which is the most important to the transport of the IXP leak between the MW-107 area and Sherman Spring. Notice a very subtle groundwater divide is predicted just north of the MW-104 and MW-105 area and flow from MW-107 is directed generally west-northwestward. The flow pattern is similar but somewhat smoothed in layer 3 as shown on **Figure 6-34**. In **Figure 6-35**, which shows the pattern in layer 5, there is a subtle groundwater divide just north of the MW-107 cluster that keeps most of the flow going west-northwestward from that area. In layers 7, 10, and 12 (**Figures 6-36, -37**, and **-38**) the flow is generally west-northwestward from the MW-107 area in the general direction of Sherman Spring. In the shallow bedrock, as shown in **Figure 6-39**, there is a rotation of the flow direction toward the southwest, westward of the axis of Sherman

Dam. **Figure 6-40** shows the deep bedrock flow pattern throughout the entire model domain. Notice that the model is simulating two general focused discharge areas in the Deerfield River Valley, both of which are at the downstream foot of dams on the River where bedrock linears perpendicular to the River are defined, based on matching bedrock heads in the site area and the estimated water elevation of the Furlon House well.

In the post-demo state, some additional recharge has been added to the model in the industrial area, where in the pre-demo state the recharge was set at zero. Also, some local soil hydraulic conductivities have been changed in the model to reflect the placement of various fill materials in excavations made to remove underground structures, remove contaminated soils, or add a fill extension on the abutment of Sherman Dam. **Figures 6-41** and **6-42** show the new hydraulic conductivity distributions in layers 1 and 2, respectively, of the model. The fill material consists of some onsite soils that were thermally treated for PCB removal, some broken up concrete into pieces smaller than one-foot across, some broken up asphalt, and some fill taken from an offsite borrow pit in what was likely silty glacial till. Of particular interest is the fact that the bottom ten feet of the excavation for soil removal that went below the water table in the Spent Fuel Pool/IXP area was filled with broken concrete, which was then topped by several feet of broken up asphalt before being topped with soil. Therefore, a small zone of high permeability material has been added in layer 2 east of MW-107 to reflect the rubble placement.

Figure 6-43 shows the net drawdown or increase in average annual water table that the model predicts will occur near the top of the water table. Negative numbers indicate that an increase in future water table elevation is predicted. In the industrial area, a water table increase of several feet is anticipated, increasing to the east, due mostly to an increase in recharge capability. One high spot to the northeast of the former VC is due to a combination of the placement of some low permeability fill to extend the Sherman Dam height to the east, and to a change in the elevation of drainage paths in that area. The area to the southwest of the ISFSI is probably due to a change in the specification of the elevation of the drainage ditches in that area.

Figure 6-43A shows the contours of the phreatic surface in the site area in the post-demo state. The head pattern is fairly similar to **Figure 6-33**. A forward particle track beginning at the mid-saturated depth of layer 1 at MW-107 follows a similar course to that shown in **Figure 6-44** (discussed below), but it veers slightly south of Sherman Spring and goes deeper into the ground (as deep as model layer 7) compared with **Figure 6-44**, where the particle stays wholly within model layer 1.

6.9 Specific Fate and Transport Simulations

6.9.1 Reverse Particle Tracking from Sherman Spring

One of the major objectives of the model development was to simulate the 1963 IXP leak and the long-term fate and transport of that leak. The first simulation that was performed after developing the calibrated model was to do a 760-day reverse particle tracking from

Sherman Spring using MODPATH, to see where the particle might have originated. On page 18 of **Reference 1-3** it states that the apparent travel time for the "core" of the plume to travel from MW-107 to Sherman Spring in the glaciofluvial deposit is 760 days. The reverse particle track for 760 days from Sherman Spring is shown on **Figure 6-44** and basically confirms this calculation with the model. Notice the path from MW-107 travels north-northwesterly first toward MW-105, then turns westward to flow to Sherman Spring.

6.9.2 Simulation of the IXP Leak of 1963

Since the SFP/IXP leak was the single most significant release of radioactive water to the groundwater at the site, and since the concentration of tritium was measured in Sherman Spring from December 1965 onward, much of the model development and calibration work was focused on reproducing the record of measured tritium concentration with time at Sherman Spring. The key variables in generating the source term were the time span over which the release occurred, the average radioactive content of tritium in the source, and the rate at which the water was released to the ground. The combination of values that most closely approximated the December 1965 peak concentration measured in Sherman Spring was an average release rate of 1000 cubic feet per day, a tritium source strength of 32,000,000 pCi/L, and a 540-day release period starting March 1963. The timing for the start and stop of the leak is based on plant operating records. The tritium concentration in the ion exchange pit was described in **Reference 6-3** as being in the range of 3.5 to 3.7E7 pCi/L. Based on conversations with YNPS employees, 1000 cubic feet per day is within the possible range. The spill was simulated by using injection wells in the location of MW-107. Since the elevation of the bottom of the Spent Fuel Pool and IXP is below the top of layer 2 of the model where the till starts, the well was defined as spread across both layers and the model was allowed to calculate the split between the layers of how the 1000 cubic feet per day was distributed. The mass balance calculation shows that 998.8 cubic feet per day went into the top layer and 1.2 cubic feet per day went into layer 2.

A model was run to simulate the initial leak followed by 210 days of no leak to get to Dec. 1965 when testing of Sherman Spring began. Then the model simulated 20 years of transport of the tritium that had already been distributed from the leak. **Figure 6-45** shows the simulated concentration of tritium at Sherman Spring compared with the measured concentration of Sherman Spring. There is very good agreement although the curves diverge slightly about 1977. It appears that another source of tritium had developed and was causing a slight rise in concentration for a few years. Plant records indicate that the Spent Fuel Poll Liner was installed between 1978 and 1981 and likely stopped small leaks through hairline cracks in the concrete.

No site-wide groundwater monitoring existed in 1985, so we have used the model to simulate the distribution from the IXP leak for the first 20 years as well as 20 years later in 2005. **Figures 6-46** through **6-50** show the change of tritium concentration with time in various layers of the model. Even at 20 years there was a remainder of the northward bifurcated plume going into Sherman Reservoir in layer 1, although that had dissipated within 40 years. In layer 1 the remaining concentration of tritium at 40 years was in the Deerfield River below Sherman Dam. Notice that the plume in that area had decreased by an order of magnitude over 20 years and had actually withdrawn somewhat northward in the last 20 years rather than migrating downstream.

In layer 3 of the model, where the continuous sand seam was defined for several hundred feet around the MW-107 area, **Figure 47** shows a more extensive presence of tritium than in layer 1 but still an order of magnitude reduction in the downgradient area from 1985 to 2005. The 2005 distribution does not agree with the known concentration of tritium in MW-107C from 2003 onward. It is apparent that other sources of tritium have leaked since the original IXP leak of 1963. In addition, the region around the VC was disturbed during decommissioning, thus releasing more mass of tritium from the unsaturated zone.

Figure 6-48 shows the distributions of tritium in layer 7. With depth, the movement of tritium is simulated to be slower and is less diluted. But the decrease between 2005 and 1985 is still an order of magnitude and the 2005 extent is less than the 1985 extent under the Sherman River.

Figure 6-49 shows the simulated distributions in model layer 14 or the top bedrock layer. As discussed above, the plume turns more southwestward in the bedrock. Again, the tritium concentration reduction in 20 years (from 1985 to 2005) is an order of magnitude and there has been some retreat in the extent of the plume.

Figure 6-50 shows the tritium distribution in the deep bedrock. Notice it has not reached the area under the Sherman River and the concentrations, which are very low in any event, have decreased an order of magnitude in twenty years.

6.9.3 Simulation of Tritium Concentrations in MW-107C in 2006

The complete tritium release history at the site can never be known in detail. However beginning in 2006 with the end of most excavation activity and the extensive groundwater testing program of April 2006, there is a reasonably complete characterization of the tritium in groundwater at the site. The April 2006 tritium concentrations were contoured in three dimensions and reverse-interpolated into the initial concentration matrices of the 15-layer groundwater model. Once the existing distribution of mass was established, the post-demo model was run for two years from 4/26/06. **Figure 6-51** shows a comparison between model-simulated tritium at MW-107C going forward and the measured tritium at MW-107C from April through December 2006. There is a relatively close comparison, although the linear regression line through the measured data suggests there may be a more rapid decrease after 300 days than the model predicts. The MCL concentration of 20,000 pCi/L is predicted to be achieved by early summer 2007 based on the linear regression of the measured samples and February 2008 based on the model simulation. Also shown in **Figure 6-51** is the tritium concentration with radioactive decay as the only attenuation mechanism for tritium. Clearly, processes including advective dispersion and associated mixing and dilution are very important in the fate and transport of tritium at YNPS.

6.9.4 The "Resident Farmer Well" Scenario

The License Termination Plan specifies that compliance with the groundwater quality requirements of the plan is met if the hypothetical "resident farmer" well does not produce water that exceeds the maximum dose specified in the LTP or the EPA MCLs, which for tritium is 20,000 pCi/L. The first issue in testing compliance is to locate the portion of the site that will produce the highest dose to a water well. Based on both the computer simulations and 2006 measurements of groundwater quality at the site, it is clear that the geologic units with the highest dose concentrations exist in the vicinity of MW-107C. The model simulates two years of pumping following April 2007 with a hypothetical "resident farmer" well located at the MW-107C location and pumping continuously at 0.67 gallons per minute as defined in the LTP. MW-107C intercepts layer 3 of the model and, based on the pumping test analysis and computer simulation, there appears to be a relatively low permeability till lying above and below the MW-107C well. For the purposes of this simulation, we further assume that the tritium concentration in those layers is the same in April 2006 as measured in MW-107C at 41,300 pCi/L. **Figure 6-52** shows the results of the simulation.

Initial attempts to simulate the well in just layer 3 or in layers 2, 3, and 4 were unsuccessful. Those layers went "dry" because the pumping rate exceeded the ability of the model to deliver water to a well pumping at 0.67 gallons per minute in those layers. The maximum yield of these three layers is simulated to be 0.035 gallons per minute. When model layer 5 was added (MW-107E and -107F are located in layer 5), the well was successful and layer 5 becomes the dominant water producer. The concentration plots of tritium in layers 2 and 4 of the model (the low permeability till units) lie almost on top of each other. The model predicts that tritium concentrations in all layers would decrease to less than 20,000 pCi/L within 2 years of April 2007. Model layer 3 tritium concentrations would decrease somewhat sooner than the model layers 2 and 4 (glacial till). Layer 5 concentrations would decrease to 5000 pCi/L within the two-year pumping period. There is more dilution and a lower initial concentration in model layer 5, so the rate of decline is slower there.

The concentration of water in the well is simulated for both April 2007 and for April 2009 as shown on **Table 6-10**. Using the model well flux from each layer times the concentration of tritium as predicted, divided by the total pumping rate, yields a weighted average concentration of tritium in the well of 8150 pCi/L in April 2007. In April 2009, the weighted tritium concentration in the well is simulated as 5100 pCi/L.

When model layers 2, 3, 4, and 5 are used to pump at 0.2 gallons per minute, the maximum tritium concentrations in the well are not much different from the **Table 6-10** numbers, which represented 0.67 gallons per minute: 8160 pCi/L in April 2007 and 5350 pCi/L in April 2009.

In summary, the model predicts that if a resident farmer activated his well in April 2007, the maximum tritium concentration in the hypothetical resident farmer's well would be significantly below the MCL.

6.10 Summary

A regional 3-D groundwater flow model based on MODFLOW96, as implemented in Groundwater Vistas GWV4.25, has been constructed to include the Yankee Nuclear Power Station site. This model covers a large area on both sides of the Deerfield River so that the model boundaries are naturally located on streams and groundwater divides far from the nuclear plant site. The finite-difference grid cells are discretized with variable spacing from 25 feet near the center of the plant site to as far apart as 400 feet near the outer limits of the model. The model consists of 15 layers: 13 soil layers and two bedrock layers. The model extends 500 feet into bedrock. All of the top 14 layers of the model were permitted to perform as unconfined layers if the layers above were dewatered by the simulation.

Data sources utilized to parameterize the model came primarily from YNPS records. Some base maps and orthophotos were taken from the State of Massachusetts GIS database, but the only geological data of use from that source was a sand and gravel aquifer map. These sources were pre-processed with Rockworks, Surfer, and ArcView software. Forty-four monitoring wells from 13 well clusters with measured water levels from a variety of depths and geologic units were used as calibration targets for the steady-state pre-demo model. Both single head comparisons and vertical head difference comparisons were used for calibration. A verification data set made up of separate wells was also checked for calibration. Sensitivity analyses were run on the major variables involved with hydraulic conductivity, recharge, and drain conductance, and showed that optimum values were chosen except for several variables for which the calibration error was not sensitive to parameter changes in any event.

The model was tested against the results of the MW-107C pumping test and the results were used to refine the selection of hydraulic conductivity and specific storage parameters. The model simulated the groundwater head effects of pumping of the plant well, of fluctuations in tailwater elevation below Sherman Dam, of Sherman Reservoir elevation fluctuation, and of response to a heavy precipitation event.

The calibration goals were to achieve a standard deviation of residuals (observed versus predicted levels) divided by the range of measured values (highest value minus lowest value) of ≤ 0.15 and to keep the vertical gradients in the right directions. The first goal was achieved in all cases; there were several exceptions to the second goal as explained in detail in the report.

The model was used to verify the direction and time of travel from the IXP to Sherman Spring and then to simulate the May 1963 leak from the IXP and compare measured Sherman Spring tritium concentrations over time with the simulated results. These results are in good agreement. The model has also been used to simulate the change in tritium concentration from April 2006 through December 2006 at MW-107C, again, with good agreement.

With only minor exceptions that do not affect the overall tritium transport analysis from the area of the IXP leak site, the model reproduces well the transport of tritium in the glaciofluvial layer and within several signature sand layers embedded within the thick glacial till under the IA. The model reproduces the magnitude of pressure transient responses to the MW-107C pumping tests and a variety of other pressure transient events. Although groundwater gradients between the bedrock and the next higher monitoring wells at several locations were not faithfully reproduced as to direction, most gradient directions were preserved among the 54 pairs tested.

The tritium transport simulations of the 1963 IXP leak suggest that the plume originally split into two main parts: one moving north to Sherman Reservoir, and one moving west to discharge in the Deerfield River. The portion discharging into the Deerfield River discharged to the River no farther than 1500 feet downstream of the toe of Sherman Dam. Concentrations of tritium decreased in the downstream area by an order of magnitude between the 1985 and 2005 simulations, and the residual center of mass receded upstream. Concentrations in the deep bedrock are simulated to be very low.

Since the 1963 leak, other releases of tritium have occurred on the site and tritium has been released from unsaturated zones under slabs and pavements that have been removed as part of decommissioning. Therefore, although the 40-year simulation of the IXP leak is instructive in terms of showing the long-term fate and transport results of a major leak, the current distribution of tritium on the site cannot be based on assuming that the IXP leak is the only source of current tritium. To simulate results going forward, the comprehensive test results of the late April 2006 sampling were used to establish the distribution of tritium in the model layers at that time and then the model was run for three years to simulate that spread and attenuation.

Knowing that the tritium concentration currently exceeds the EPA MCL at MW-107C, the model was used to evaluate the potential attenuation of tritium in that area, which has been identified as the only portion of the site even close to exceeding LTP dose standards or EPA MCLs. Because the thin sand zone in which MW-107C is located cannot provide more than 5% of the needs of the hypothetical resident farmer well as specified in the LTP, other soil units above and below MW-107C were tried in various combinations that would produce the required well yield, but at the highest dose. This resulted in combining other soil units with lower tritium concentrations but higher flow rates, such that the well concentration would be 8150 pCi/L in April 2007, decreasing to 5100 pCi/L in April 2009. Therefore, a randomly-located resident farmer's well at the site would not produce water in excess of LTP dose limits or EPA MCLs. The model suggests, however, that the highest point concentrations of tritium will not decrease below the EPA MCL of 20,000 pCi/L until about April of 2009. These points are in the glacial till above and below MW-107C. MW-107C is predicted by the model to decrease below the tritium MCL in February 2008, although the current trend based on sampling suggests it may come into compliance about June 2007.

7.0 Conclusions and Recommendations

7.1 Groundwater Quality Status

The LTP groundwater monitoring program at YNPS 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 YNPS provide the data for comparing to standards, regulatory limits, and developing metrics for evaluating overall groundwater quality and plume status at YNPS.

Groundwater contamination by plant-related substances of concern (SOCs) has been observed in the glaciofluvial, glacial till, glaciolacustrine and bedrock aquifers units currently described at the facility. Consistent with the CSM for YNPS, the general configuration of contaminant plumes extends from the area adjacent and immediately downgradient of the former SFP/IXP to the Deerfield River. The mapped plumes are well defined both horizontally and vertically, and based on modeling results presented in **Section 6** and site history, the observed groundwater contamination at the plant appears to have originated from releases of contaminated waters within the SFP/IXP complex.

Tritium is the only radionuclide that is detected in site groundwater, and is broadly distributed across YNPS site. Plant-related tritium concentrations in groundwater have declined substantially in recent years, and only one monitoring well (MW-107C) currently has tritium concentration in excess of the EPA MCL concentration of 20,000 pCi/L.

A statistical trend analysis for tritium was conducted for all monitoring wells included in the YNPS quarterly sampling plan. The results of the trend analysis indicate that most of the monitoring wells are stable and have no trend. Nine monitoring wells (CB-6, MW-101A, MW-105B, MW-106A, MW-107A, MW-107D, MW-107E, MW-110A, and MW-111) and Sherman Spring have defined downward trends, and one monitoring well (MW-110C) has an upward trend. The monitoring well with the identified upward trend (MW-110C) had tritium concentrations ranging from 1,160 pCi/L in Q1 2006 to 2,590 pCi/L in Q4 2006, well below the 20,000 pCi/L MCL.

7.2 Evaluation of LTP Closure Criteria

The LTP requirement for closure is 25 mrem/yr dose rate for all media and pathways. That is further refined to contributions from soil, concrete debris, subsurface partial structures, and groundwater, based on the media-specific Derived Concentration Guideline Level (DCGLs). The results of groundwater testing have demonstrated that tritium is the only radionuclide consistently detected at the YNPS site. Since tritium is the only target radionuclide consistently detected in groundwater YNPS, DCGLs were not specifically developed for tritium or other radionuclides in groundwater. To evaluate a DCGL for tritium, YNPS used the approved groundwater DCGL from the Connecticut

Yankee LTP to calculate the dose rate that tritium would generate at the MCL (20,000 pCi/L), and used that dose rate (0.77 mrem/yr) to establish the total dose rate for groundwater.

While DCGLs for other radionuclides were not developed by YAEC for the YNPS site, NRC License Amendment No. 158 identified specific threshold concentrations of site-generated radionuclides. If the threshold values are exceeded or if a sum of the fractions formed by dividing the detected concentration by the threshold value is greater than 2.0, YAEC would be required to evaluate the need for site-specific groundwater DCGLs. These NRC threshold values are summarized in **Table 3-1**.

In addition to the tritium dose rate developed in the LTP and the threshold values identified in NRC Amendment 158, YNPS has also committed to meeting the EPA MCLs for available well water that meets the resident farmer scenario. As summarized in Table 9-1 of Appendix 6A of the YNPS LTP, the water use for the resident farmer scenario on a yearly basis is estimated to range from 957 to 1,689 cubic meters per year with a calculated median value of 1323 cubic meters per year (**Reference 1-1**). The median value of 1,323 cubic meters per year corresponds to a well pumping rate of 0.665 gallons per minute (gpm). Thus, for a water supply well to be able to meet the resident farmer scenario, the well will be required to be pumped constantly, delivering water at a minimum rate of 0.665 gpm.

In addition to comparing the 2006 quarterly groundwater data to the MCLs for the resident farmer and NRC threshold values, time series plots were generated for tritium, and trend analysis was conducted. Results of the tritium trend analyses meet the LTP termination requirements if the trends are steady state or decreasing at the end of the monitoring period, and below the respective NRC threshold limits. Trends were evaluated using recognized industry standard statistical analyses.

None of the NRC threshold values were exceeded during Q1 through Q4 2006, as the only radionuclide detected in site groundwater was tritium. Tritium concentrations are below the MCL in all monitoring wells except MW-107C. MW-107C has had decreasing values during 2006 and has a statistically determined downward trend with concentrations decreasing from 41,300 pCi/L in Q1 2006 to 29,100 pCi/L in Q4 2006. All other monitoring wells in the monitoring program have either stable or no trend or downward trends, except for MW-110C. The tritium concentration in MW-110C increased from 1,160 pCi/L in Q1 2006 to 2,590 pCi/L in Q4 2006. The tritium concentrations are an order of magnitude below the tritium MCL of 20,000 pCi/L and significant increases are not expected in this portion of the site. MW-110C is downgradient of the former SFP/IXP area where significant soil remediation was conducted, and all other monitoring wells in this portion of the site have stable or decreasing trends.

Recognizing that the tritium concentration currently exceeds the EPA MCL at MW-107C, a three-dimensional groundwater model was used to evaluate the potential attenuation of tritium in that area, which has been identified as the only portion of the site even close to exceeding LTP dose standards or EPA MCLs. Because the thin sand zone in which MW-107C is located is incapable of supplying the needs of the hypothetical resident farmer well as specified in the LTP, other soil units above and below MW-107C were tried in various combinations that would produce the required well yield, but at the highest dose. This resulted in combining other soil units with lower tritium concentrations but higher flow rates, such that the well concentration would be 8,150 pCi/L in April 2007, decreasing to 5,100 pCi/L in April 2009. Therefore, we conclude that a randomly-located resident farmer's well at the site would not produce water in excess of LTP dose limits or EPA MCLs. The model suggests, however, that the highest point concentrations of tritium (in glacial till above and below the sand seam in which MW-107C is located) will not decrease below the EPA MCL of 20,000 pCi/L until about April of 2009. In the absence of any pumping, MW-107C is predicted by the model to decrease below the tritium MCL in February 2008, although the current trend based on sampling suggests it may come into compliance about June 2007.

Based on the groundwater sampling and model results, site groundwater meets the LTP closure requirements for License Termination.

7.3 Subsequent Sampling Recommendations

Based on the review of the results of Q1 through Q4 2006, quarterly sampling and observed long-term trends in wells, several recommendations concerning subsequent groundwater monitoring sampling events are as follows:

- Conduct one additional sampling round in the first quarter 2007 to confirm the tritium plume distribution and trend analysis developed in Q1 through Q4 2006

- The recommended analytical suite for the upcoming first quarter 2007 quarterly sampling event can be reduced and focused on those wells with high concentrations of tritium and increasing trends: MW-101A; MW102D; MW-105B; MW-106A; MW-107A; MW-107C; MW-107D; MW-107E; MW-107F; MW-110C; MW-111C; and MW-113C.

8.0 Acronyms

CSM	Conceptual Site Model
DCGL	Derived Concentration Guideline Level
DI	De-ionized
DOE	Department of Energy
EPA	Environmental Protection Agency
FDR	Field Daily Reports
FSS	Final Status Survey
GEL	General Engineering Laboratory
GWV	Groundwater Vistas
HTD	Hard-to-detect
IA	Industrial Area
ISFSI	Independent Spent Fuel Storage Installation
IXP	Ion Exchange Pit
Kd	Soil-water partition coefficient
LSP	Licensed Site Professional
LTP	License Termination Plan
MADEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
MDC	Minimum Detection Concentration
MDL	Method Detection Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
MSL	Mean Sea Level
NAVD	North American Vertical Datum
NRC	Nuclear Regulatory Commission
NTU	Nephelometric Turbidity Unit
pCi/L	picocurie per liter
QAPP	Quality Assurance Project Plan

QA/QC	Quality Assurance/Quality Control
Q1	First quarter water sampling period (April 18 to May 3, 2006)
Q2	Second quarter water sampling period (June 26 to July 12, 2006)
Q3	Third quarter water sampling period (September 12 to September 21, 2006)
Q4	Fourth quarter water sampling period (December 4 to December 14, 2006)
SCFA	Southeast Construction Fill Area
SFP	Spent Fuel Pool
SOC	Substance of Concern
SOP	Standard Operation Procedure
SSR	sum of squared residuals
TEDE	Total Effective Dose Equivalent
TVD	total-variation-diminishing
μg/L	microgram per Liter
USEPA	United States Environmental Protection Agency
USGS	US Geological Survey
VC	Vapor Containment
YAEC	Yankee Atomic Electric Company
YNPS	Yankee Nuclear Power Station

9.0 References

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Reference 1-2 Yankee Atomic Electric Company, *Site Ground Water Data Collection for YNPS Decommissioning*, DESD-TD-YR-02-001, Rev 1, February 3, 2003.

Reference 1-3 Yankee Atomic Electric Company, *Hydrogeologic Report of 2003 Supplemental Investigation*, YA-REPT-00-004-04, March 15, 2004.

Reference 1-4 Yankee Atomic Electric Company, *Report of Continuing Hydrogeologic Investigations in 2004*, YA-REPT-00-010-05, April 14, 2005.

Reference 1-5 Yankee Atomic Electric Company, *2006 Interim Groundwater Report*, BYR 2006-112, 2006, November 28, 2006.

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Reference 1-7 Yankee Atomic Electric Company, AP-9601, Rev. 3; Site Characterization and Site Release Quality Assurance Program Plan (QAPP) for Sample Data Quality, April 2006.

Reference 1-8 Yankee Atomic Electric Company, AP-8601, Rev 4; Ground and Well Water Monitoring Program for the Yankee Nuclear Power Station Site, October 2003.

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Reference 3-1 YA-REPT-00-007-06, Data Assessment Report for Groundwater Sampling at YNPS January/February 2006.

Reference 3-2 YA-REPT-00-013-06, First Quarter 2006 Groundwater Report.

Reference 3-3 YA-REPT-00-014-06, Special Tritium Sampling Event, May 2006.

Reference 3-4 YA-REPT-00-017-06, Re-Analysis of 1st Quarter 2006 Samples for Tritium, Nickel-63 and Carbon-14.

Reference 3-5 YA-REPT-00-019-06, 2nd Quarter 2006 Groundwater Report.

Reference 3-6 YA-REPT-00-025-06, 3rd Quarter 2006 Groundwater Report.

Reference 3-7 YA-REPT-00-026-06, 4th Quarter 2006 Groundwater Report.

Reference 4-1 YA-REPT-00-016-04, Assessment of Boron Concentration in Groundwater at YNPS.

Reference 4-2 United States Environmental Protection Agency, 1999, *Understanding Variation in Partition Coefficient, Kd, Values, Volume II; Review of Geochemistry and Available Kd Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium and Uranium*, EPA 402-R-99-004B, August 1999.

Reference 5-1 YA-REPT-00-013-04, *Interim Groundwater Monitoring Report for Yankee Nuclear Power Station*, September, 2004.

Reference 5-2 YA-REPT-00-004-06, *Summary Groundwater Report for the Yankee Nuclear Power Station – 2005.*

Reference 6-1 YA-REPT-01-008-03, 2003, *Evaluation of GeoTesting Express Soil Testing and Determination of Depth to Ground Water.*

Reference 6-2 Rushton, K.R., and Redshaw, S.C., 1979, *Seepage and Groundwater Flow.* John Wiley & Sons.

Reference 6-3 Yankee Atomic Electric Company, 1965, Operation Report No. 51 for the Month of March 1965, a report for Yankee Nuclear Power Station submitted on April 27, 1965.

Table 1-1
Summary of Monitoring Well Completion Details

Well ID	Date Completed	Total Depth Drilled (feet)	Well Screen Length (feet)	Well Screen Interval (ft bg)	Geologic Unit at Screen Interval	Screen Sand Pack Interval (ft bg)	Diameter of Sand Pack (inches)	Bentonite Seal Interval (ft bg)	Cement Grout Seal Interval (ft bg)	Well Inside Dia. (in.)	Well Wall (PVC)	Well Screen Slot Size (in.)	8-Inch Steel Casing Interval (ft bg)
CB-3	29-Apr-93	15	10	3 to 10	GF	3 to 15	5.000	2 to 3	0 to 2	2.25	Schd 40	I/U	N/A
CB-3R	29-Aug-06	16	10	6 to 16	GF	4 to 16	5.500	2.5 to 4	0 to 2.5	2.00	Schd 40	0.010	0 to 6*
CB-4	5-May-93	19	10	9 to 19	GF	8 to 20	5.000	7 to 8	0 to 7	2.25	Schd 40	I/U	N/A
CB-6	13-Sep-94	25	10	15 to 25	GF/UT	14 to 26	5.000	12 to 14	0 to 12	2.25	Schd 40	I/U	N/A
CB-8	20-Sep-94	19	5	14 to 19	GF	13 to 19	5.000	11.5 to 13	0 to 11.5	2.25	Schd 40	I/U	N/A
CW-10	8-Jun-98	30	15	15 to 30	Bedrock	14 to 30.5	4.000	13 to 14	0 to 13	2.00	Schd 40	0.010	N/A
CFW-1	13-Dec-99	8	5	3 to 8	GF	2 to 8	4.000	1 to 2	0 to 1	2.00	Schd 40	0.010	N/A
CFW-5	14-Dec-99	5	5	1 to 5	GF	0.5 to 5	5.000	0 to 0.5	1 to 0	2.00	Schd 40	0.010	N/A
CFW-6	14-Dec-99	6	5	1 to 6	GF	0.5 to 6	5.000	0 to 0.5	0.5 to 0	2.00	Schd 40	0.010	N/A
CW-5R	30-Aug-06	17	10	7 to 17	GF	6 to 17	5.500	4 to 6	0 to 4	2.00	Schd 40	0.010	0 to 7*
MW-100A	5-Aug-03	20	10	10 to 20	GF	8.3 to 20	5.500	6.0 to 8.3	0 to 6.0	2.00	Schd 40	0.010	N/A
MW-100B	4-Aug-03	43	10	32.9 to 42.9	Bedrock	31.0 to 43	4.625	28.0 to 31.0	0 to 28.0	2.00	Schd 40	0.010	N/A
MW-101A	11-Apr-06	23.5	5	18 to 23	GF/Fill	16 to 23.5	5.500	13 to 16	0 to 13	2.00	Schd 40	0.010	0 to 10*
MW-101B	13-Aug-03	156	10	142 to 152	Bedrock	140.2 to 156	4.625	138.5 to 140.2	0 to 138.5	2.25	Schd 80	0.010	0 to 11.25
MW-101C	15-Aug-03	99	5	94 to 99	LT-GL	92.1 to 99	5.500	90.0 to 92.1	0 to 90.0	2.00	Schd 40	0.010	0 to 15.3
MW-102A	31-Jul-03	39	5	33 to 38	UT	31.0 to 39	5.500	29.0 to 31.0	0 to 29.0	2.00	Schd 40	0.010	N/A
MW-102B	24-Jul-03	131.5	10	120.2 to 130.2	Bedrock	117.9 to 131.5	4.625	116.0 to 117.9	0 to 116.0	2.00	Schd 40	0.010	0 to 15
MW-102C	29-Jul-03	99	5	94 to 99	LT-GL	92.4 to 99	5.500	90.8 to 92.4	0 to 90.8	2.00	Schd 40	0.010	0 to 14.5
MW-102D	10-Feb-06	22	10	11 to 21	GF	9 to 22	5.500	7 to 9	0 to 7	2.00	Schd 40	0.010	0 to 8
MW-103A	17-Jul-03	26	10	15 to 25	GF	13 to 26	5.500	11 to 13	0 to 11	2.00	Schd 40	0.010	N/A
MW-103B	10-Jul-03	295	10	284.5 to 294.5	Bedrock	282 to 295	4.625	279 to 282	0 to 279	2.25	Schd 80	0.010	0 to 30
MW-103C	16-Jul-03	125	10	115 to 125	LT-GL	112.3 to 125	5.500	110.5 to 112.3	0 to 110.5	2.00	Schd 40	0.010	N/A
MW-104A	6-Feb-06	27	10	10 to 20	GF	8 to 20	5.500	6 to 8	0 to 6	2.00	Schd 40	0.010	0 to 10
MW-104B	3-Sep-03	194.5	10	184 to 194	Bedrock	182 to 194.5	5.5: 182' to 187' 4.625: 187' to 194.5'	180 to 182	0 to 180	2.25	Schd 80	0.010	0 to 25
MW-104C	11-Sep-03	99	10	87 to 97	LT-GL	84.8 to 99	7.625	82.8 to 84.8	0 to 82.8	2.25	Schd 80	0.010	N/A
MW-104D	8-Sep-06	50	5	40 to 45	UT	38 to 46.5	5.500	35 to 38	0 to 35	2.00	Schd 40	0.010	0 to 25.5*
MW-105A	8-Feb-06	25	10	10 to 20	GF	8 to 20	5.500	6 to 8	0 to 6	2.00	Schd 40	0.010	0 to 8
MW-105B	20-Aug-03	75	10	64 to 74	Bedrock	61.8 to 75	4.625	59.6 to 61.8	0 to 59.6	2.00	Schd 40	0.010	0 to 25
MW-105C	21-Aug-03	45	10	27 to 37	UT	25.1 to 37	5.500	23.1 to 25.1	0 to 23.1	2.00	Schd 40	0.010	N/A
MW-106A	30-Aug-04	22	10	12 to 22	GF	9.5 to 22	7.625	7.5 to 9.5	0 to 7.5	2.00	Schd 40	0.010	N/A

Table 1-1
Summary of Monitoring Well Completion Details

Well ID	Date Completed	Total Depth Drilled (feet)	Well Screen Length (feet)	Well Screen Interval (ft bg)	Geologic Unit at Screen Interval	Screen Sand Pack Interval (ft bg)	Diameter of Sand Pack (inches)	Bentonite Seal Interval (ft bg)	Cement Grout Seal Interval (ft bg)	Well Inside Dia. (in.)	Well Wall (PVC)	Well Screen Slot Size (in.)	8-inch Steel Casing Interval (ft bg)
MW-106B	27-Aug-04	265	10	251 to 261	Bedrock	249 to 265	4.625	230 to 249	0 to 230	2.25	Schd 80	0.010	N/A
MW-106C	8-Sep-04	95	5	90 to 95	UT	86.5 to 95	5.500	80 to 86.5	0 to 80	2.00	Schd 40	0.010	0 to 25
MW-106D	14-Sep-04	155	10	144 to 154	LT-GL	142 to 154	5.500	132 to 142	0 to 132	2.25	Schd 80	0.010	0 to 25
MW-107A	5-Apr-06	30	5	21 to 26	GF	19 to 26	5.500	16 to 19	0 to 16	2.00	Schd 40	0.010	0 to 9
MW-107B	17-Sep-03	110	10	99.7 to 109.7	Bedrock	97.8 to 109.7	4.625	96.0 to 97.8	0 to 96.0	2.25	Schd 80	0.010	0 to 12.5
MW-107C	19-Sep-03	32	5	27 to 32	UT	25 to 32	5.500	23 to 25	0 to 23	2.00	Schd 40	0.010	N/A
MW-107D	24-Sep-03	81.2	5	75 to 80	LT-GL	73 to 81.2	5.500	71.1 to 73	0 to 71.1	2.00	Schd 40	0.010	N/A
MW-107E	15-May-06	70	5	52 to 57	UT	50 to 59	5.500	46 to 50	0 to 46	2.00	Schd 40	0.010	0 to 32
MW-107F	23-May-O6	57	5	49 to 54	UT	47 to 55	5.500	40.5 to 47	0 to 40.5	2.00	Schd 40	0.010	0 to 25
MW-108A	17-Jul-04	25	10	14.7 to 24.7	GF	10 to 25	5.500	6.1 to 10	0 to 6.1	2.00	Schd 40	0.010	N/A
MW-108B	16-Jul-04	215	10	205 to 215	Bedrock	202.5 to 215	5.500	197.5 to 202.5	0 to 197.5	2.25	Schd 80	0.010	0 to 26
MW-108C	8-Jul-04	170	5	60 to 65	UT	57 to 67	7.625	51-57&67-170	0 to 51	2.00	Schd 40	0.010	0 to 26
MW-109A	3-Feb-06	20	10	10 to 20	GF	8 to 20	5.500	4 to 8	0 to 4	2.00	Schd 40	0.010	0 to 8
MW-109B	2-Aug-04	190	10	180 to 190	Bedrock	177.5 to 190	4.625	175.5 to 177.5	0 to 175.5	2.25	Schd 80	0.010	0 to 20
MW-109C	9-Aug-04	55	5	49 to 54	UT	46.8 to 55	5.500	42.5 to 46.8	0 to 42.5	2.00	Schd 40	0.010	N/A
MW-109D	6-Aug-04	113	5	88.7 to 93.7	LT-GL	86 to 95	5.500	83-86&95-113	0 to 83	2.00	Schd 40	0.010	0 to 21
MW-110A	16-Feb-06	31	5	25 to 30	GF	22 to 31	5.500	17 to 22	0 to 17	2.00	Schd 40	0.010	0 to 10
MW-110B	6-Mar-06	110	10	100 to 110	Bedrock	98 to 110	4.625	93 to 98	0 to 93	2.00	Schd 40	0.010	0 to 38
MW-110C	20-Mar-06	51	5	46 to 51	UT	44 to 51	5.500	38 to 44	0 to 38	2.00	Schd 40	0.010	0 to 38
MW-110D	17-Mar-06	88	5	83 to 88	LT-GL	81 to 88	5.500	75 to 81	0 to 75	2.00	Schd 40	0.010	0 to 33
MW-111A	30-Mar-06	23	5	18 to 23	GF	15.5 to 23	7.625	12 to 15.5	0 to 12	2.00	Schd 40	0.010	0 to 8
MW-111B	28-Mar-06	80	10	70 to 80	Bedrock	67 to 80	4.625	62 to 67	0 to 62	2.00	Schd 40	0.010	0 to 30
MW-111C	31-Mar-06	41	5	32 to 37	UT	30 to 37	5.500	26 to 30	0 to 26	2.00	Schd 40	0.010	0 to 29
MW-112A	30-Aug-06	24	10	13 to 23	GF	10 to 23	5.500	8 to 10	0 to 8	2.00	Schd 40	0.010	0 to 8.5*
MW-113A	27-Apr-06	25	10	15 to 25	GF	13 to 25	5.500	7.5 to13	0 to 7.5	2.00	Schd 40	0.010	0 to 8
MW-113C	26-Apr-06	140	10	127 to 137	UT	125 to 137	5.500	120 to 125	0 to 120	2.00	Schd 40	0.010	0 to 30
MW-6R	29-Aug-06	20	10	8 to 18	GF	6.7 to 20	5.500	4.5 to 6.7	0 to 4.5	2.00	Schd 40	0.010	0 to 8*

* = 6-inch diameter steel casing

Notes: ft bg=feet below grade; N/A=not applicable; Schd=schedule; all wells completed with # 0 (medium) sand pack

GF = Glaciofluvial stratified sand and gravel; UT = upper Till, including sand seams; LT-GL = lower Till and Glaciolacustrine, including sand seams

Table 1-2
History of Surveyed Locations of Monitoring Wells

Well Number	date installed	Elevation Top Casing (earlier survey)	Elevation Ground (earlier survey)	Elevation Top PVC (2003 survey)	Elevation Top Casing (2003 survey)	Elevation Ground (2003 survey)	Northing (2003 survey)	Easting (2003 survey)
CB-1	27-Apr-93		1126.80	1128.63	1128.63	1127.0	3093618.64	272442.49
CB-2	21-Apr-93		1119.87	1118.07	1118.47	1118.5	3093716.68	272148.03
CB-3	29-Apr-93		1139.97	1138.62	1138.76	1138.8	3093282.03	272493.16
CB-3R	28-Aug-06							
CB-4	05-May-93	1087.21	1084.5	1085.61	1085.86	1084.1	3093627.45	271469.90
CB-5	04-Sep-94	1179.88	1176.1	1181.38	1181.49	1177.7	3093260.51	273112.20
CB-6	13-Sep-94	1113.79	1110.6	1112.06	1112.36	1110.1	3093781.64	272014.04
CB-7	07-Jan-97		1141.34	1139.73	1139.93	1139.9	3093398.20	272485.16
CB-8	20-Sep-94		1140.83	1139.14	1139.67	1139.6	3093424.39	272609.39
CB-9	19-Sep-94		1126.84	1124.69	1125.04	1125.0	3093562.03	272371.46
CB-10	19-Dec-97		1126.7	1126.70				
CB-11A	18-Dec-97	1129	1126	1129.00				
CB-12	10-Dec-97		1134.3	1134.20				
CW-1								
CW-2	29-Apr-93		1138.57	1136.87	1137.28	1137.3	3093387.17	272388.70
CW-3	03-May-93		1140.20	1138.38	1138.91	1138.9	3093532.13	272534.79
CW-4	04-May-93		1141.17	1139.13	1139.78	1139.8	3093367.75	272594.72
CW-5	27-Apr-93		1126.70	1124.92	1125.27	1125.3	3093690.69	272518.16
CW-5R	30-Aug-06							
CW-6	23-Apr-93		1124.44	1122.25	1122.93	1123.0	3093596.29	272151.81
CW-7	13-Sep-94		1127.89	1126.16	1126.41	1126.4	3093769.82	272368.55
CW-8	14-Sep-94		1128.25	1126.49	1126.74	1126.7	3093660.04	272231.20
CW-9								
CW-10	08-Jun-98		1120	1124.53	1124.79	1124.8	3093880.19	272659.52
CW-11	11-Jun-98		1128.5	1128.20				
MW-1	24-Apr-98		1140	1138.48	1138.88	1138.9	3093490.37	272484.97
MW-2 (metal)	24-Apr-98		1126	1125.97	1126.19	1126.2	3093492.13	272419.48
MW-3	24-Apr-98					1126.8		
MW-5	13-Oct-99			1126.70				
MW-6	14-Oct-99			1125.30	1127.10	1127.1	3093483.72	272280.07
MW-6R	28-Aug-06							
MW-100A	05-Aug-03			1125.10	1126.05		3093668.12	272489.61
MW-100B	04-Aug-03			1125.06	1126.12		3093665.06	272485.23
MW-101A*	11-May-06							
MW-101B	13-Aug-03			1125.68	1125.93	1125.9	3093485.38	272378.68
MW-101C	15-Aug-03			1125.43	1125.73	1125.7	3093487.09	272384.30
MW-102A	31-Jul-03			1125.62	1125.82	1125.8	3093576.50	272336.98
MW-102B	24-Jul-03			1125.67	1125.87	1125.9	3093573.63	272333.70
MW-102C	29-Jul-03			1125.55	1125.88	1125.9	3093570.88	272329.77
MW-102D*	10-Feb-06							

Table 1-2
History of Surveyed Locations of Monitoring Wells

Well Number	date installed	Elevation Top Casing (earlier survey)	Elevation Ground (earlier survey)	Elevation Top PVC (2003 survey)	Elevation Top Casing (2003 survey)	Elevation Ground (2003 survey)	Northing (2003 survey)	Easting (2003 survey)
MW-103A	17-Jul-03			1110.65	1110.91	1110.9	3093581.71	271903.99
MW-103B	10-Jul-03			1110.92	1111.10	1111.1	3093584.34	271907.73
MW-103C	16-Jul-03			1110.59	1110.71	1110.7	3093579.00	271899.45
MW-104A*	06-Feb-06							
MW-104B	03-Sep-03			1117.75	1118.36	1118.4	3093729.75	272165.65
MW-104C	11-Sep-03			1118.17	1118.47	1118.5	3093726.18	272161.38
MW-104D	06-Sep-06							
MW-105A*	08-Feb-06							
MW-105B	20-Aug-03			1126.29	1126.52	1126.5	3093767.39	272372.83
MW-105C	21-Aug-03			1126.22	1126.48	1126.5	3093768.04	272367.91
MW-106A	30-Aug-04			1088.49	1088.91	1089.2	3093817.60	271790.77
MW-106B	27-Aug-04			1088.14	1088.92	1088.9	3093826.45	271815.71
MW-106C	08-Sep-04			1088.30	1088.72	1089.0	3093824.14	271808.43
MW-106D	14-Sep-04			1088.66	1088.89	1089.1	3093820.82	271799.26
MW-107A	05-May-06							
MW-107B	17-Sep-03			1124.58	1124.93	1124.9	3093574.41	272399.33
MW-107C	19-Sep-03			1124.65	1125.00	1125.0	3093577.56	272396.49
MW-107D	24-Sep-03			1124.68	1125.03	1125.0	3093573.59	272391.42
MW-107E*	15-May-06							
MW-107F*	23-May-06							
MW-108A	17-Jul-04			1118.00	1118.40	1118.4	3093961.35	272329.51
MW-108B	16-Jul-04			1118.18	1118.52	1118.5	3093955.34	272329.93
MW-108C	08-Jul-04			1118.26	1118.68	1118.7	3093947.82	272330.90
MW-109A*	03-Feb-06							
MW-109B	02-Aug-04			1123.70	1124.56	1124.6	3093544.64	272197.46
MW-109C	09-Aug-04			1123.40	1124.20	1124.2	3093559.34	272187.60
MW-109D	06-Aug-04			1123.38	1124.18	1124.2	3093552.59	272192.18
MW-110A*	16-Feb-06							
MW-110B*	06-Mar-06							
MW-110C*	20-Mar-06							
MW-110D*	17-Mar-06							
MW-111A*	30-Mar-06							
MW-111B*	28-Mar-06							
MW-111C*	31-Mar-06							
MW-112A	29-Aug-06							
MW-112								
MW-113A*	27-Apr-06							

Table 1-2
History of Surveyed Locations of Monitoring Wells

Well Number	date installed	Elevation Top Casing (earlier survey)	Elevation Ground (earlier survey)	Elevation Top PVC (2003 survey)	Elevation Top Casing (2003 survey)	Elevation Ground (2003 survey)	Northing (2003 survey)	Easting (2003 survey)
MW-113C*	26-Apr-06							
CFW-1	13-Dec-99	1169.59	1167.4	1168.69	1169.59	1167.2	3093089.35	272941.07
CFW-2	15-Dec-99	1178.60	1175.3	1178.34	1178.60	1175.9	3093361.45	273029.58
CFW-3	15-Dec-99	1182.90	1179.2	1182.83	1182.90	1179.4	3093430.26	273120.86
CFW-4	13-Dec-99	1181.80	177.3	1181.77	1181.80	1177.6	3093431.19	273125.08
CFW-5	14-Dec-99	1144.57	1140.8	1143.93	1144.57	1140.9	3093499.54	273242.27
CFW-6	14-Dec-99	1140.40	1136.8	1140.07	1140.40	1137.0	3093653.22	273170.03
CFW-7	03-Aug-01	1180.78	1177.2	1180.58	1180.78	1177.4	3093400.13	273079.10
OSR-1	22-Oct-97		1158.2	1159.73	1159.98	1158.2	3093245.82	272938.97
NSR-1	22-Oct-97		1120					
MW-no#				1159.73	1159.98	1158.2	3093245.82	272938.97
SG-1				1161.75		1159.3	3093217.67	272958.34
SG-3				1158.57	1158.94	1156.7	3093223.63	272883.52
SG-4				1160.96	1161.23	1158.1	3093238.88	272905.47
SG-5				1163.42	1163.67	1161.6	3093183.35	272959.81
SG-6				1161.55	1161.70	1158.7	3093206.85	272930.54
IP-1	30-Jan-97		1156				3093158.40	272736.30
Sherman Spring		1047.22				1091.0	3093796.22	271934.92
12" CMP Invert Sherman Spring Sample Point						1045.5	3093977.22	271739.42
Plant SupplyWell					1178.32	1175.60	3092867.76	272528.20
Furlon House Well						1183.1	3091285.14	270022.69
Elevations in green are top of steel casing--used to calculate 2004 quarterly levels								
MSL datum is 105.66 feet above plant datum (NEP)								
*** On Service Bldg Slab								
Coordinates are referenced to NAD 83								
Elevations are referenced to NAVD 1988								
Depths in red are pre-fill depths with corresponding pre-fill screened intervals								
+change 4/6/06								
102B & 102C were switched in first 2006 survey								

Table 1-2
History of Surveyed Locations of Monitoring Wells

Well Number	Elevation Top PVC (*Winter* 2006 survey)	Elevation Top Casing (*Winter* 2006 survey)	Elevation Ground (*Winter* 2006 survey)	*Northing* (Winter 2006 survey)	*Easting* (Winter 2006 survey)	Elevation Top PVC (*Summer* 2006 survey)	Elevation Top Casing (*Summer* 2006 survey)	Elevation Ground (*Summer* 2006 survey)	*Northing* (Summer 2006 survey)	*Easting* (Summer 2006 survey)
CB-1										
CB-2										
CB-3										
CB-3R										
CB-4										
CB-5										
CB-6										
CB-7										
CB-8										
CB-9										
CB-10										
CB-11A										
CB-12										
CW-1										
CW-2	1144.25	1144.39	1136.7	3093387.47	272388.51					
CW-3										
CW-4										
CW-5										
CW-5R										
CW-6										
CW-7										
CW-8										
CW-9										
CW-10	1128.71	1128.85	1124.4	3093880.33	272659.75					
CW-11										
MW-1										
MW-2 (metal)										
MW-3										
MW-5										
MW-6										
MW-6R										
MW-100A	1134.48	1134.95	1131.4	3093668.49	272490.28	1139.94+	1140.84+	1131.4+	3093668.7+	272490.23+
MW-100B	1134.07	1134.27	1131.4	3093666.10	272485.70	1139.33+	1140.4+	1131.4+	3093666.67+	272486.3+
MW-101A*	1146.13	1146.23	1138.0	3093489.73	272378.09					
MW-101B	1145.52	1146.07	1137.3	3093486.75	272384.57					
MW-101C	1145.78	1146.37	1137.3	3093484.74	272378.25					
MW-102A	1139.28	1139.75	1133.8	3093570.92	272329.95					
MW-102B	1139.82	1140.41	1133.8	3093573.61	272333.84	1139.12	1140.41	1133.80	3093575.98	272336.91
MW-102C	1139.12	1139.49	1133.8	3093575.98	272336.91	1139.82	1139.49	1133.80	3093573.61	272333.84
MW-102D*	1141.91	1142.07	1133.8	3093580.02	272341.79					

Table 1-2
History of Surveyed Locations of Monitoring Wells

Well Number	Elevation Top PVC (Winter 2006 survey)	Elevation Top Casing (Winter 2006 survey)	Elevation Ground (Winter 2006 survey)	Northing (Winter 2006 survey)	Easting (Winter 2006 survey)	Elevation Top PVC (Summer 2006 survey)	Elevation Top Casing (Summer 2006 survey)	Elevation Ground (Summer 2006 survey)	Northing (Summer 2006 survey)	Easting (Summer 2006 survey)
MW-103A										
MW-103B										
MW-103C										
MW-104A*	1118.17	1118.37	1118.5	3093724.57	272155.55					
MW-104B										
MW-104C										
MW-104D										
MW-105A*	1136.80	1137.21	1126.9***	3093751.23	272380.38					
MW-105B	1135.74	1136.07	1126.5	3093767.63	272373.00					
MW-105C	1136.86	1137.17	1126.5	3093768.62	272368.08					
MW-106A										
MW-106B										
MW-106C										
MW-106D										
MW-107A	1140.07	1140.72	1135.1	3093568.57	272395.83					
MW-107B	1140.00	1140.39	1135.1	3093573.79	272399.66					
MW-107C	1139.89	1139.99	1135.1	3093577.27	272397.88	1139.75	1139.98	1134.30	3093577.05	272397.93
MW-107D	1139.18	1139.65	1135.1	3093573.72	272392.21					
MW-107E*	1139.34	1139.72	1134.1	3093569.44	272402.36					
MW-107F*	1138.08	1138.63	1134.2	3093581.57	272394.08					
MW-108A										
MW-108B										
MW-108C										
MW-109A*	1127.99	1128.23	1124.1	3093549.56	272185.04					
MW-109B	1128.19	1128.51	1124.1	3093545.33	272197.15					
MW-109C	1127.68	1128.35	1124.1	3093559.87	272187.55					
MW-109D	1127.71	1127.93	1124.1	3093552.60	272191.96					
MW-110A*	1143.38	1144.36	1138.4	3093527.68	272446.20					
MW-110B*	1143.40	1143.90	1138.2	3093529.81	272449.39					
MW-110C*	1143.36	1144.17	1138.0	3093534.19	272447.06					
MW-110D*	1143.38	1143.90	1137.7	3093531.59	272442.14					
MW-111A*	1141.02	1141.51	1134.8	3093618.36	272430.18					
MW-111B*	1141.75	1142.19	1135.8	3093610.31	272443.91					
MW-111C*	1140.59	1140.95	1134.8	3093621.60	272437.36					
MW-112A										
MW-112										
MW-113A*	1084.74	1085.00	1083.2	3093679.89	271448.91					

Table 1-2
History of Surveyed Locations of Monitoring Wells

Well Number	Elevation Top PVC (Winter 2006 survey)	Elevation Top Casing (Winter 2006 survey)	Elevation Ground (Winter 2006 survey)	Northing (Winter 2006 survey)	Easting (Winter 2006 survey)	Elevation Top PVC (Summer 2006 survey)	Elevation Top Casing (Summer 2006 survey)	Elevation Ground (Summer 2006 survey)	Northing (Summer 2006 survey)	Easting (Summer 2006 survey)
MW-113C*	1084.83	1085.11	1083.2	3093678.29	271446.62					
CFW-1										
CFW-2										
CFW-3										
CFW-4										
CFW-5										
CFW-6										
CFW-7										
OSR-1										
NSR-1										
MW-no#										
SG-1										
SG-3										
SG-4										
SG-5										
SG-6										
IP-1										
Sherman Spring										
12" CMP Invert Sherman Spring Sample Point										
Plant SupplyWell										
Furlon House W										
Elevations in gre used to calculate										
MSL datum is 1((NEP)										
*** On Service Bldg Slab										
Coordinates are										
Elevations are r										
Depths in red ar corresponding p										
+change 4/6/06										
102B & 102C we survey										

Table 1-2
History of Surveyed Locations of Monitoring Wells

Well Number	10/12/2006 Elevation Top PVC	10/12/2006 Elevation Top Casing	10/12/2006 Elevation Ground	Northing (10/12/2006 survey)	Easting (10/12/2006 survey)
CB-1					
CB-2					
CB-3					
CB-3R	1145.27	1145.58	1141.4	3093291.49	272491.14
CB-4					
CB-5					
CB-6					
CB-7					
CB-8	1146.06	1146.23	1142.9	3093424.82	272610.09
CB-9					
CB-10					
CB-11A					
CB-12					
CW-1					
CW-2					
CW-3					
CW-4					
CW-5					
CW-5R	1137.06	1137.49	1133.5	3093696.99	272515.06
CW-6					
CW-7					
CW-8					
CW-9					
CW-10	1128.89	1129.04	1126.1	3093880.33	272659.75
CW-11					
MW-1					
MW-2 (metal)					
MW-3					
MW-5					
MW-6					
MW-6R	1135.02	1135.32	1132.0	3093489.25	272286.05
MW-100A	1135.71	1135.96	1133.6	3093668.70	272490.23
MW-100B	1135.87	1136.14	1133.4	3093666.67	272486.30
MW-101A*	1139.40	1139.68	1136.5	3093489.73	272378.09
MW-101B	1139.64	1139.85	1136.7	3093486.75	272384.57
MW-101C	1139.13	1139.44	1136.6	3093484.74	272378.25
MW-102A	1135.14	1135.42	1131.9	3093570.92	272329.95
MW-102B	1135.15	1135.41	1132.1	3093575.98	272336.91
MW-102C	1135.55	1135.73	1132.1	3093573.61	272333.84
MW-102D*	1135.66	1135.97	1132.4	3093580.02	272341.79

Table 1-2
History of Surveyed Locations of Monitoring Wells

Well Number	10/12/2006 Elevation Top PVC	10/12/2006 Elevation Top Casing	10/12/2006 Elevation Ground	Northing (10/12/2006 survey)	Easting (10/12/2006 survey)
MW-103A					
MW-103B					
MW-103C					
MW-104A*	1125.94	1126.40		3093724.54	272155.20
MW-104B	1127.63	1128.06		3093729.54	272165.74
MW-104C	1126.62	1126.88		3093726.52	272161.07
MW-104D	1127.60	1128.00	1124.0	3093733.31	272162.11
MW-105A*	1130.79	1131.04	1128.5	3093751.23	272380.38
MW-105B	1129.69	1129.95	1128.0	3093767.63	272373.00
MW-105C	1129.79	1130.07	1128.1	3093768.62	272368.08
MW-106A					
MW-106B					
MW-106C					
MW-106D					
MW-107A	1137.35	1137.68	1135.1	3093568.57	272395.83
MW-107B	1137.25	1137.58	1135.1	3093573.79	272399.66
MW-107C	1137.44	1137.62	1134.9	3093577.05	272397.93
MW-107D	1137.35	1137.61	1134.8	3093573.72	272392.21
MW-107E*	1137.08	1137.45	1135.4	3093569.44	272402.36
MW-107F*	1137.10	1137.38	1134.6	3093581.57	272394.08
MW-108A					
MW-108B					
MW-108C					
MW-109A*	1126.09	1126.35	1123.6	3093549.56	272185.04
MW-109B	1126.33	1126.54	1123.2	3093545.33	272197.15
MW-109C	1125.88	1126.16	1123.0	3093559.87	272187.55
MW-109D	1126.11	1126.38	1123.4	3093552.60	272191.96
MW-110A*	1140.46	1140.71	1137.7	3093527.68	272446.20
MW-110B*	1140.54	1140.80	1137.7	3093529.81	272449.39
MW-110C*	1140.28	1140.69	1137.4	3093534.19	272447.06
MW-110D*	1140.19	1140.48	1137.3	3093531.59	272442.14
MW-111A*	1136.89	1137.17	1134.0	3093618.36	272430.18
MW-111B*	1137.75	1138.02	1134.9	3093610.31	272443.91
MW-111C*	1137.07	1137.34	1134.0	3093621.60	272437.36
MW-112A	1134.05	1134.39	1131.0	3093694.78	272396.65
MW-112	1134.05	1134.39	1131.0	3093694.78	272396.65
MW-113A*					

Table 1-2
History of Surveyed Locations of Monitoring Wells

Well Number	10/12/2006 Elevation Top PVC	10/12/2006 Elevation Top Casing	10/12/2006 Elevation Ground	Northing (10/12/2006 survey)	Easting (10/12/2006 survey)
MW-113C*					
CFW-1					
CFW-2					
CFW-3					
CFW-4					
CFW-5					
CFW-6					
CFW-7					
OSR-1					
NSR-1					
MW-no#					
SG-1					
SG-3					
SG-4					
SG-5					
SG-6					
IP-1					
Sherman Spring					
12" CMP Invert Sherman Spring Sample Point					
Plant SupplyWell					
Furlon House W					
Elevations in gre used to calculat					
MSL datum is 1((NEP)					
*** On Service Bldg Slab					
Coordinates are					
Elevations are r					
Depths in red ar corresponding p					
+change 4/6/06					
102B & 102C w survey					

Table 2-1

Inventory of Long-Term Pressure Transducer Records in Rowe Monitoring Wells

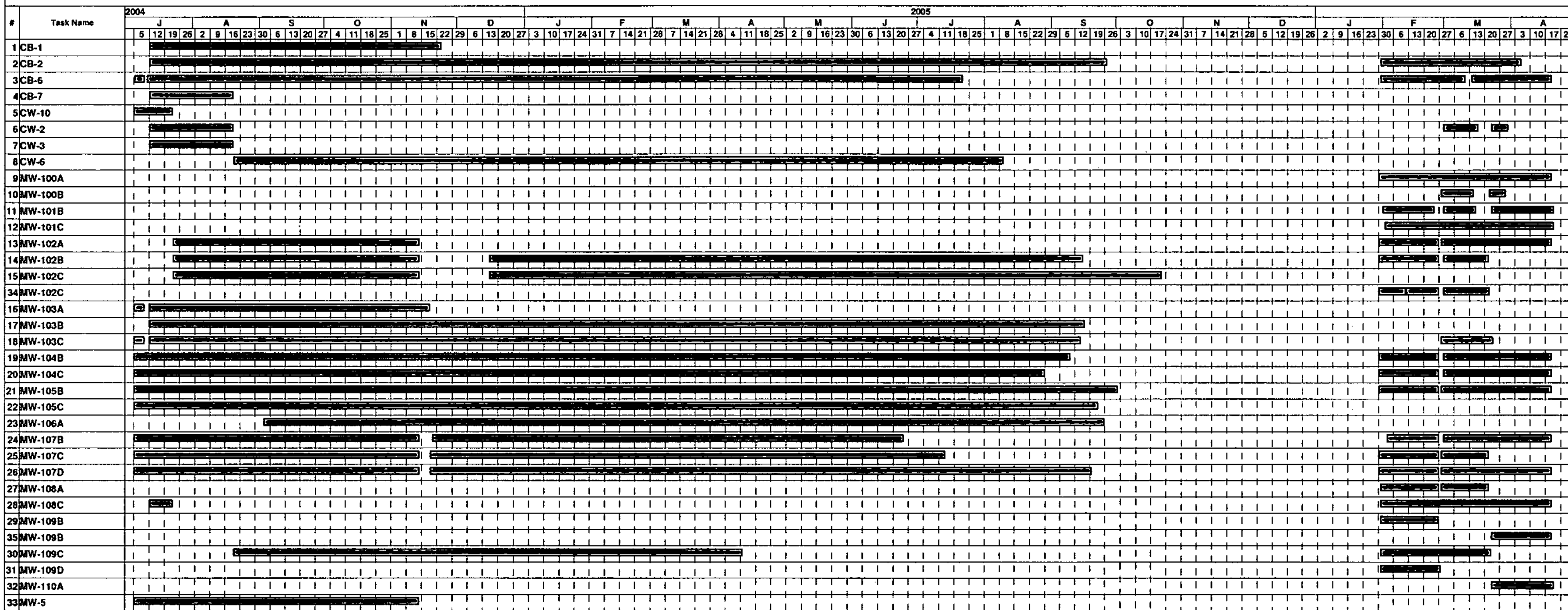


Table 2-2
History of Hand-Measured Water Elevations

Well Number	7/12/93	7/27/93	8/9/93	8/24/93	9/7/1993	9/24/93	10/4/93	10/18/93	11/1/93	11/15/93	11/30/93	12/30/93	1/11/94	1/25/94	3/8/94	3/16/94	3/28/94
CB-1	1116.05	1116.39	1115.88	1115.71	1115.21	1115.63	1116.13	1116.30	1116.63	1117.21	1117.88	1118.21	1117.38	1116.38	1115.96	1116.80	1118.21
CB-2	1103.57	1102.90	1102.49	1102.07	1101.82	1101.82	1101.99	1102.40	1102.65	1103.40	1104.40	1105.90	1105.07	1103.90	1102.24	1102.74	1104.49
CB-3	1134.12	1134.37	1134.20	1134.04	1134.20	1134.29	1134.54	1134.20	1135.12	1134.70	1134.95		1133.20	1133.04			
CB-3R																	
CB-4	1074.28	1074.31	1074.28	1074.21	1074.11	1074.11	1074.19	1074.19	1074.19	1074.28	1074.36	1074.36	1074.28	1074.19		1074.28	1074.36
CB-5																	
CB-6																	
CB-7																	
CB-8																	
CB-9																	
CB-10																	
CB-11A																	
CB-12																	
CW-1																	
CW-2	1123.79	1123.79	1123.79	1123.95	1123.62	1124.20	1124.70	1124.54	1124.54	1124.79	1125.12	1124.87	1123.95	1123.29	1123.54	1125.12	1123.12
CW-3	1129.71	1129.71	1129.63	1129.96	1129.55	1129.88	1130.21	1130.05	1130.55	1130.21	1130.63	1129.63	1129.30	1128.88	1130.13	1130.13	1131.30
CW-4	1130.88	1130.83	1130.88	1131.05	1130.80	1130.96	1131.46	1131.05	1133.05	1131.21	1132.55	1130.71	1130.13	1129.80			
CW-5	1114.50	1114.22	1113.92	1114.25	1113.34	1114.50	1115.84	1115.67	1117.34	1117.00	1118.42		1116.75	1115.75		1119.25	1120.00
CW-5R																	
CW-6	1109.75	1109.58	1109.42	1109.33	1109.33	1109.67	1109.92	1109.83	1110.00	1110.33	1110.92	1110.83	1109.83	1109.08	1111.17	1109.92	1111.08
CW-7																	
CW-8																	
CW-9																	
CW-10																	
CW-11																	
MW-1																	
MW-2 (metal)																	
MW-3																	
MW-5																	
MW-6																	
MW-6R																	
MW-100A																	
MW-100B																	
MW-101A																	
MW-101B																	
MW-101C																	
MW-102A																	
MW-102B																	
MW-102C																	
MW-102D																	
MW-103A																	
MW-103B																	
MW-103C																	
MW-104A																	
MW-104B																	
MW-104C																	

Table 2-2
History of Hand-Measured Water Elevations

Well Number	7/12/93	7/27/93	8/9/93	8/24/93	9/7/1993	9/24/93	10/4/93	10/18/93	11/1/93	11/15/93	11/30/93	12/30/93	1/11/94	1/25/94	3/8/94	3/16/94	3/28/94
MW-104D																	
MW-105A																	
MW-105B																	
MW-105C																	
MW-106A																	
MW-106B																	
MW-106C																	
MW-106D																	
MW-107A																	
MW-107B																	
MW-107C																	
MW-107D																	
MW-107E																	
MW-107F																	
MW-108A																	
MW-108B																	
MW-108C																	
MW-109A																	
MW-109B																	
MW-109C																	
MW-109D																	
MW-110A																	
MW-110B																	
MW-110C																	
MW-110D																	
MW-111A																	
MW-111B																	
MW-111C																	
MW-112A																	
MW-112																	
MW-113A																	
MW-113C																	
CFW-1																	
CFW-2																	
CFW-3																	
CFW-4																	
CFW-5																	
CFW-6																	
CFW-7																	
OSR-1																	
NSR-1																	
MW-no#																	
SG-1																	
SG-3																	
SG-4																	
SG-5																	

Table 2-2
History of Hand-Measured Water Elevations

Well Number	7/12/93	7/27/93	8/9/93	8/24/93	9/7/1993	9/24/93	10/4/93	10/18/93	11/1/93	11/15/93	11/30/93	12/30/93	1/11/94	1/25/94	3/8/94	3/16/94	3/28/94
SG-6																	
IP-1																	
Sherman Spring																	
Elevations are referenced to NAVD 1988																	

Table 2-2
History of Hand-Measured Water Elevations

Well Number	4/10/94	4/27/94	5/11/94	5/26/94	6/10/94	6/23/94	8/10/94	10/5/94	10/8/94	11/8/94	12/6/94	1/5/95	2/13/95	4/6/95	5/31/95	8/30/95	10/4/95
CB-1		1119.05	1119.13	1118.71	1117.55	1117.55	1116.42	1117.46	1116.42	1116.80	1117.13	1117.96	1118.05	1118.55	1116.80	1116.55	1115.30
CB-2	1108.07	1108.32	1107.32	1106.57	1105.74	1105.24	1104.40	1107.32	1104.40	1104.82	1105.97	1106.87		1106.82	1107.74	1105.32	1102.17
CB-3			1134.95	1135.12	1133.95	1134.49	1133.95	1134.45	1133.95	1134.54	1135.12	1134.12			1135.04	1133.70	1134.20
CB-3R																	
CB-4	1075.03	1074.94	1074.44	1074.28	1074.19	1074.32	1074.32	1074.36	1074.11	1074.44	1074.51	1074.44		1074.53	1074.44	1074.28	1074.21
CB-5									1153.96	1154.48	1154.58	1155.63		1156.13	1155.13	1154.13	1153.68
CB-6								1097.23	1097.23	1097.14	1097.66	1097.56		1097.48	1097.48	1097.48	1095.46
CB-7																	
CB-8								1134.81		1134.72	1135.64	1133.81		1135.22	1134.97		1134.22
CB-9									1117.19	1117.19	1117.11	1117.02		1117.19	1116.94		1115.86
CB-10																	
CB-11A																	
CB-12																	
CW-1																	
CW-2	1126.95	1125.45	1124.70	1125.29	1123.95	1124.24	1124.04	1125.20	1124.04	1123.95	1125.54	1124.70		1124.79	1124.70	1123.79	1123.70
CW-3	1131.55	1130.80	1130.38	1130.30	1130.13	1130.13	1130.46	1130.46	1129.80	1130.05	1130.96	1130.38		1129.96	1130.63	1129.46	1129.80
CW-4		1132.71	1132.30	1131.88		1131.21	1131.80	1131.80	1130.88	1131.05	1133.96	1131.46		1131.71	1132.05	1130.71	1131.13
CW-5	1120.92	1120.17	1119.34	1119.17	1117.34	1116.42	1117.34	1117.34	1114.92	1117.34	1118.50	1117.75		1118.75	1117.17	1114.25	1113.92
CW-5R																	
CW-6	1112.92	1111.75	1111.00	1112.67	1110.50	1110.42	1113.42	1111.75	1113.42	1113.50	1112.75	1112.25		1111.42	1113.17	1109.75	1109.35
CW-7								1107.24	1107.24	1107.08	1106.41	1108.49		1108.33	1108.91	1106.36	1105.16
CW-8								1107.74	1107.74	1107.99	1108.39	1108.74		1108.74	1109.49	1106.89	1106.49
CW-9																	
CW-10																	
CW-11																	
MW-1																	
MW-2 (metal)																	
MW-3																	
MW-5																	
MW-6																	
MW-6R																	
MW-100A																	
MW-100B																	
MW-101A																	
MW-101B																	
MW-101C																	
MW-102A																	
MW-102B																	
MW-102C																	
MW-102D																	
MW-103A																	
MW-103B																	
MW-103C																	
MW-104A																	
MW-104B																	
MW-104C																	

Table 2-2
History of Hand-Measured Water Elevations

Well Number	4/10/94	4/27/94	5/11/94	5/26/94	6/10/94	6/23/94	8/10/94	10/5/94	10/8/94	11/8/94	12/6/94	1/5/95	2/13/95	4/6/95	5/31/95	8/30/95	10/4/95
MW-104D																	
MW-105A																	
MW-105B																	
MW-105C																	
MW-106A																	
MW-106B																	
MW-106C																	
MW-106D																	
MW-107A																	
MW-107B																	
MW-107C																	
MW-107D																	
MW-107E																	
MW-107F																	
MW-108A																	
MW-108B																	
MW-108C																	
MW-109A																	
MW-109B																	
MW-109C																	
MW-109D																	
MW-110A																	
MW-110B																	
MW-110C																	
MW-110D																	
MW-111A																	
MW-111B																	
MW-111C																	
MW-112A																	
MW-112																	
MW-113A																	
MW-113C																	
CFW-1																	
CFW-2																	
CFW-3																	
CFW-4																	
CFW-5																	
CFW-6																	
CFW-7																	
OSR-1																	
NSR-1																	
MW-no#																	
SG-1																	
SG-3																	
SG-4																	
SG-5																	

Table 2-2
History of Hand-Measured Water Elevations

Well Number	4/10/94	4/27/94	5/11/94	5/26/94	6/10/94	6/23/94	8/10/94	10/5/94	10/8/94	11/8/94	12/6/94	1/5/95	2/13/95	4/6/95	5/31/95	8/30/95	10/4/95
SG-6																	
IP-1																	
Sherman Spring																	
Elevations are referenced to NAVD 1988																	

Table 2-2
History of Hand-Measured Water Elevations

Well Number	12/5/95	1/10/96	4/4/1996	7/1/96	8/22/96	9/30/1996	1/9/97	2/12/97	3/13/97	7/2/97	8/19/97	11/11/97	2/1/98	6/1/98	8/1/98	7/1/03	11/1/03
CB-1	1118.55	1115.96	1118.80	1117.46		1116.46		1116.46	1116.63	1116.62	1116.99	1118.25				1114.19	1114.62
CB-2	1106.40	1103.24	1105.15	1104.90	1103.15	1102.49		1103.82	1103.50	1103.62	1102.70	1104.28				1105.69	1107.28
CB-3	1134.29	1135.20	1136.04	1134.29	1133.87	1134.54		1129.62	1130.39		1134.66	1134.56				1134.03	1134.22
CB-3R																	
CB-4	1074.61	1074.28	1074.78	1074.53	1074.61	1074.36		1074.28	1074.51		1074.56	1074.63				1074.74	1075.04
CB-5	1156.71	1155.46	1157.46	1155.55	1154.13	1154.55		1155.30			1154.74		1155.58	1156.08	1154.58	1151.39	
CB-6	1097.56	1097.31	1097.14	1096.73	1096.31	1095.98		1096.56	1096.68		1094.01	1097.10				1097.21	1098.56
CB-7							1129.90	1127.73	1129.03		1129.69	1129.61				1128.77	
CB-8		1131.47	1135.14	1134.39	1133.78	1134.81		1132.89	1133.78		1135.39	1135.08				1135.42	
CB-9	1116.77	1115.52	1116.52	1117.19	1116.86					1116.56	1117.37	1117.15				1116.43	1118.35
CB-10																1123.87	1124.33
CB-11A																1125.91	1126.50
CB-12																1130.27	1131.20
CW-1																	
CW-2	1124.45	1123.45	1125.62	1124.29	1123.87	1125.04		1123.54	1125.12		1125.30	1125.27				1124.98	1125.17
CW-3	1129.96	1128.96	1127.13	1130.05	1129.88	1130.80		1129.88	1130.41		1130.78	1131.09				1131.52	1131.46
CW-4	1131.30	1130.05	1132.88	1131.05	1130.88	1131.88		1130.30	1131.37		1131.53	1132.43				1132.47	
CW-5	1118.50	1114.59	1119.75	1115.75	1114.09	1117.42		1115.25	1115.99		1116.42	1116.76				1116.26	1120.14
CW-5R																	
CW-6	1110.67	1109.17	1111.50	1109.92	1108.83	1110.67			1110.25		1110.56	1110.99				1110.51	1111.27
CW-7	1109.08	1103.16	1106.99	1107.49	1106.16	1105.41		1106.49	1106.51		1110.75	1106.48				1108.20	
CW-8	1107.91	1106.32	1107.07	1106.99	1106.49	1106.91		1106.41	1106.90		1107.08	1107.05				1107.03	
CW-9																	
CW-10																1102.51	
CW-11																1126.93	1127.09
MW-1																1125.22	1126.04
MW-2 (metal)																1123.07	1121.62
MW-3																	
MW-5																1122.74	1121.00
MW-6																1120.55	1118.48
MW-6R																	
MW-100A																1116.55	
MW-100B																1115.68	
MW-101A																	
MW-101B																1105.00	1107.23
MW-101C																1091.23	1094.23
MW-102A																1111.92	1113.20
MW-102B																1102.97	1105.86
MW-102C																1090.22	1093.20
MW-102D																	
MW-103A																1092.07	
MW-103B																1073.02	1056.57
MW-103C																1073.09	1076.27
MW-104A																	
MW-104B																	1058.33
MW-104C																	1078.80

Table 2-2
History of Hand-Measured Water Elevations

Well Number	12/5/95	1/10/96	4/4/1996	7/1/96	8/22/96	9/30/1996	1/9/97	2/12/97	3/13/97	7/2/97	8/19/97	11/11/97	2/1/98	6/1/98	8/1/98	7/1/03	11/1/03
MW-104D																	
MW-105A																	
MW-105B																1105.80	1106.95
MW-105C																1108.66	1109.62
MW-106A																	
MW-106B																	
MW-106C																	
MW-106D																	
MW-107A																	
MW-107B																	1105.75
MW-107C																	1114.16
MW-107D																	1096.25
MW-107E																	
MW-107F																	
MW-108A																	
MW-108B																	
MW-108C																	
MW-109A																	
MW-109B																	
MW-109C																	
MW-109D																	
MW-110A																	
MW-110B																	
MW-110C																	
MW-110D																	
MW-111A																	
MW-111B																	
MW-111C																	
MW-112A																	
MW-112																	
MW-113A																	
MW-113C																	
CFW-1																1165.72	1165.94
CFW-2																1154.33	1158.53
CFW-3																1145.99	1149.12
CFW-4																1145.86	1148.71
CFW-5																1139.40	1139.71
CFW-6																1134.18	1135.10
CFW-7																1154.16	1158.53
OSR-1																1153.08	
NSR-1																	
MW-no#																	
SG-1																	
SG-3																	
SG-4																	
SG-5																	

Table 2-2
History of Hand-Measured Water Elevations

Well Number	12/5/95	1/10/96	4/4/1996	7/1/96	8/22/96	9/30/1996	1/9/97	2/12/97	3/13/97	7/2/97	8/19/97	11/11/97	2/1/98	6/1/98	8/1/98	7/1/03	11/1/03
SG-6																	
IP-1																	
Sherman Spring																	
Elevations are referenced to NAVD 1988																	

Table 2-2
History of Hand-Measured Water Elevations

Well Number	2/26/04	5/14/04	8/15/04	10/31/04	3/13/05	11/7/05	4/18/06	6-26/06	9/11/06	12/4/06	Average GW Elevation 1990s	Average GW Elevation 2003- June 2006
CB-1		1118.73	1116.48	1115.83							1117.06	1115.97
CB-2	1103.54	1108.34		1105.35	1103.89						1104.41	1105.68
CB-3	1133.41	1135.10	1134.30	1134.08			1132.28	1135.00	1135.14		1134.17	1134.05
CB-3R									1133.68	1133.46		
CB-4	1074.51	1075.09	1074.61			1077.01	1076.84	1076.90	1077.69	1079.29	1074.38	1075.59
CB-5		1153.14	1151.38	1151.80							1155.15	1151.93
CB-6	1097.16	1097.76	1097.36	1097.35	1096.95	1098.36	1098.48	1099.18	1098.30	1097.98	1096.85	1097.84
CB-7	1127.83	1129.53	1128.80	1128.33							1129.19	1128.65
CB-8	1135.13	1135.88	1134.25	1134.63			1135.24	1135.69	1129.55	1129.24	1134.38	1135.18
CB-9		1114.94									1116.83	1116.57
CB-10	1122.73	1125.25										1124.05
CB-11A	1129.00	1127.42										1127.21
CB-12	1129.20	1131.19	1130.44	1129.93								1130.37
CW-1												
CW-2	1124.45	1125.51	1125.12								1124.46	1125.05
CW-3	1130.09	1131.31	1131.45	1130.42							1130.08	1131.04
CW-4	1131.87	1132.25	1132.80	1132.50							1131.41	1132.38
CW-5		1119.72	1116.87	1115.61							1116.73	1117.72
CW-5R									1116.82			
CW-6	1109.55	1111.81	1110.75	1111.26	1109.93						1110.78	1110.73
CW-7	1106.21	1110.96	1107.81	1107.98	1106.84						1107.04	1108.00
CW-8											1107.44	1107.03
CW-9												
CW-10	1105.21	1103.93	1103.53	1104.43	1104.48		1105.14	1106.20	1103.85	1105.12		1104.43
CW-11												1127.01
MW-1		1126.29	1138.48									1129.01
MW-2 (metal)		1124.49	1123.72									1123.23
MW-3												
MW-5	1120.98	1124.41	1123.69	1122.95								1122.63
MW-6	1117.41											1118.81
MW-6R									1123.35	1123.64		
MW-100A		1118.41	1115.39	1114.55			1117.75	1119.78	1116.20	1115.71		1117.07
MW-100B		1116.42	1112.83	1113.90			1116.36	1118.34	1115.27	1115.14		1115.59
MW-101A								1122.88	1125.86	1126.72		1122.88
MW-101B	1104.94	1104.48	1103.47	1103.59			1104.77	1106.32	1104.54	1105.86		1104.98
MW-101C	1094.11	1091.93	1091.40	1090.75			1093.93	1096.32	1093.22	1094.60		1092.99
MW-102A	1111.33	1113.01	1111.13				1113.63	1114.87	1112.53	1112.45		1112.73
MW-102B	1102.77	1102.80	1101.46				1103.16	1104.07	1102.17	1103.43		1103.30
MW-102C	1091.65	1090.56	1089.88				1092.62	1093.46	1091.85	1093.25		1091.66
MW-102D							1118.46	1117.77	1117.23	1117.27		1118.12
MW-103A	1091.40	1092.50	1091.52	1091.55	1091.96	1102.75	1092.61	1092.87	1091.81	1092.48		1093.25
MW-103B	1054.96	1053.74	1053.32	1051.90	1053.87	1055.02	1054.06	1052.85	1052.92	1055.19		1055.93
MW-103C	1075.96	1076.28	1074.72	1074.87	1076.21	1075.74	1076.03	1075.87	1076.30	1076.20		1075.50
MW-104A							1109.67	1111.34	1106.31	1105.63		1110.51
MW-104B		1056.39	1056.25	1054.79	1056.88	1049.75	1056.63	1056.89	1056.52	1058.82		1055.74
MW-104C	1077.82	1078.07	1076.74	1076.89	1078.17	1079.37	1078.47	1078.81	1077.29	1079.38		1078.13

Table 2-2
History of Hand-Measured Water Elevations

Well Number	2/26/04	5/14/04	8/15/04	10/31/04	3/13/05	11/7/05	4/18/06	6-26/06	9/11/06	12/4/06	Average GW Elevation 1990s	Average GW Elevation 2003- June 2006
MW-104D										1108.12		
MW-105A							1110.85	1113.76	1108.97	1108.00		1112.31
MW-105B	1105.31	1107.29	1105.56	1105.77	1105.71		1106.88	1108.92	1106.03	1106.22		1106.47
MW-105C	1107.50	1108.74	1107.82	1118.47	1106.74		1109.55	1113.41	1108.76	1107.83		1110.06
MW-106A				1081.89	1082.46	1080.59	1082.37	1083.00	1081.99	1082.89		1082.06
MW-106B				1049.14	1052.16	1052.69	1049.98	1053.42	1051.56	1054.18		1051.48
MW-106C				1049.40	1061.28	1059.90	1061.00	1061.96	1058.31	1061.45		1058.71
MW-106D				1044.96	1049.45	1056.16	1050.76	1051.54	1050.64	1051.05		1050.57
MW-107A								1122.80	1122.74	1122.81		1122.80
MW-107B	1103.06	1103.30	1101.76				1103.61	1102.50	1102.91	1103.87		1103.33
MW-107C	1110.73	1114.00	1112.33				1114.81	1116.28	1114.32	1114.37		1113.72
MW-107D	1094.56	1093.87	1094.23				1096.15	1097.06	1095.51	1096.65		1095.35
MW-107E								1113.00	1110.30	1110.11		1113.00
MW-107F								1112.98	1110.18	1109.95		1112.98
MW-108A				1105.69		1106.32	1105.25	1106.72	1105.65	1104.46		1106.00
MW-108B				1064.75		1067.98	1067.20	1068.21	1065.41	1067.94		1067.04
MW-108C				1104.06		1104.16	1104.23	1105.97	1103.37	1104.92		1104.61
MW-109A							1115.58	1114.95	1114.67	1114.68		1115.27
MW-109B				1095.00	1097.22		1084.74	1097.40	1095.29	1096.92		1093.59
MW-109C				1108.12	1107.51		1107.75	1112.18	1109.64	1108.89		1108.89
MW-109D				1085.51	1085.65		1082.06	1087.71	1086.49	1087.74		1085.23
MW-110A							1123.82	1124.20	1124.91	1125.13		1124.01
MW-110B							1103.98	1105.04	1103.19	1104.03		1104.51
MW-110C							1115.85	1117.37	1115.83	1116.05		1116.61
MW-110D							1094.02	1096.01	1094.34	1095.75		1095.02
MW-111A							1120.74	1122.22	1122.65	1122.47		1121.48
MW-111B							1106.50	1107.75	1106.67	1106.32		1107.13
MW-111C							1118.74	1120.08	1116.60	1116.08		1119.41
MW-112A										1112.67		
MW-112									1113.18			
MW-113A								1064.24	1064.03	1064.88		1064.24
MW-113C								1031.23	1029.70	1031.16		1031.23
CFW-1		1160.69	1165.89	1165.74	1165.49		1165.68		1166.34	1166.58		1165.02
CFW-2	1154.84	1157.51	1153.34	1154.12								1155.45
CFW-3	1146.33	1148.39	1145.43	1146.11								1146.90
CFW-4	1146.17	1148.02	1145.17	1145.95								1146.65
CFW-5	1139.33	1139.53	1139.33	1139.49	1139.38		1139.32		1139.80	1140.02		1139.44
CFW-6	1134.07	1134.79	1133.87	1134.13	1134.11		1134.47		1134.29	1135.00		1134.34
CFW-7	1154.68	1157.49	1153.33	1154.09								1155.38
OSR-1	1152.33	1154.90	1151.86	1150.34								1152.50
NSR-1												
MW-no#												
SG-1												
SG-3												
SG-4												
SG-5												

Table 2-2
History of Hand-Measured Water Elevations

Well Number	2/26/04	5/14/04	8/15/04	10/31/04	3/13/05	11/7/05	4/18/06	6-26/06	9/11/06	12/4/06	Average GW Elevation 1990s	Average GW Elevation 2003- June 2006
SG-6												
IP-1												
Sherman Spring					1091	1091	1091	1091				
Elevations are referenced to NAVD 1988												

Table 2-3
Plant Well Weekly Water Usage

Week Ending	Weekly Usage, Gallons
12/5/2005	2100
12/12/2005	2000
12/19/2005	2400
12/26/2005	6500
1/2/2006	1300
1/9/2006	1800
1/16/2006	1800
1/23/2006	1900
1/30/2006	2200
2/6/2006	2000
2/13/2006	1800
2/20/2006	1800
2/27/2006	1800
3/6/2006	2600
3/13/2006	2200
3/20/2006	2000
3/27/2006	2700
4/3/2006	2200
4/10/2006	2200
4/17/2006	1900
4/24/2006	1800
5/1/2006	2100
5/8/2006	1800
5/15/2006	2100
5/22/2006	1300
5/29/2006	1100
6/5/2006	1700
6/12/2006	2500
6/19/2006	500
6/26/2006	300
7/3/2006	200
7/10/2006	500
7/17/2007	500

Table 2-4
Summary of Influences on Monitoring Well Water Levels

Well ID	Earth Tide?	Barometric Response?	Precipitation Response?	Snowmelt Response?	Plant Well Pumping Response?	Reservoir Fluctuation Response?	Tailwater Elevation Fluctuation Response?	Long-term Temperature Variation	Vertical Gradient Direction	Dec. 2006 Average Purge Rate, gpm	Notes
CB-1	No	Slight	Yes	N/D	No	Yes	N/D	large but gradual change; peak early November	N/D	N/D	
CB-2	No	Slight	Yes	Yes	No	Slight; delayed	N/D	large but gradual change; peak early	N/D	N/D	
CB-3	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	
CB-3R	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	
CB-4	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	9.55E-02	
CB-6	No	None	Yes	Yes	No	No	N/D	large but gradual change; peak late December	N/D	1.05E-01	
CB-7	No	None	Yes	N/D	No	No	N/D	large range; short record	N/D	N/D	
CB-8	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	1.44E-02	
CFW-1	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	5.56E-03	
CFW-5	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	1.54E-02	
CFW-6	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	1.85E-02	
CW-10	No	None	N/D	N/D	No	Yes	N/D	large range; short record	N/D	3.33E-02	
CW-2	No	None	Yes	Yes	No	No	N/D	large range; short record	N/D	N/D	
CW-3	No	None	Yes	N/D	No	No	N/D	large range; short record	N/D	N/D	
CW-6	No	None	Slight; delayed	Yes	No	Slight; delayed	N/D	large range; peak mid-October	N/D	N/D	Shows drawdown during summer 2005 excavation and dewatering activities
MW-100A	No	Slight	Yes	Yes	No	No	N/D	large range; short record	downward	5.23E-02	
MW-100B	Yes	No	Yes	Yes	Slight	No	N/D	moderate range	N/D	2.67E-02	
MW-101A	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	6.32E-03	
MW-101B	Yes	Yes	No	No	Yes	No	N/D	moderate range; short record	upward	2.41E-02	2006 winter record too irregular to discern earthtide
MW-101C	Yes	slight	Slight	No	No	No	N/D	low range	N/D	7.14E-03	low permeability well; pressure spike 3/7/06 when temp goes above freezing; influenced by filling of stormwater basin
MW-102A	Yes	Slight	Yes	N/D	No	No	N/D	moderate range	downward	2.68E-02	temperature affected by pumping MW-109C
MW-102B	Yes	Slight	Yes	Yes	Yes	No	N/D	low range	upward	2.48E-02	influenced by filling stormwater basin
MW-102C	Yes	Slight	Yes	Yes	Yes	No	N/D	low range	N/D	1.07E-02	Shows drawdown during summer 2005 excavation and dewatering activities

Table 2-4
Summary of Influences on Monitoring Well Water Levels

Well ID	Earth Tide?	Barometric Response?	Precipitation Response?	Snowmelt Response?	Plant Well Pumping Response?	Reservoir Fluctuation Response?	Tailwater Elevation Fluctuation Response?	Long-term Temperature Variation	Vertical Gradient Direction	Dec. 2006 Average Purge Rate, gpm	Notes
MW-102D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	N/D	
MW-103A	No	None	Yes	N/D	No	No	N/D	large range; peak mid-November	downward	3.20E-02	
MW-103B	Yes	Yes	Yes	Yes	Slight	Yes	N/D	low range	N/D	1.52E-02	
MW-103C	Yes	Yes	No	Yes	No	No	N/D	low range	downward	6.15E-03	slow recovery from sampling; pressure spike 3/7/06 when temp goes above freezing
Mw-104A	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	5.75E-02	
MW-104B	No	Slight	Yes	Yes	Slight	Yes	N/D	low range	N/D	2.83E-02	
MW-104C	Yes	Yes	Slight; delayed	Yes	No	Yes	N/D	low range	downward	1.78E-02	
MW-104D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	upward	8.94E-03	
MW-105A	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	3.27E-02	
MW-105B	No	Slight	Yes	Yes	slight	See Note	N/D	low range	downward	1.36E-02	slow, diffuse response to reservoir level
MW-105C	No	None	Yes	Yes	No	No	N/D	Mod. Range; peak in mid-January	N/D	1.54E-02	
MW-106A	No	Slight	Yes	Yes	No	No	N/D	large range; peak early December	downward	5.00E-02	Shows drawdown during summer 2005 excavation and dewatering activities
MW-106B	N/D	N/D	Yes	N/D	N/D	N/D	slight	N/D	upward	2.74E-02	
MW-106C	N/D	N/D	N/D	N/D	N/D	N/D	slight	N/D	downward	8.28E-03	
MW-106D	N/D	N/D	N/D	N/D	N/D	Yes	slight	N/D	N/D	1.51E-02	
MW-107A	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	7.69E-03	influenced by filling stormwater basin
MW-107B	Yes	Yes	Yes	Yes	Yes	See Note	N/D	low range	upward	1.30E-02	delayed reaction to reservoir change; influenced by filling stormwater basin; temperature fluctuated in MW-107C pumping test
MW-107C	Yes	Yes	Yes	Yes	Slight	No	N/D	low range	downward	6.90E-03	excavation and dewatering activities; influenced by filling stormwater basin
MW-107D	Yes	Yes	Yes	Yes	Yes	No	N/D	low range	N/D	8.70E-03	Shows drawdown during summer 2005 excavation and dewatering activities; influenced by filling stormwater basin
MW-107E	Yes	N/D	Yes	N/D	N/D	N/D	N/D	N/D	downward	1.71E-02	influenced by filling stormwater basin; temperature affected by pumping MW-107C & MW-109C
MW-107F	Yes	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	2.55E-02	influenced by filling stormwater basin; temperature affected by pumping MW-107C & MW-109C & MW-105C
MW-108A	No	No	N/D	Yes	No	See Note	N/D	large range	downward	8.33E-03	small response to high frequency drawdown; larger response to low frequency drawdown
MW-108B	No	N/D	N/D	N/D	N/D	Slight, diffused	N/D	N/D	N/D	1.50E-02	

Table 2-4
Summary of Influences on Monitoring Well Water Levels

Well ID	Earth Tide?	Barometric Response?	Precipitation Response?	Snowmelt Response?	Plant Well Pumping Response?	Reservoir Fluctuation Response?	Tailwater Elevation Fluctuation Response?	Long-term Temperature Variation	Vertical Gradient Direction	Dec. 2006 Average Purge Rate, gpm	Notes
MW-108C	Yes	Slight	N/D	Yes	No	See Note	N/D	low range	downward	1.80E-02	slow, diffuse response to reservoir level
MW-109A	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	2.58E-02	
MW-109B	Yes	Yes	Slight; delayed	Slight	Slight	Slight, diffused	N/D	low range	upward	2.17E-02	
MW-109C	Yes	Yes	Yes	Yes	No	No	N/D	large range; peak early November	downward	3.27E-02	
MW-109D	No	Slight	Slight	No	No	No	N/D	low range		1.19E-02	
MW-110A	No	Yes	Yes	N/D	No	No	N/D	large range	downward	6.55E-02	influenced by filling stormwater basin
MW-110B	Yes	N/D	N/D	N/D	N/D	N/D	N/D	N/D	upward	2.64E-02	temperature affected by pumping MW-107D
MW-110C	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	8.00E-03	temperature affected by MW-107C and MW-107F pumping tests; influenced by filling of stormwater basin
MW-110D	Yes	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	2.30E-02	
MW-111A	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	1.90E-02	influenced by filling stormwater basin
MW-111B	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	1.33E-02	influenced by filling stormwater basin
MW-111C	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	8.46E-03	influenced by filling stormwater basin; temperature affected by MW-107C pumping test
MW-112	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	
MW-113A	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	downward	2.96E-02	
MW-113C	N/D	N/D	N/D	N/D	slight	slight	Yes	N/D	N/D	1.26E-02	
MW-5	No	No	Yes	Yes	No	No	N/D	large range	N/D	N/D	
MW-6R	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	

Notes: N/D = Not Determined; gpm = gallons per minute

Table 3-1
Summary of Laboratory Analysis for Quarterly Groundwater Sampling

Analyte	Analytical Method	MDC (pCi/L)	MCL (pCi/L)	NRC Threshold Level (pCi/L)
Radionuclides (pCi/L)				
Tritium (2)	EPA 906.0	500	20000	NA
Strontium-90 (2)	EPA 905.0 Modified	1	8	3
Americium-241(2)	Gamma Spec EPA 901.1	1	15	0.5
Cobalt-60 (2)	Gamma Spec EPA 901.1	0.7	100	25
Cesium-134 (2)	Gamma Spec EPA 901.1	20	80	14
Cesium-137(2)	Gamma Spec EPA 901.1	2	200	15
Niobium-94 (2)	Gamma Spec EPA 901.1	20	NA	50
Antimony-125 (2)	Gamma Spec EPA 901.1	20	300	50
Europium-152 (2)	Gamma Spec EPA 901.1	20	200	50
Europium-154 (2)	Gamma Spec EPA 901.1	10	60	50
Europium-155 (2)	Gamma Spec EPA 901.1	20	600	50
Silver-108m (2)	Gamma Spec EPA 901.1	20	NA	50
Carbon-14	EPA EERF C-01 Modified	200	2000	200
Iron-55	DOE RESL Fe-1, Modified	200	2000	25
Nickle-63	DOERESL Ni-1, Modified	10	50	15
Technicium-99	DOE EML HASL-300, Tc-02-RC Modified	25	900	15
Americium-241	Alpha Spec DOE EML HASL-300, Am-05-RC Modified	1	15	50
Plutonium-238	Alpha Spec DOE EML HASL-300, Pu-11-RC Modified	1	15	0.5
Plutonium-239	Alpha Spec DOE EML HASL-300, Pu-11-RC Modified	1	15	0.5
Plutonium-240	Alpha Spec DOE EML HASL-300, Pu-11-RC Modified			0.5
Plutonium-241	Alpha Spec DOE EML HASL-300, Pu-11-RC Modified	15	300	NA
Curium-242	Alpha Spec DOE EML HASL-300, Am-05-RC Modified	1	15	NA
Curium-243	Alpha Spec DOE EML HASL-300, Am-05-RC Modified	1	115	0.5
Curium-244	Alpha Spec DOE EML HASL-300, Am-05-RC Modified	1	15	0.5
Gross alpha/beta	EPA 900.0	20	NA	NA
General Geochemistry (mg/L) (1)				
Alkalinity	SM 2320B	2	NA	NA
Sulfate	EPA 300.0	0.4	NA	NA
Chloride	EPA 300.0	20	NA	NA
Calcium	SW-846 3005/6010B	0.1	NA	NA
Magnesium	SW-846 3005/6010B	0.3	NA	NA
Potassium	SW-846 3005/6010B	0.15	NA	NA
Sodium	SW-846 3005/6010B	0.15	NA	NA
Metals (ug/L)				
Boron	SW-846 3005/6020	75	NA	NA

Notes:
(1) General geochemistry and boron analyses were conducted for Q2 2006 only
(2) For Q2 2006 sampling round both filtered (preserved sample at laboraotry) and unfiltred samples were taken
NA - Not Available
MDC - Minimum Dectction Concentration
MCL Maximum Contaminant Level

Table 3-2
Summary of Groundwater Laboratory Analytical Program for Q4 2006

Well ID	Q4 Sampling Program
CB-3	ABCD
CB-4	A
CB-6	ABC
CB-8	A
CW-10	A
CFW-1	A
CFW-5	A
CFW-6	A
MW-100A	A
MW-100B	A
MW-101A	ABC
MW-101B	A
MW-101C	A
MW-102A	ABC
MW-102B	A
MW-102C	ABC
MW-102D	ABCD
MW-103A	A
MW-103B	A
MW-103C	A
MW-104A	A
MW-104B	A
MW-104C	A
MW-104D	ABCD
MW-105A	A
MW-105B	ABC
MW-105C	ABC
MW-106A	ABC

Well ID	Q4 Sampling Program
MW-106B	A
MW-106C	A
MW-106D	A
MW-107A	ABC
MW-107B	A
MW-107C	ABCD
MW-107D	ABCD
MW-107E	ABCD
MW-107F	ABCD
MW-108A	A
MW-108B	A
MW-108C	A
MW-109A	A
MW-109B	A
MW-109C	A
MW-109D	A
MW-110A	A
MW-110B	A
MW-110C	A
MW-110D	A
MW-111A	A
MW-111B	A
MW-111C	ABCD
MW-113A	A
MW-113C	A
SP-1	A

Notes:
A - Tritium only
B - Gamma
C- Sr-90, TC-99, C-14
D - Am-241, Pu-238, Pu-239/240
Pu-0241, CM-242, CM-243/244

Table 4-1
Summary of 2006 Tritium Analytical Results

Monitoring Well	Jan-06	Feb-06	Q1 2006	May-06	Non-Filtered Q2 2006	Filtered Q2 2006	Aug-06	Q3 2006	Oct-06	Nov-06	Q4 2006
CB-3	NS	NS	U	NS	U	NA	NS	NS	U	NS	U
CB-4	U	U	U	U	U	NA	NS	403	NS	NS	189
CB-6	14,730	12,100	7,680	4,300	1,910	2,090	2,090	959	451	NS	869
CB-8	NS	NS	U	NS	U	NA	NS	264	NS	NS	U
CFW-1	NS	NS	332	NS	U	NA	NS	U	NS	NS	U
CWF-5	NS	NS	U	NS	NS	NA	NS	225	NS	NS	U
CWF-6	NS	NS	300	NS	1,180	NA	NS	2,650	NS	249	581
CW-2	NS	NS	U	NS	NS	NA	NS	NS	NS	NS	NS
CW-10	NS	NS	U	NS	U	NA	NS	349	NS	U	317
MW-100A	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-100B	NS	NS	U	NS	U	NA	NS	U	NS	NS	211
MW-101A	NS	NS	16,900	NS	8,520	NA	7,720	10,100	NS	4,740	3,880
MW-101B	NS	NS	U	U	U	NA	NS	U	NS	NS	U
MW-101C	NS	NS	NS	NS	NS	NA	NS	323	NS	NS	U
MW-102A	NS	NS	4,490	4,630	4,260	4,640	NS	4,470	NS	NS	4,240
MW-102B	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-102C	NS	NS	4,610	3,920	4,980	4,590	NS	4,210	NS	NS	3,520
MW-102D	NS	NS	16,100	6,890	11,100	8,810	NS	6,970	NS	NS	6,530
MW-103A	NS	NS	U	NS	416	NA	NS	337	NS	NS	U
MW-103B	NS	NS	U	NS	U	NA	NS	182	NS	NS	U
MW-103C	NS	NS	U	NS	U	NA	NS	249	NS	NS	U
MW-104A	NS	3,320	4,580	2,960	844	798	NS	1,430	NS	NS	2,850
MW-104B	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-104C	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-104D	NI	NI	NI	NI	NI	NI	NI	NI	U	U	U
MW-105A	NS	NS	U	NS	U	U	U	310	NS	NS	175
MW-105B	NS	NS	3,970	4,780	3,860	NA	NS	3,290	NS	NS	2,900
MW-105C	NS	NS	1,990	NS	1,030	NA	NS	1,650	NS	NS	2,750
MW-106A	11,260	13,100	10,300	9,810	7,170	7,620	6,740	5,280	NS	NS	3,010
MW-106B	NS	NS	U	NS	U	NA	NS	528	NS	U	U
MW-106C	NS	NS	U	NS	U	NA	NS	U	NS	NS	277
MW-106D	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-107A	NS	NS	4,910	5,050	5,910	6,130	5,600	5,410	NS	NS	4,040

Table 4-1
Summary of 2006 Tritium Analytical Results

Monitoring Well	Jan-06	Feb-06	Q1 2006	May-06	Non-Filtered Q2 2006	Filtered Q2 2006	Aug-06	Q3 2006	Oct-06	Nov-06	Q4 2006
MW-107B	NS	NS	U	U	U	NA	NS	U	NS	NS	U
MW-107C	NS	NS	41,300	37,200	36,000	36,600	34,700	32,500	NS	NS	29,100
MW-107D	NS	NS	11,900	12,000	11,800	13,300	11,600	11,000	NS	NS	9,310
MW-107E	NI	NI	NI	8,130	7,900	7,840	7,840	5,440	NS	NS	5,700
MW-107F	NI	NI	NI	NI	10,900	10,900	NS	9,580	NS	NS	3,210
MW-108A	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-108B	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-108C	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-109A	NS	NS	U	NS	U	NA	NS	U	NS	NS	231
MW-109B	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-109C	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-109D	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-110A	7,720	NS	2,930	2,770	2,990	2,810	2,810	1,680	NS	NS	1,660
MW-110B	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-110C	NS	NS	1,160	NS	1,980	NA	NS	1,870	NS	NS	2,590
MW-110D	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-111A	NS	NS	4,440	3,940	3,050	3,640	3,640	2,650	NS	NS	1,680
MW-111B	NS	NS	U	NS	U	NA	NS	U	NS	NS	U
MW-111C	NS	NS	U	NS	5,160	NA	NS	4,250	NS	NS	U
MW-113A	NI	NI	NI	U	U	U	ND	U	NS	NS	231
MW-113C	NI	NI	NI	NS	601	826	826	766	NS	NS	798
SP001	4,340	4,610	4,670	2,650	1,420	NA	1,510	1,390	NS	NS	1,100

Notes:
1) All tritium concentrations pCi/L
2) NS - Not Sampled
3) NA - Not Analyzed
4) NI - Not Installed

Table 4-2
Tritium Results for 2006 Replacement Monitoring Wells

Monitoring Well	Jan-06	Feb-06	Q1 2006	May-06	Non-Filtered Q2 2006	Filtered Q2 2006	Aug-06	Q3 2006	Oct-06	Nov-06	Q4 2006
CB-3	NS	NS	U	NS	U	NA	NS	NS			
CB-3R									U		U
CW-10	NS	NS	U	NS	U	NA	NS	349			
CW-10R										U	317

Table 4-3
Summary of Q2 2006 Boron and Cation-Anion Analytical Results

	Boron	Calcium	Mangnesium	Potassium	Sodium	Chloride	Sulfate	Bicarb	Carb
Well ID	ug/L	mg/L							
CB-3	42.7	14.7	2.07	2.81	78.4	115	22.5	69.30	0.00
CB-4	14.2	17.7	2.97	3.17	83.8	110	13	57.89	0.01
CB-6	68.3	18	2.5	4.64	92.5	62.1	40.5	64.99	0.01
CB-8	7.5	29.9	8.07	6.23	30.5	780	18.1	36.60	0.00
CFW-1	6.8	2.32	1.09	1.31	2.66	0.457	3.57	6.85	0.00
CFW-5	45	31.9	5.08	5.7	4.1	14	0.628	108.97	0.03
CFW-6	7.3	22.4	3.37	3.18	1.85	8.01	0.875	81.18	0.02
CW-10	258	17.5	1.5	3.82	82	68.9	33.4	88.46	0.04
MW-100A	25.1	11.4	1.11	2.36	39	19.4	19.9	73.27	0.03
MW-100B	12.9	10.6	0.846	3.2	22.2	10.9	9.74	53.79	0.01
MW-101A	72.8	93.9	0.085	5.48	35.6	109	33.6	10.90	81.38
MW-101B	7.1	19.8	6.03	4	9.58	0.708	7.6	84.14	1.00
MW-102A	12	27.1	3.92	2.2	10.6	24.1	8.86	58.70	0.28
MW-102B	6.3	18.7	5.51	2.67	8.6	0.968	7.79	80.79	0.38
MW-102C	67.6	38.5	6.47	2.82	10.5	26	10.8	94.16	0.70
MW-102D	134	30	0.348	12.4	116	87.5	61.6	112.60	1.33
MW-103A	19.2	14.8	1.95	2.91	54.2	71.3	15.5	29.50	0.00
MW-103B	9.1	31.9	3.96	3.69	16.5	16.5	12.6	92.14	0.63
MW-103C	7.1	61.2	20.3	4.13	70	34.6	17.5	320.31	0.67
MW-104A	61.3	16.9	1.61	2.66	47.7	32	33.3	62.18	0.01
MW-104B	10.2	30.9	4.56	5.97	13.4	19.1	13.2	101.14	1.77
MW-104C	11.6	223	68.4	13.6	184	21.6	21	94.74	0.81
MW-105A	53.7	16.8	2.04	4.64	37.3	34.2	23.7	26.39	0.00
MW-105B	41.9	82.5	12.9	6.14	29.2	156	22.1	70.42	0.17
MW-105C	47.2	71.1	16.7	5.88	31.6	157	13.1	71.03	0.07
MW-106A	70.8	35.1	6.22	4.74	68.7	110	37.3	54.59	0.01
MW-106B	4	40.7	4.72	4.15	6.22	12.4	7.35	112.97	0.03
MW-106C	6.4	22.8	6.93	4.36	16	0.559	10.6	107.89	0.10
MW-106D	4.1	54	8.76	3.98	16.4	2.17	8.27	200.43	0.56

Table 4-3
Summary of Q2 2006 Boron and Cation-Anion Analytical Results

	Boron	Calcium	Mangnesium	Potassium	Sodium	Chloride	Sulfate	Bicarb	Carb
Well ID	ug/L	mg/L							
MW-107A	116	73.5	0.085	9.76	77.7	62.3	102	6.16	66.44
MW-107B	18.9	38.9	3.24	4.18	18.7	33.2	12.6	88.94	0.62
MW-107C	214	49.4	9.68	3.74	16.2	46.6	21.5	105.81	0.19
MW-107D	168	40.3	6.72	4.15	8.67	40.8	8.98	81.32	0.36
MW-107E	20.4	25.7	3.48	2.21	7.87	13.4	7.87	65.79	0.56
MW-107F	10.8	29.5	4.66	2.34	7.67	22.6	8.63	68.93	0.62
MW-108A	8.5	102	14.1	11.5	83.2	230	2.24	172.95	0.05
MW-108B	4.6	27.8	2.94	3.02	6.36	3.58	9.94	76.55	2.38
MW-108C	5.2	74.8	18.4	5.96	15.2	61.3	12.8	194.06	0.91
MW-109A	18	12.6	1.53	4.93	82	68.5	27.3	99.35	0.23
MW-109B	7	18.8	5.69	3.05	8.71	0.673	7.32	81.29	0.38
MW-109C	4	17.4	2.22	1.42	8.19	0.81	13.7	56.44	0.42
MW-109D	8.4	38.3	12.4	3.64	28.6	0.772	13.1	86.26	0.13
MW-110A	43.9	123	0.085	14.1	72.8	35.5	25.6	12.18	233.73
MW-110B	10.9	38.8	2.81	4.88	9.63	12.1	15	88.06	0.41
MW-110C	4	25.1	3.23	2.08	6.04	22.7	8.55	53.25	0.50
MW-110D	6.3	40.3	8.6	7.09	16.2	67	11	66.02	1.56
MW-111A	30.5	116	0.085	25.2	80.9	34.1	23.7	3.31	156.09
MW-111B	25.4	42	3.45	5.86	30.1	70.4	18.9	65.46	0.04
MW-111C	168	25.4	4.46	2.55	89.7	60.4	10	160.73	0.26
MW-113A	21.8	20.6	3.24	3.94	87.5	107	14.5	65.00	0.00
MW-113C	5.4	28.3	5.84	3.31	11.2	4.48	10.4	107.79	0.20
SP-1	38.2	20.1	2.98	3.1	36.5	49.5	18.5	55.09	0.19

Table 5-1
Summary of Trend Analysis for Monitoring Wells Included in the LTP Monitoring Plan

Well ID	Tritium Trend Q1-Q4 2006
CB-3	NT
CB-4	NT
CB-6	DT
CB-8	NT
CW-10	NT
CFW-1	NT
CFW-5	NT
CFW-6	NT
MW-100A	NT
MW-100B	NT
MW-101A	DT
MW-101B	NT
MW-101C	NT
MW-102A	NT
MW-102B	NT
MW-102C	NT
MW-102D	NT
MW-103A	NT
MW-103B	NT
MW-103C	NT
MW-104A	NT
MW-104B	NT
MW-104C	NT
MW-104D	NT
MW-105A	NT
MW-105B	DT
MW-105C	NT
MW-106A	DT
MW-106B	NT

Well ID	Tritium Trend Q1-Q4 2006
MW-106C	NT
MW-106D	NT
MW-107A	NT
MW-107B	NT
MW-107C	DT
MW-107D	DT
MW-107E	DT
MW-107F	NT
MW-108A	NT
MW-108B	NT
MW-108C	NT
MW-109A	NT
MW-109B	NT
MW-109C	NT
MW-109D	NT
MW-110A	DT
MW-110B	NT
MW-110C	UT
MW-110D	NT
MW-111A	DT
MW-111B	NT
MW-111C	NT
MW-113A	NT
MW-113C	NT
SP-001	DT

NT - No Trend
DT - Down Trend
UT - Up Trend

Table 6-1
Conceptual Model Design in Vertical Cross Section

	Description in Plant Area	Description in Upland Area
Layer 1	5'-15' thick glaciofluvial = Zone 1	0.5' thick till zone = Zone 9
Layer 2	Low K Till = Zone 2	0.5' thick till zone = Zone 9
Layer 3	Locally 1st sand seam = Zone 12 or 13	0.5' thick till zone = Zone 9
Layer 4	Low K Till = Zone 2	0.5' thick till zone = Zone 9
Layer 5	Locally 2nd sand seam = Zone 3	0.5' thick till zone = Zone 9
Layer 6	Low K Till = Zone 2	0.5' thick till zone = Zone 9
Layer 7	Locally 3rd sand seam = Zone 3	0.5' thick till zone = Zone 9
Layer 8	Low K Till = Zone 2	0.5' thick till zone = Zone 9
Layer 9	Low K Glaciolacustrine = Zone 2	0.5' thick till zone = Zone 9
Layer 10	Locally 4th sand seam = Zone 3	0.5' thick till zone = Zone 9
Layer 11	Low K Glaciolacustrine = Zone 2	0.5' thick till zone = Zone 9
Layer 12	Locally 5th sand seam = Zone 1 or 3	0.5' thick till zone = Zone 9
Layer 13	Low K Glaciolacustrine = Zone 2	0.5' thick till zone = Zone 9
Layer 14	Upper 50' of rock (Zone 9), weathered, locally high K	Upper 50' of rock = Zone 7
Layer 15	Lower 450' of rock (Zone 10), locally high K = Zone 8	Lower 450' of rock = Zone 10

Table 6-2
Pre-Demo Model Hydraulic Conductivity Zone Values

Zone #	Kx, Ft/day	Ky, Ft/day	Kz, Ft/day	Geologic Material
1	10.0000	10.0000	1.0000	Glaciofluvial sand & gravel
2	0.0600	0.0600	0.0090	Thick silty glacial till
3	5.0000	5.0000	0.1000	Stratified sand & silt
4	0.1000	0.1000	0.0010	Stratified silt near MW-108 & MW-113
5	1.0000	1.0000	0.0100	Fill Material Placed in areas of soil remediation
6	10.0000	10.0000	10.0000	Inferred high K zone in bottom of valley above competent bedrock
7	0.0100	0.0100	0.0100	Upper 50' of bedrock in upland area
8	1.0000	1.0000	1.0000	Inferred high K zone downstream and paralled to Sherman Dam
9	0.1500	0.1500	0.1500	Thin sandy till & wx bedrock
10	0.0560	0.0560	0.0056	Lower 450' of bedrock
11	0.0060	0.0060	0.0004	Silty glacial till near MW-107
12	1.0000	1.0000	0.0100	Stratified fine sand & silt near MW-107
13	5.0000	5.0000	0.1000	Stratified fine sand & silt near MW-107
14	10.0000	10.0000	10.0000	Inferred Shallow fractured rock zone from plant well through MW-107

Figure 6-3
Pre-Demo Model Average Annual Precipitation Rate

Zone #	**Recharge Rate, Ft/day**	**Rate, inches per year**	**Area Applied**
1	0.00009	0.38475	Upland Thin Till and Exposed Bedrock
2	0.01000	42.75000	Glacio-fluvial deposits in the River Valley
3	0.00000	0.00000	Impervious Areas of Plant Prior to Pavement and Building Removal

Overall average land-applied recharge = 2.6 inches per year or 5.3% of precipitation

Table 6-4
Model Specific Storage, Specific Yield, and Porosity Zone Descriptions

Zone #	Specific Storage, /Ft	Sy	Porosity	Geologic Unit
1	1.00E-05	0.05	0.30	Glacio-fluvial sand and gravel; upland thin glacial till; sand layers; thin high yield fractured rock zone
2	5.00E-06	0.05	0.20	Thick dense glacial till
3	1.00E-07	0.03	0.30	Glaciolacustrine deposits, layers 9 through 13
4	3.00E-06	0.01	0.01	Typical bedrock
5	5.00E-06	0.20	0.20	Mixed origin soil near MW-107 in layers 2, 3, and 4

Table 6-5
Pre-Demo Model Average Annual Recharge Mass Balance

Description	Inflow, Ft3/day	Outflow, Ft3/day
Recharge	71501.89	0.00
Constant Head	657.16	55831.25
Drain	0.00	15597.00
Storage	0.00	0.00
TOTAL	72159.06	71428.24
ERROR	**1.02%**	

Table 6-6
Model Chemical Mass Balance for IXP Tritium Leak Simulation
1965-1985

Model Layer	Chemical Mass Balance
1	-2.49%
2	-3.90%
3	-0.78%
4	-4.37%
5	-8.26%
6	-3.46%
7	-6.88%
8	-199%
9	-0.65%
10	-0.64%
11	-0.10%
12	48.07%
13	-199%
14	-199%
15	-120%
TOTAL	**-199%**

Note that the large total mass balance is due to large errors at only a few cells not involved in the main transport pathways

Table 6-7
Pre-Demo Model Calibration Statistics for Steady-State Recharge

Mon. Well	Model Layer	Observed Head, Ft.	Computed Head, Ft.	Residual Head, Ft.
MW-100A	1	1117.07	1120.32	-3.25
MW-100B	14	1115.59	1111.51	4.08
MW-101A	2	1122.88	1123.21	-0.33
MW-101B	14	1104.98	1104.49	0.49
MW-101C	10	1092.99	1103.94	-10.95
MW-102A	3	1112.73	1110.16	2.57
MW-102B	14	1103.3	1099.20	4.10
MW-102C	7	1091.66	1101.19	-9.53
MW-102D	1	1118.12	1122.47	-4.35
MW-103A	1	1093.25	1099.01	-5.76
MW-103B	14	1055.93	1049.89	6.04
MW-103C	7	1075.5	1072.54	2.96
MW-104A	1	1110.51	1101.19	9.32
MW-104B	14	1055.74	1057.17	-1.43
MW-104C	5	1078.13	1084.53	-6.40
MW-105A	1	1112.31	1119.14	-6.83
MW-105B	14	1106.47	1093.15	13.32
MW-105C	3	1110.06	1107.07	2.99
MW-106A	1	1082.06	1084.72	-2.66
MW-106B	14	1051.48	1050.78	0.70
MW-106C	7	1058.71	1064.23	-5.52
MW-106D	12	1050.57	1052.97	-2.40
MW-107A	1	1122.8	1123.56	-0.76
MW-107B	14	1103.33	1102.72	0.61
MW-107C	3	1113.72	1114.33	-0.61
MW-107D	7	1095.35	1104.28	-8.93
MW-107E	5	1113	1107.87	5.13
MW-107F	5	1112.98	1107.77	5.21
MW-108A	1	1106	1108.49	-2.49
MW-108B	14	1067.04	1064.26	2.78
MW-108C	5	1104.61	1099.99	4.62
MW-109A	1	1115.27	1119.14	-3.87
MW-109B	14	1093.59	1080.05	13.54
MW-109C	3	1108.89	1105.85	3.04
MW-109D	7	1085.23	1084.47	0.76
MW-110A	1	1124.01	1125.24	-1.23
MW-110B	14	1104.51	1108.97	-4.46

Table 6-7
Pre-Demo Model Calibration Statistics for Steady-State Recharge

MW-110C	3	1116.61	1117.19	-0.58
MW-110D	5	1095.02	1108.67	-13.65
MW-111A	1	1121.48	1122.26	-0.78
MW-111B	14	1107.13	1106.88	0.25
MW-111C	3	1119.41	1112.66	6.75
MW-113A	1	1064.24	1058.60	5.64
MW-113C	5	1031.23	1044.25	-13.02

Residual Mean	**-0.34**
Res. Std. Dev.	**6.02**
Sum of Squares	**1599.49**
Abs. Res. Mean	**4.65**
Min. Residual	**-13.65**
Max. Residual	**13.54**
Range	**92.78**
Std/Range	**0.065**

Table 6-8

Pre-Demo Model Vertical Gradient Calibration Statistics for Average Annual Recharge

Name	Model Layer 1	Model Layer 2	Observed Gradient, Ft.	Computed Gradient, Ft.	Residual Gradient, Ft.
MW-100A	1	14	1.5	3.58	-2.08
MW-101A	2	14	17.5	19.18	-1.68
MW-101C	10	2	-29.5	-19.73	-9.77
MW-101C	10	14	-12	-0.64	-11.36
MW-102A	3	14	10	11.07	-1.07
MW-102A	3	7	21	8.99	12.01
MW-102A	3	1	-5.39	-13.21	7.82
MW-102C	7	14	-11	1.46	-12.46
MW-102D	1	14	14	23.81	-9.81
MW-102D	1	7	25	21.70	3.30
MW-103A	1	14	38.5	45.95	-7.45
MW-103B	14	7	-20	-22.18	2.18
MW-103C	7	1	-17.5	-23.73	6.23
MW-104A	1	14	54.5	44.61	9.89
MW-104A	1	5	32.5	17.01	15.49
MW-104B	14	5	-22	-27.05	5.05
MW-105A	1	14	5.5	23.05	-17.55
MW-105C	3	1	-2	-13.34	11.34
MW-105B	14	3	-3.5	-14.05	10.55
MW-106A	1	14	30.5	30.47	0.03
MW-106A	1	7	23	18.97	4.03
MW-106A	1	12	31.5	28.13	3.37
MW-106B	14	7	-7	-13.39	6.39
MW-106D	12	14	-1	2.44	-3.44
MW-106C	7	12	8	10.31	-2.31
MW-107A	2	14	19.5	17.35	2.15
MW-107A	2	3	9	5.51	3.49
MW-107A	2	7	27.5	15.65	11.85
MW-107A	2	5	10	12.43	-2.43
MW-107B	14	3	-10.5	-11.92	1.42
MW-107B	14	7	8	-1.69	9.69
MW-107B	14	5	-9.5	-4.86	-4.64
MW-107C	3	7	18.5	10.07	8.43
MW-107C	3	5	0.7	6.83	-6.13
MW-107D	7	5	-17.5	-3.34	-14.16
MW-108A	1	14	39	44.76	-5.76
MW-108B	14	5	-37.5	-36.19	-1.31

Table 6-8
Pre-Demo Model Vertical Gradient Calibration Statistics for Average Annual Recharge

MW-108C	5	1	-1.5	-10.23	8.73
MW-109A	1	14	21.5	43.17	-21.67
MW-109A	1	3	6.5	13.69	-7.19
MW-109B	14	3	-15.5	-27.81	12.31
MW-109B	14	7	8.5	-5.41	13.91
MW-109C	3	7	23.5	22.34	1.16
MW-109D	7	1	-30	-36.28	6.28
MW-110A	1	14	19.5	17.13	2.37
MW-110A	1	3	7.5	7.76	-0.26
MW-110A	1	5	29	16.80	12.20
MW-110B	14	3	-12	-8.82	-3.18
MW-110C	3	5	21.5	8.39	13.11
MW-110D	5	14	-9.5	0.42	-9.92
MW-111A	1	14	14.5	17.98	-3.48
MW-111B	14	3	-12.5	-7.23	-5.27
MW-111C	3	1	-2	-10.07	8.07
MW-113A	1	5	33	14.80	18.20
Residual Mean			**1.23**		
Res. Std. Dev.			**8.81**		
Sum of Squares			**4275.54**		
Abs. Res. Mean			**7.32**		
Min. Residual			**-21.67**		
Max. Residual			**18.20**		
Range			**92.00**		
Std/Range			**0.096**		

Table 6-9
Pre-Demo Verification Data Set Calibration Statistics

Mon. Well	X	Y	Model Layer	Observed Head, Ft.	Computed Head, Ft.	Residual Head, Ft.
CB-1	272,442.5	3,093,618.6	2	1115.97	1118.67	-2.70
CB-10	272,458.1	3,093,542.6	1	1124.05	1124.90	-0.85
CB-2	272,148.0	3,093,716.7	2	1105.68	1105.20	0.48
CB-3	272,493.2	3,093,282.0	1	1134.05	1137.87	-3.82
CB-4	271,469.9	3,093,627.5	1	1075.59	1089.17	-13.58
CB-5	273,112.2	3,093,260.5	2	1151.93	1162.36	-10.43
CB-6	272,014.0	3,093,781.6	2	1097.84	1097.32	0.52
CB-8	272,609.4	3,093,424.4	1	1135.18	1139.81	-4.63
CB-9	272,371.5	3,093,562.0	2	1116.57	1118.53	-1.96
CFW-1	272,941.1	3,093,089.4	1	1165.02	1167.31	-2.29
CFW-2	273,029.6	3,093,361.5	2	1155.45	1171.80	-16.35
CFW-3	273,120.9	3,093,430.3	5	1146.9	1170.62	-23.72
CFW-4	273,125.1	3,093,431.2	7	1146.65	1170.04	-23.39
CFW-5	273,242.3	3,093,499.5	1	1139.44	1128.33	11.11
CFW-6	273,170.0	3,093,653.2	1	1134.34	1134.87	-0.53
CFW-7	273,079.1	3,093,400.1	2	1155.38	1163.75	-8.37
CW-10	272,659.7	3,093,880.3	14	1104.43	1120.34	-15.91
CW-11	272,450.3	3,093,523.8	1	1127.01	1125.37	1.64
CW-2	272,388.5	3,093,387.5	2	1125.05	1126.94	-1.89
CW-3	272,534.8	3,093,532.1	2	1131.04	1131.00	0.04
CW-4	272,594.7	3,093,367.8	2	1132.38	1137.25	-4.87
CW-5	272,518.2	3,093,690.7	1	1117.72	1119.32	-1.60
CW-6	272,151.8	3,093,596.3	2	1110.73	1109.49	1.24
CW-7	272,368.6	3,093,769.8	2	1108	1112.42	-4.42
CW-8	272,231.2	3,093,660.0	2	1107.03	1107.16	-0.13
MW-2	272,419.5	3,093,492.1	1	1123.23	1126.44	-3.21
MW-5	272,434.6	3,093,555.6	1	1122.63	1124.34	-1.71
MW-6	272,280.1	3,093,483.7	2	1118.81	1119.82	-1.01
OSR-1	272,939.0	3,093,245.8	1	1152.5	1159.52	-7.02
Residual Mean				-4.81		
Res. Std. Dev.				7.47		
Sum of Squares				2288.23		
Abs. Res. Mean				5.84		
Min. Residual				-23.72		
Max. Residual				11.11		
Range in Target Values				89.43		
Std. Dev./Range				0.084		

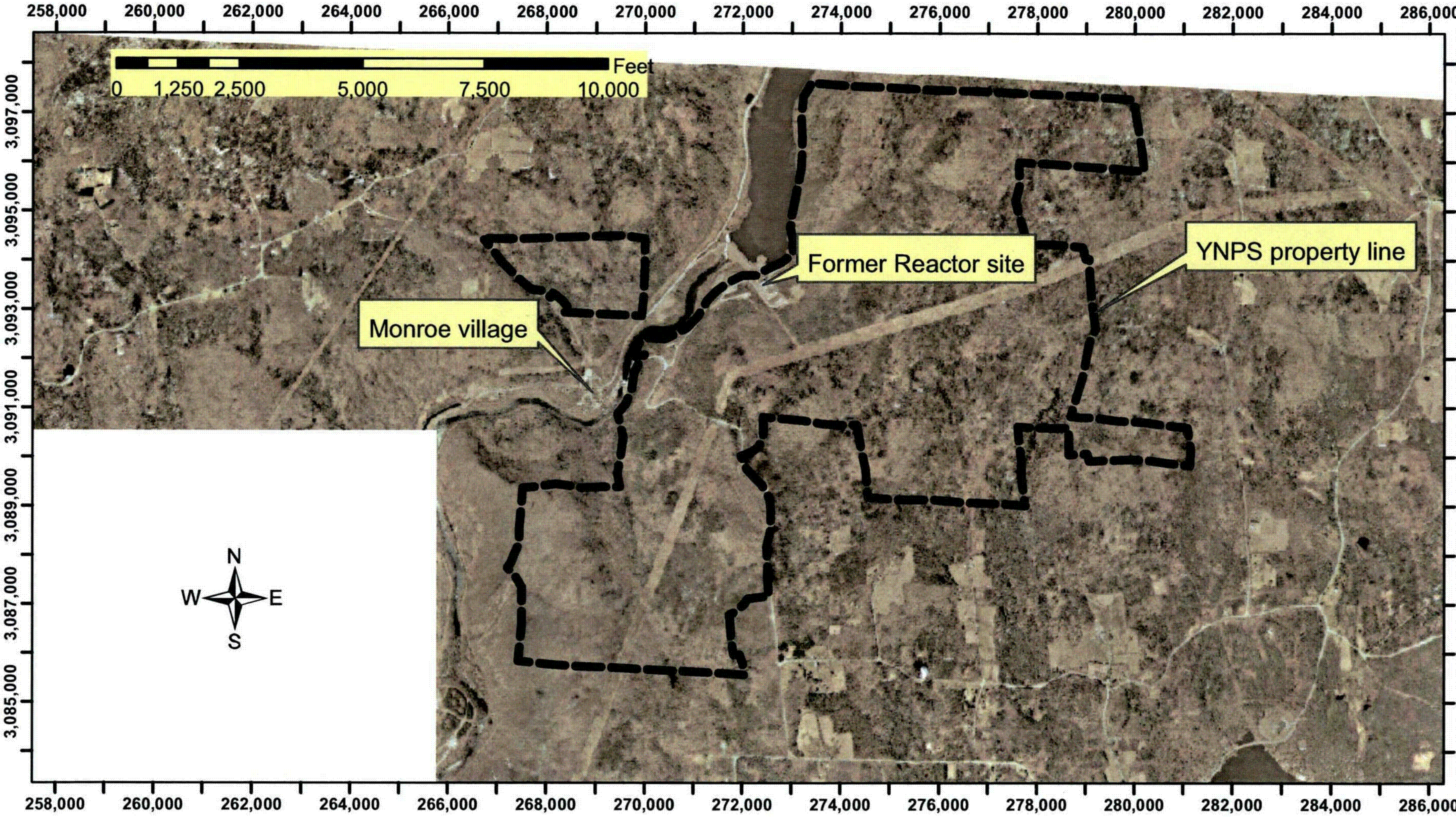
Table 6-10
Calculation of Weighted Tritium Concentration in Resident Farmer Well

Model Layer	Pumping Well Contribution from Each Layer, Ft3/day	Tritium Conc., pCi/L, at start of pumping April 2007	Flux times Mass
2	0.878	33,000	28,974
3	0.152	28,000	4,256
4	0.7	35,000	24,500
5	126.271	7,800	984,914
		TOTAL	**1,042,644**

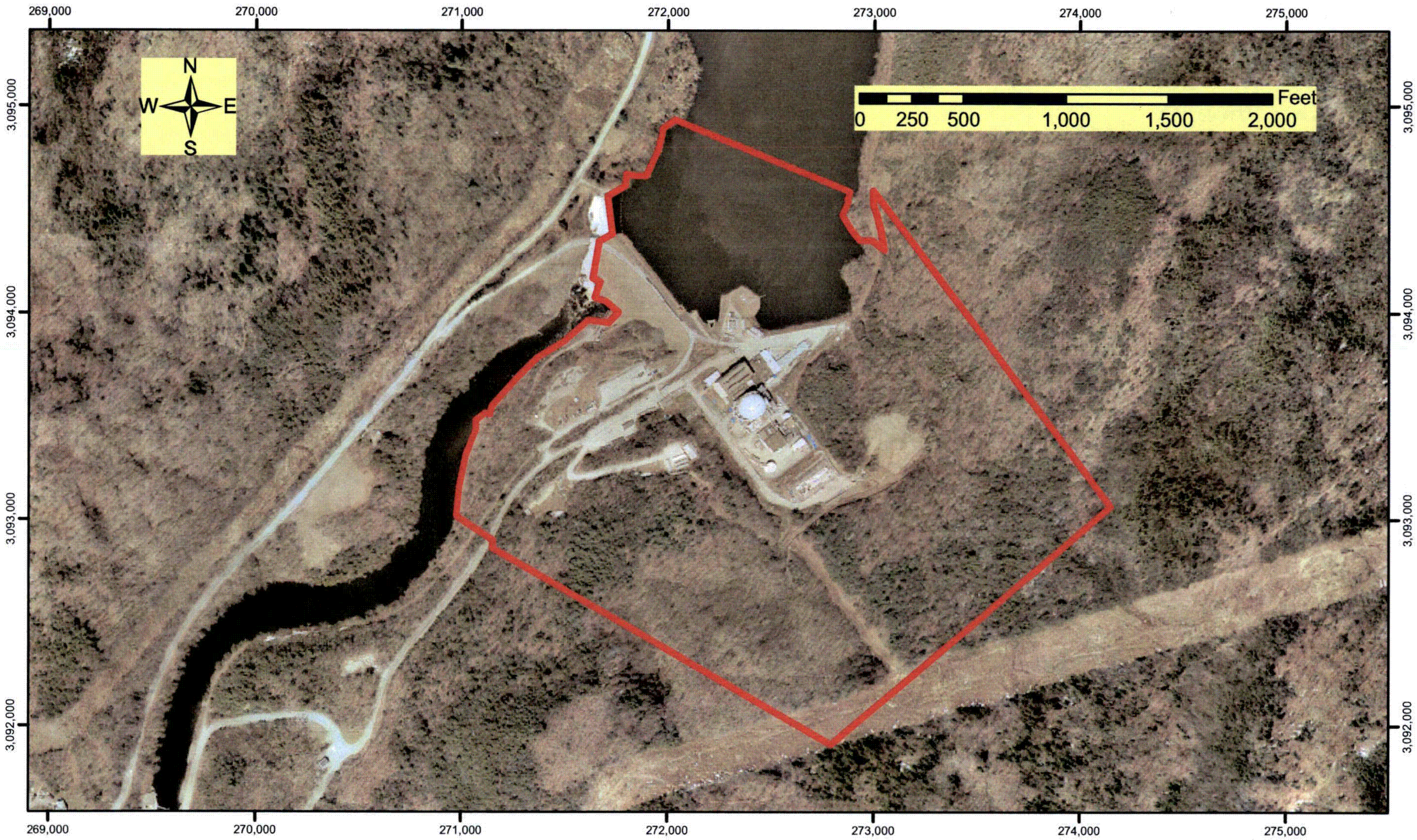
1,042,644 divided by 128 = **8146 pCi/L of tritium as weighted concentration**

Model Layer	Pumping Well Contribution from Each Layer, Ft3/day	Tritium Conc., pCi/L, after 2 Years of Pumping	Flux times Mass
2	0.878	19,188	16,847
3	0.152	16,822	2,557
4	0.7	18,813	13,169
5	126.271	4,900	618,728
		TOTAL	**651,301**

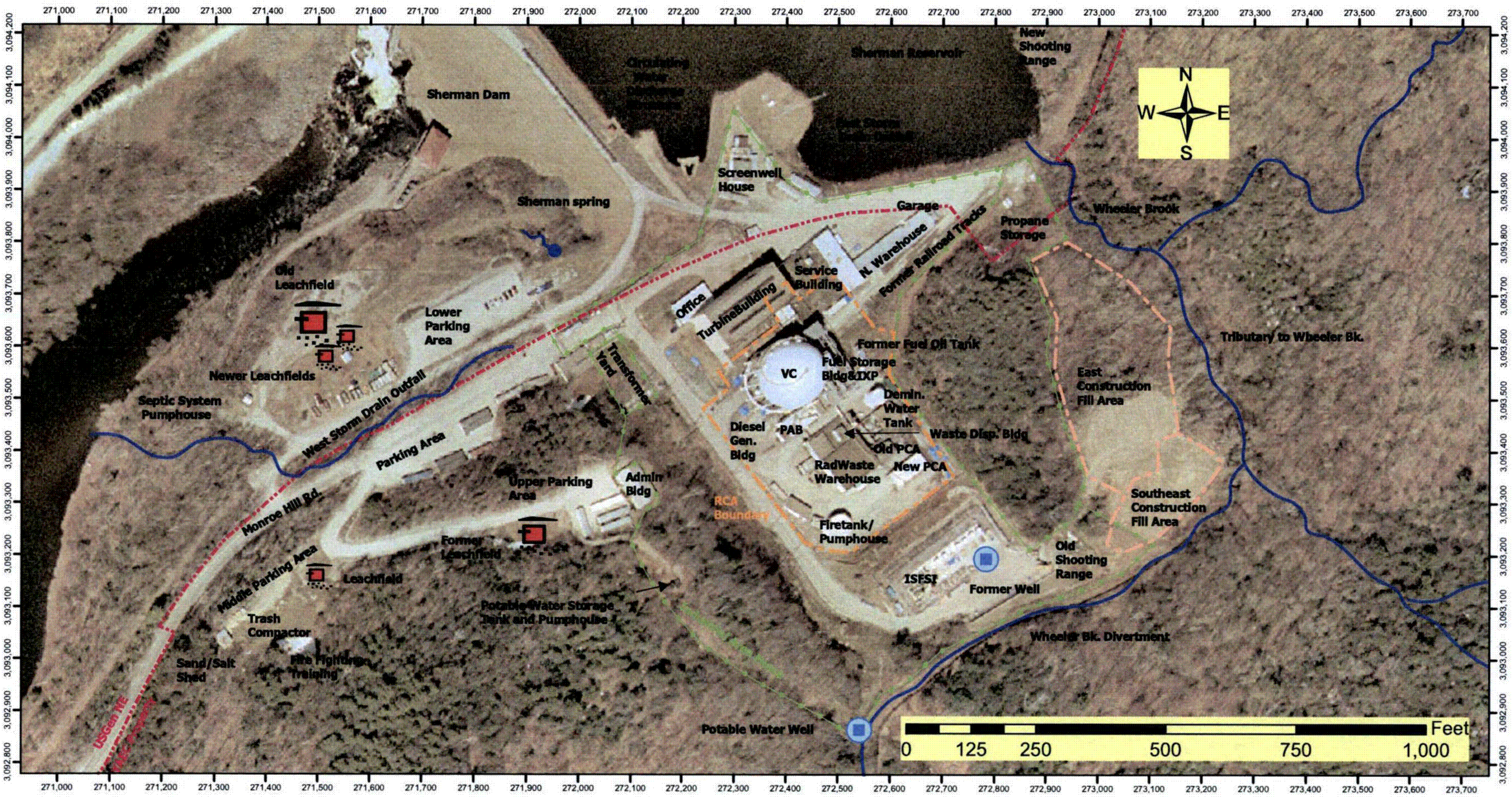
651,301 divided by 128 = **5088 pCi/L of tritium as weighted concentration**



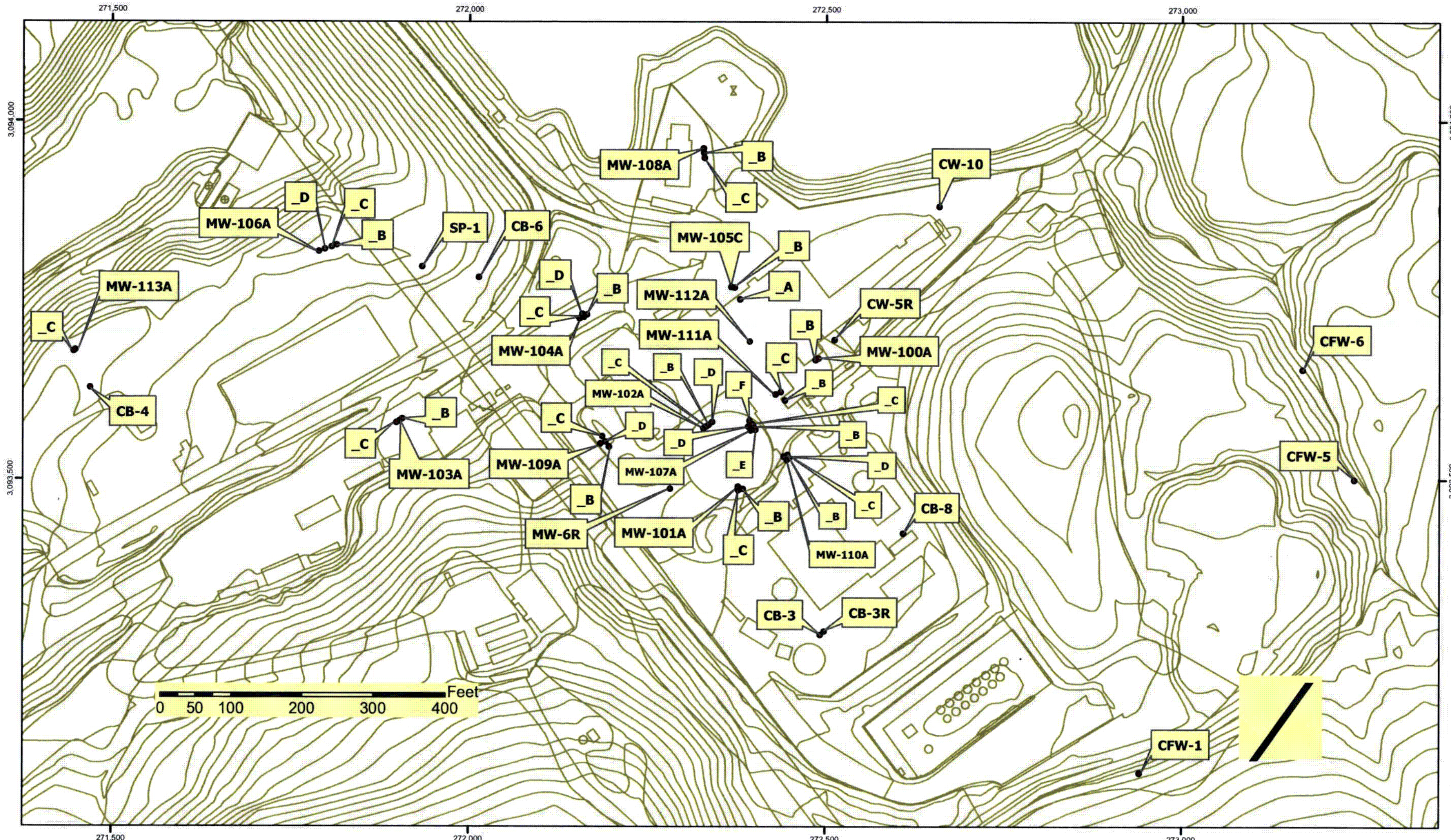
Yankee Nuclear Power Station Rowe, MA	Location of Yankee Nuclear Power Station Property Boundaries and Regional Context on the Deerfield River 1/29/07	Final Groundwater Condition Report *Figure 1-1*



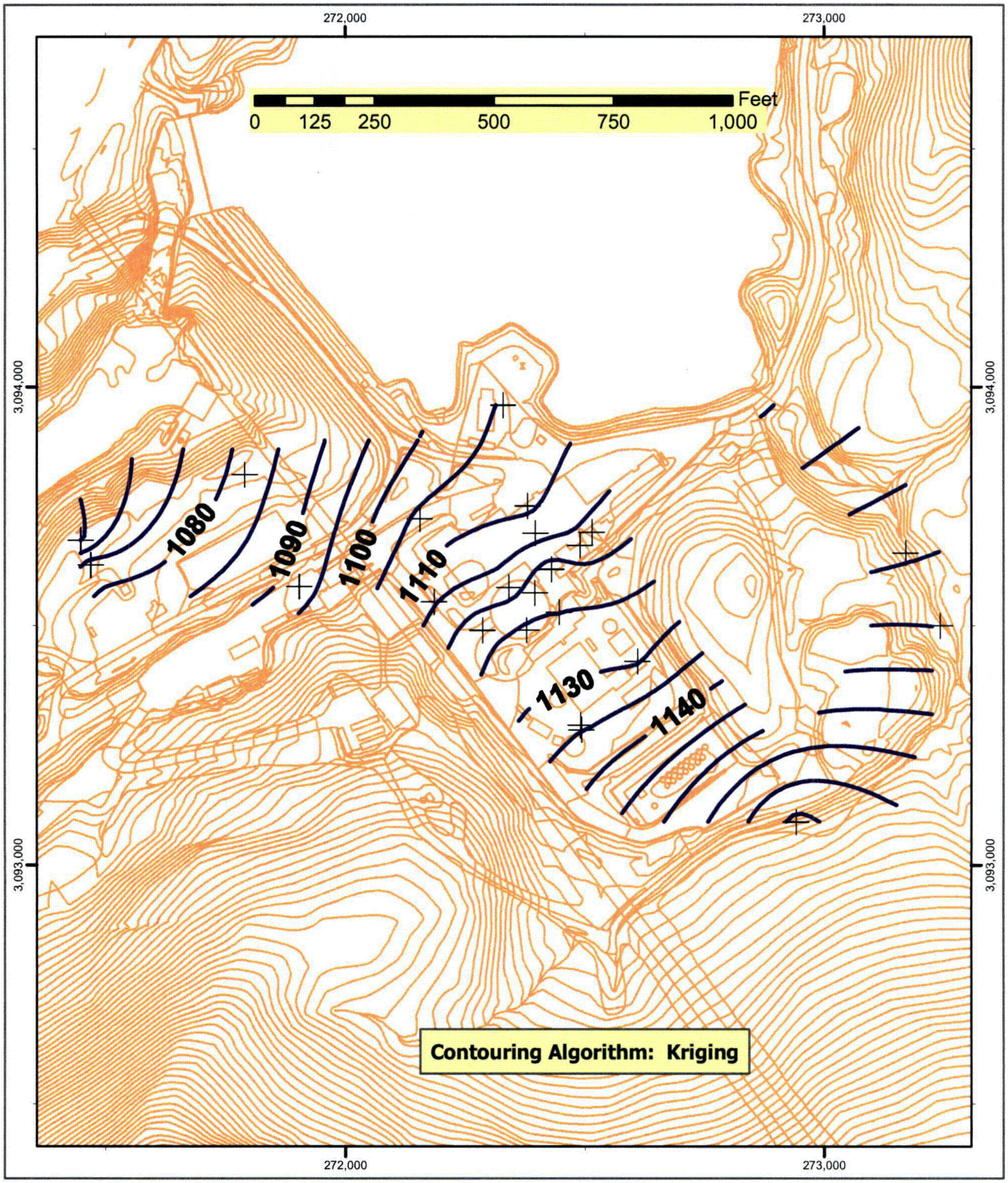
Yankee Nuclear Power Station Rowe, MA	**Current 10 CFR Part 50 Licensed Site Boundary** Source: FSAR Figure 300-2 Aerial photos taken 4/15/97 1/29/07	**Final Groundwater Condition Report** ***Figure 1-2***



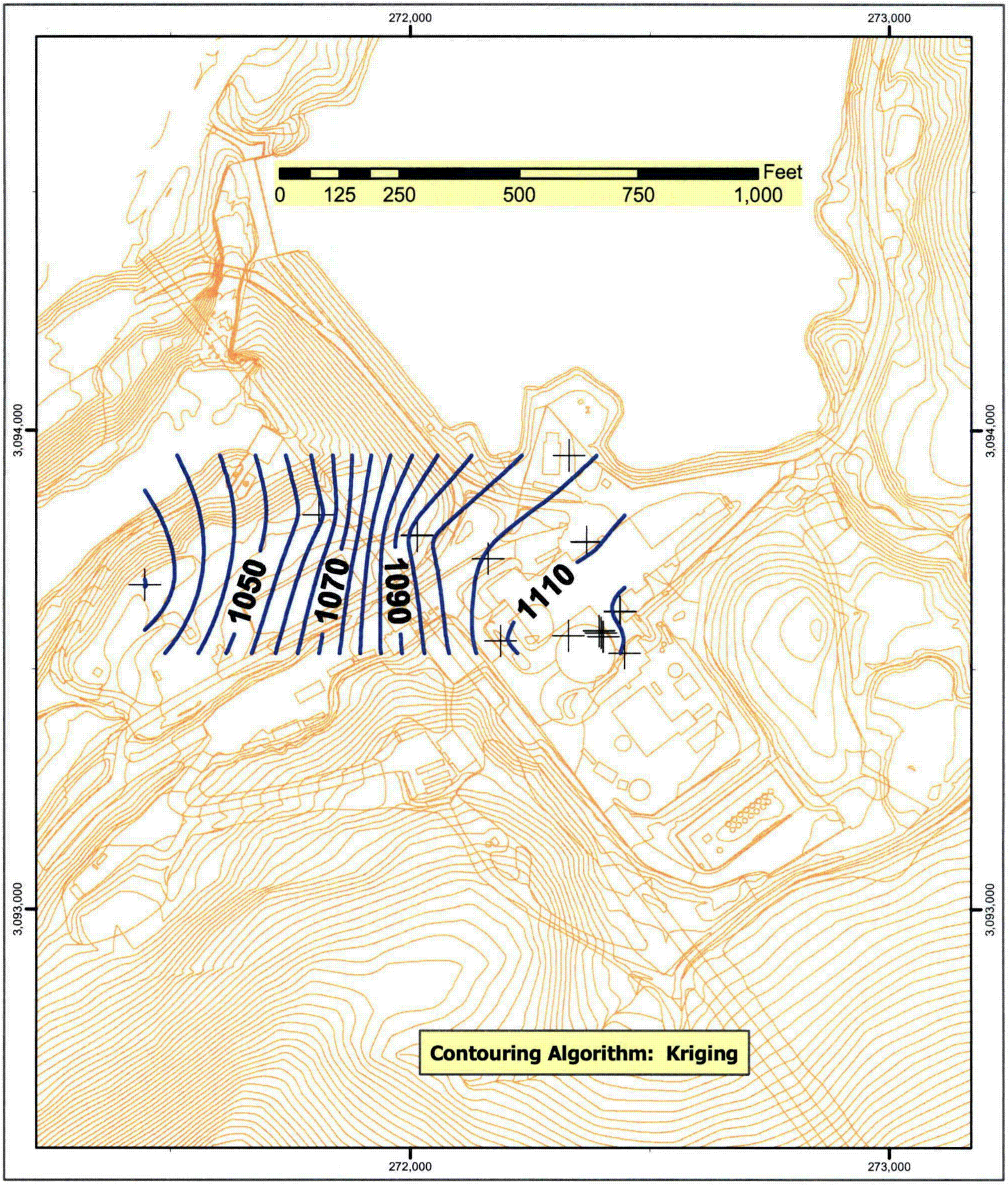
Yankee Nuclear Power Station Rowe, MA	*YNPS Plant Site Map* Aerial photos taken 4/15/97 1/29/07	**Final Groundwater Condition Report** ***Figure 1-3***



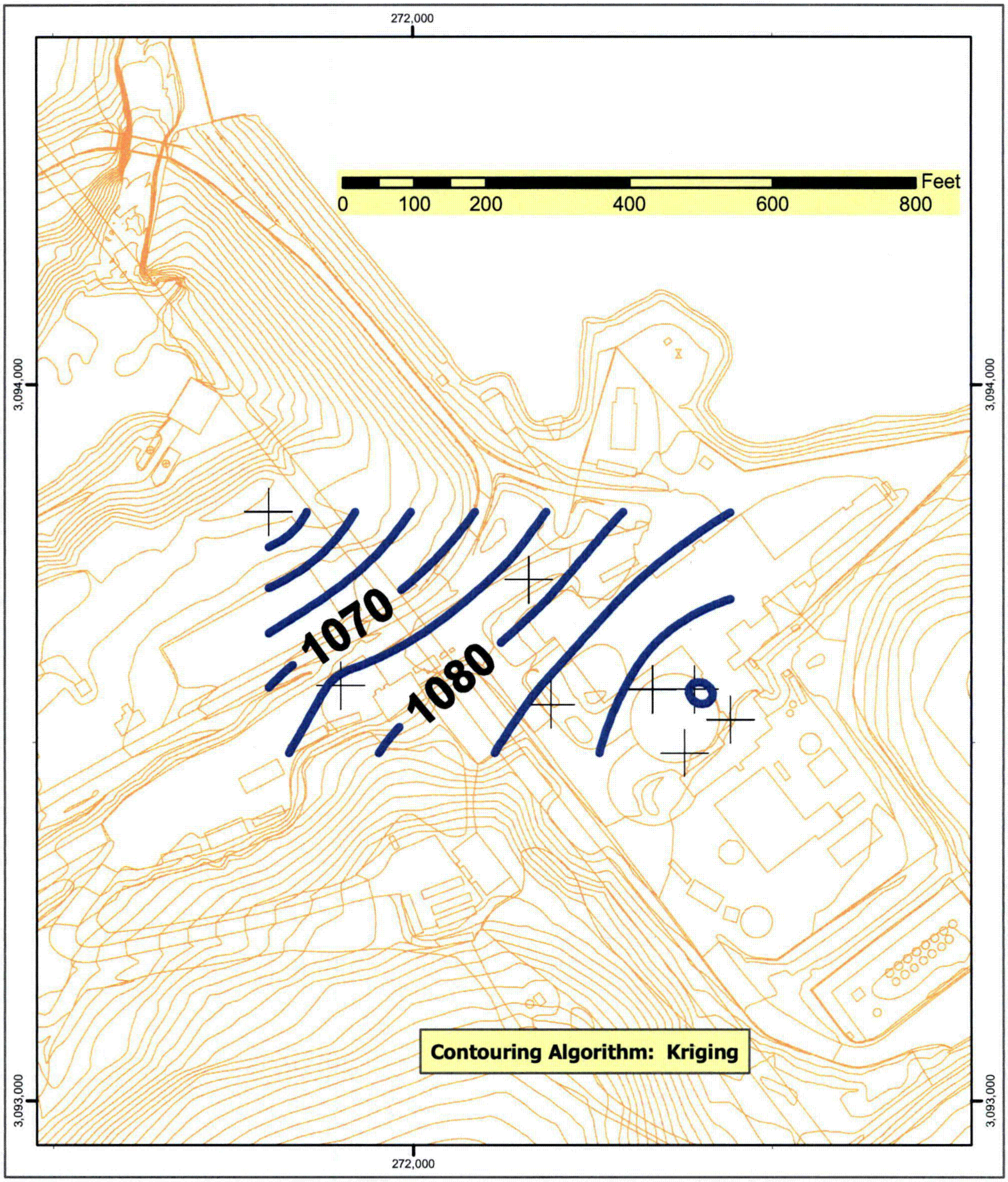
Yankee Nuclear Power Station Rowe, MA	***Locations of Groundwater Monitoring Wells***	1/30/07	**Final Groundwater Condition Report** ***Figure 1-4***



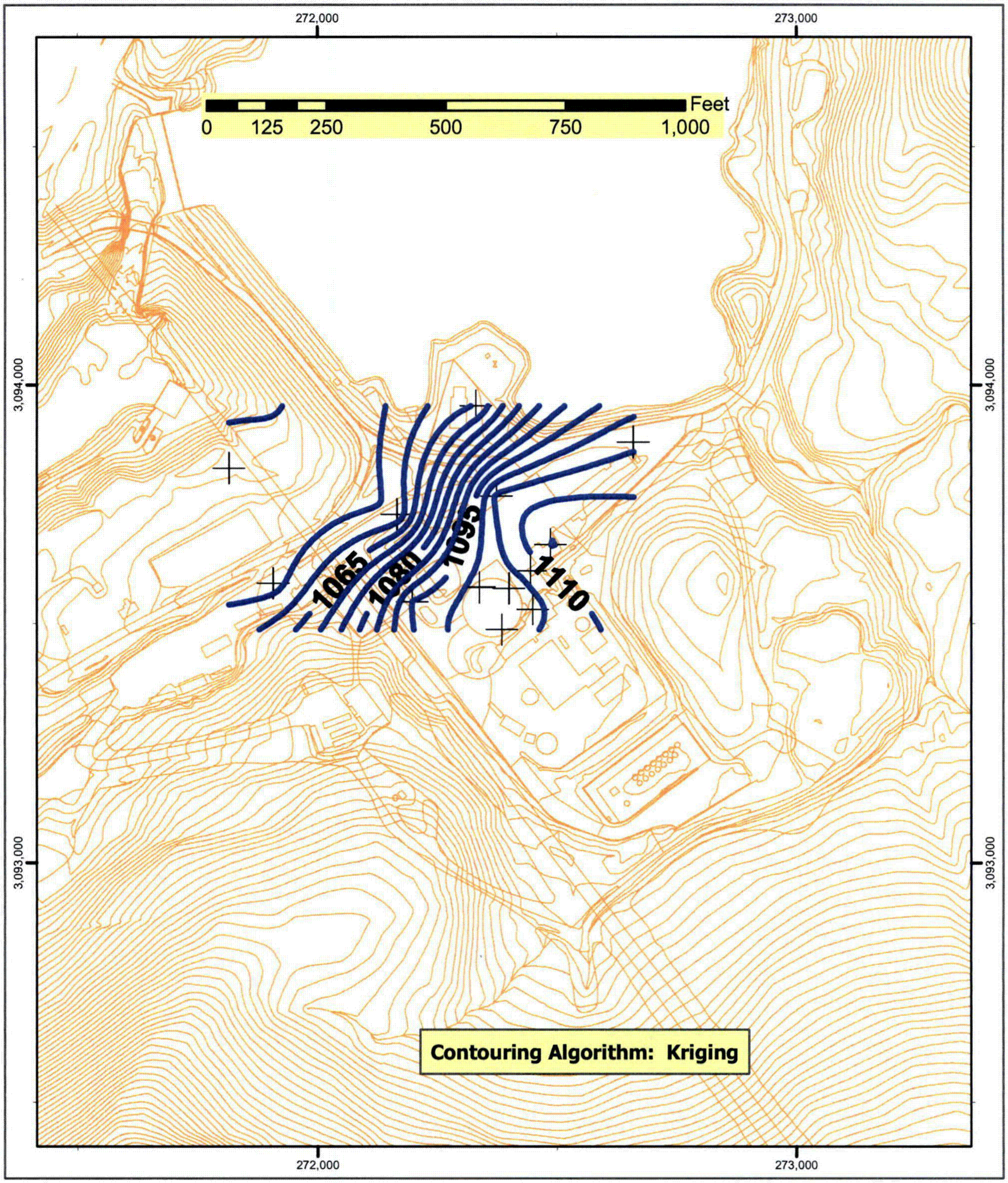
Yankee Nuclear Power Station Rowe, MA	***9/11/06 Glaciofluvial Groundwater Contours and Data Points*** **Contour Interval 5' NAVD88, Ft.**	**1/24/07**	**Final Groundwater Condition Report** ***Figure 2-1***



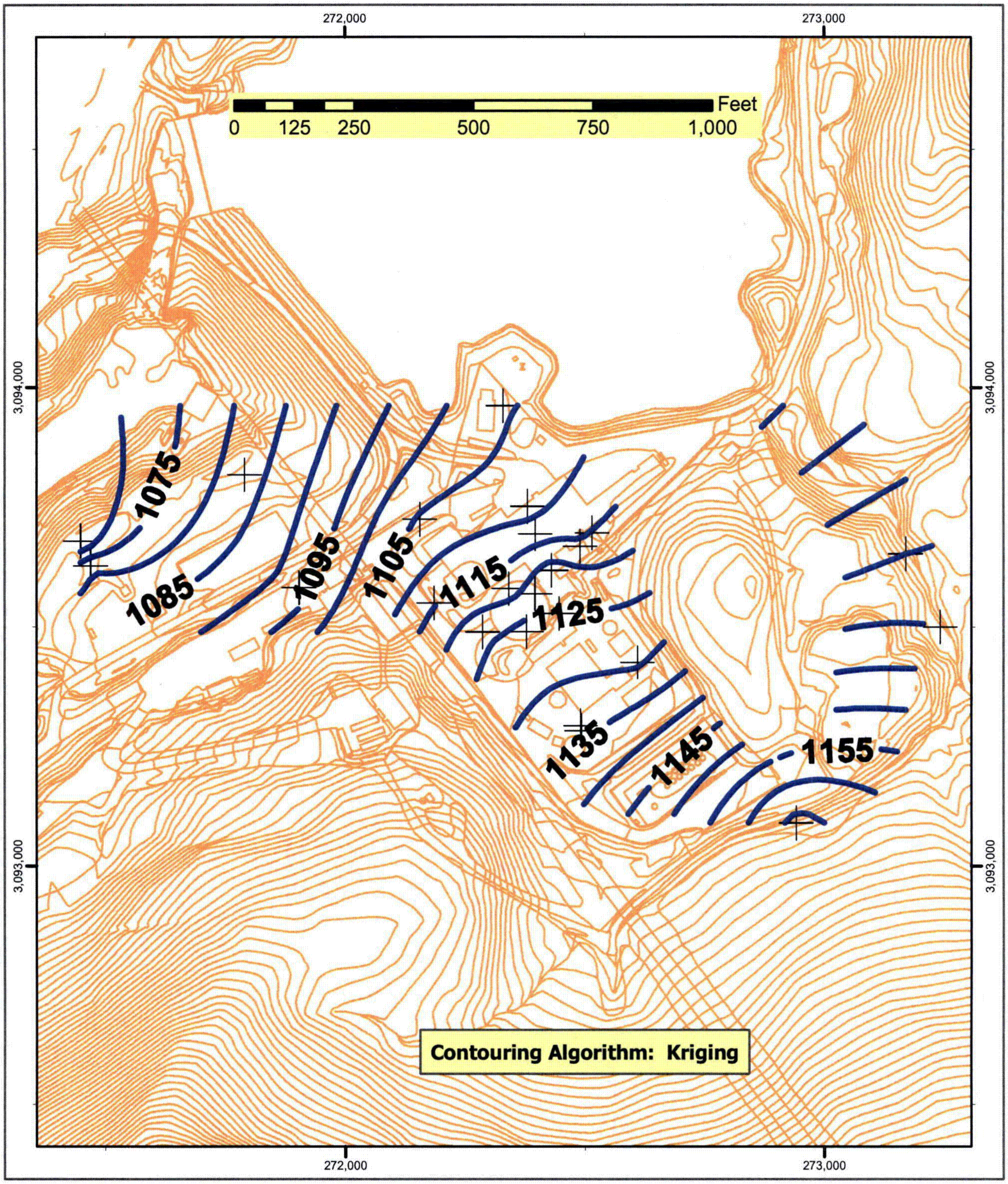
Yankee Nuclear Power Station Rowe, MA	***9/11/06 Groundwater Elevation in Upper Till and Data Points*** **Contour Interval 5' NAVD88, Ft.**	**1/24/07**	**Final Groundwater Condition Report** ***Figure 2-2***



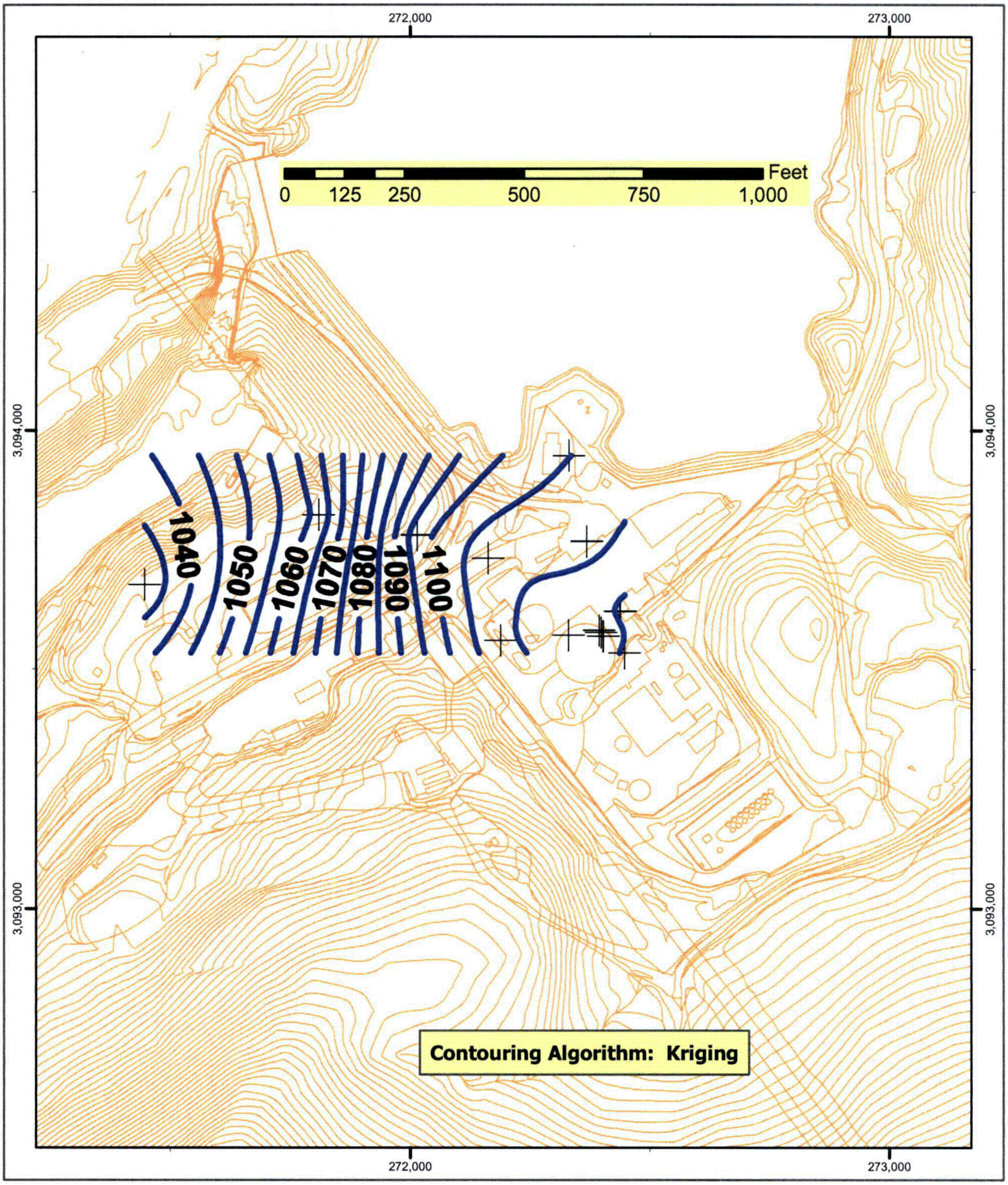
Yankee Nuclear Power Station Rowe, MA	***9/11/06 Groundwater Elevation in Lower Till & Glaciolacustrine and Data Points*** **Contour Interval 5' NAVD88, Ft.**	**1/24/07**	**Final Groundwater Condition Report** ***Figure 2-3***



Yankee Nuclear Power Station Rowe, MA	***9/11/06 Groundwater Elevation in Bedrock and Data Points*** **Contour Interval 5' NAVD88, Ft.**	/ **1/24/07**	**Final Groundwater Condition Report** ***Figure 2-4***

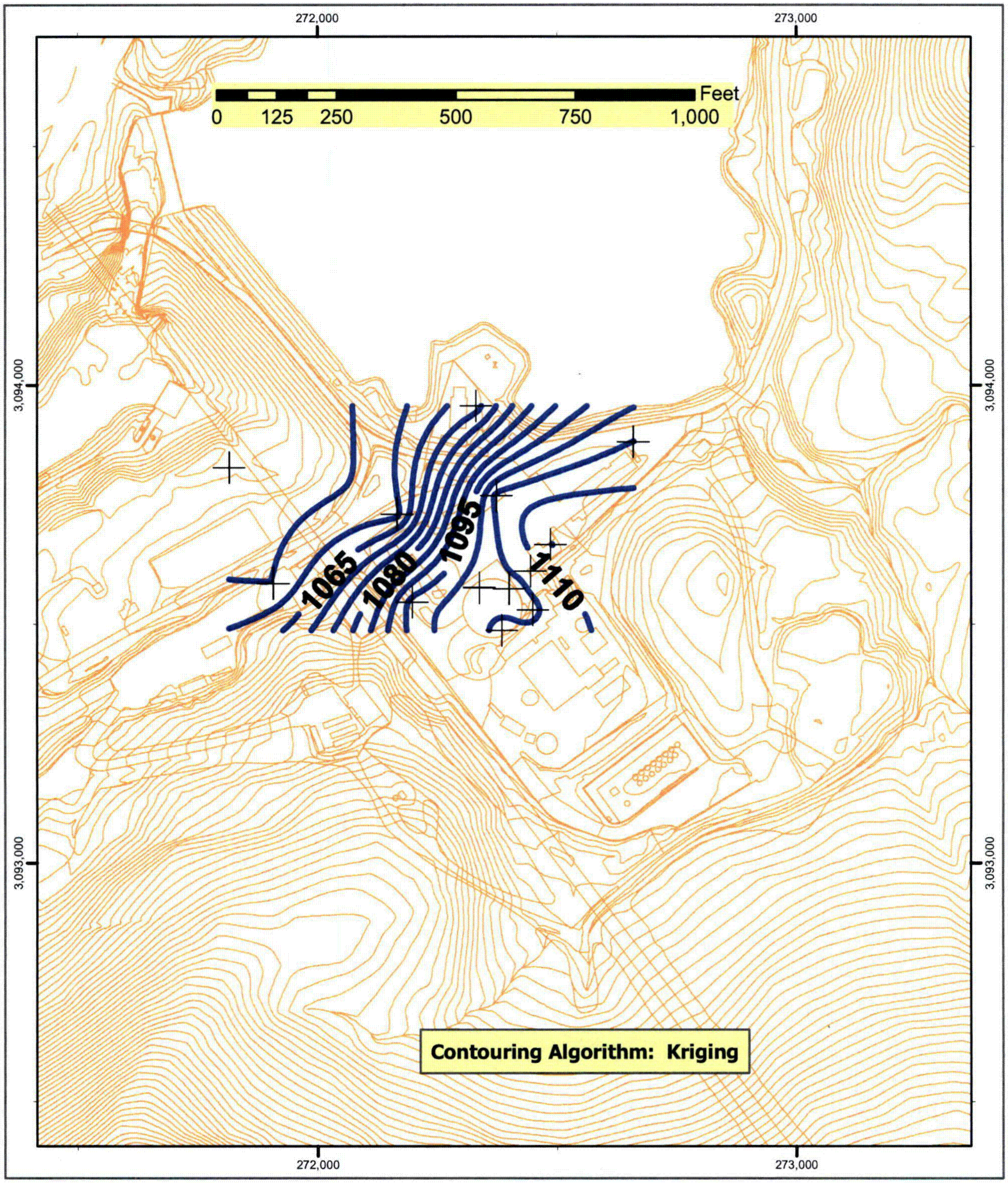


Yankee Nuclear Power Station Rowe, MA	***12/4/06 Glaciofluvial Groundwater Contours and Data Points*** **Contour Interval 5' NAVD88, Ft.**	**1/25/07**	**Final Groundwater Condition Report** ***Figure 2-5***



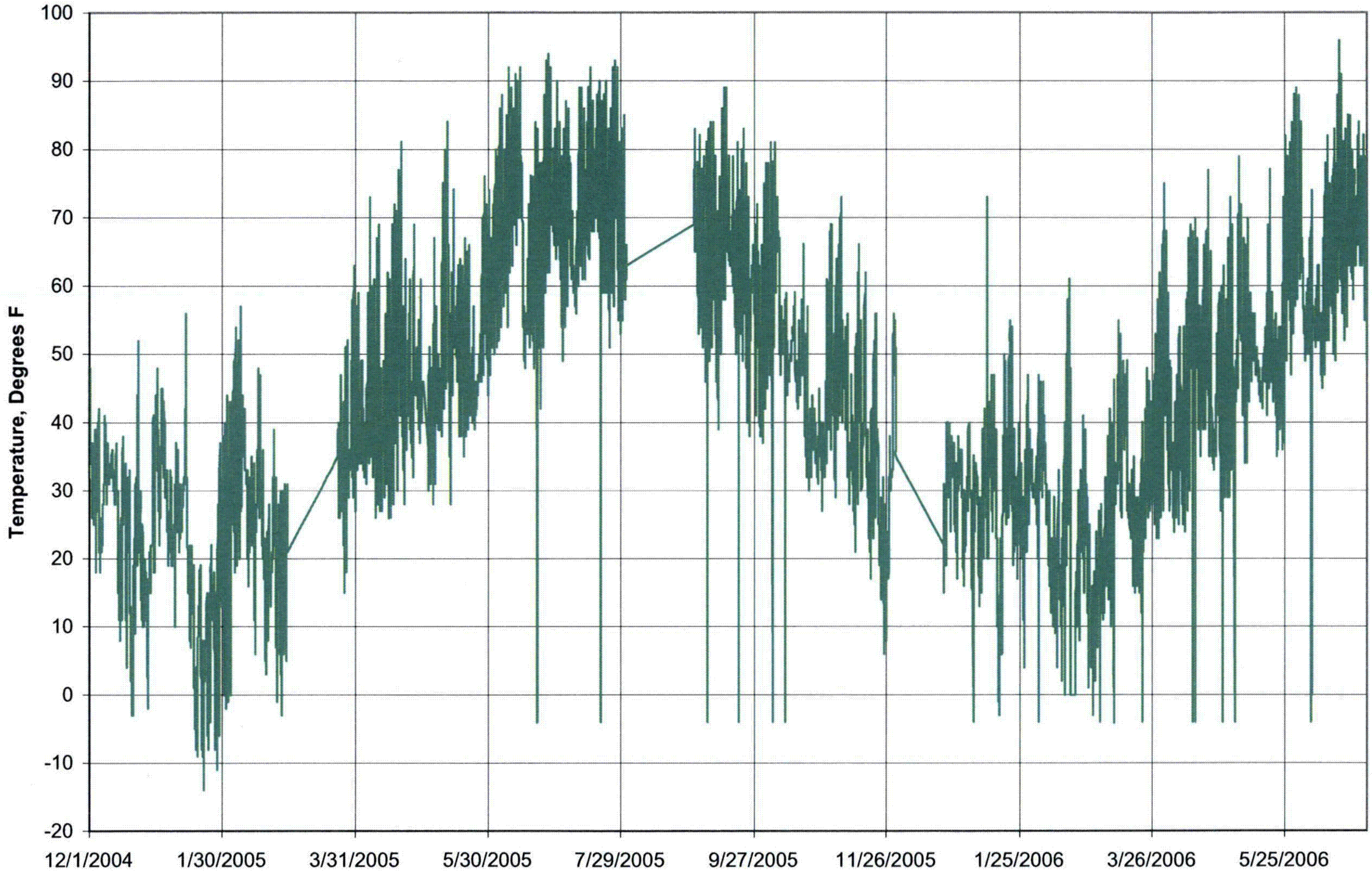
Yankee Nuclear Power Station Rowe, MA	***12/4/06 Groundwater Elevation in Upper Till and Data Points*** Contour Interval 5' NAVD88, Ft.	/ 1/25/07	Final Groundwater Condition Report ***Figure 2-6***

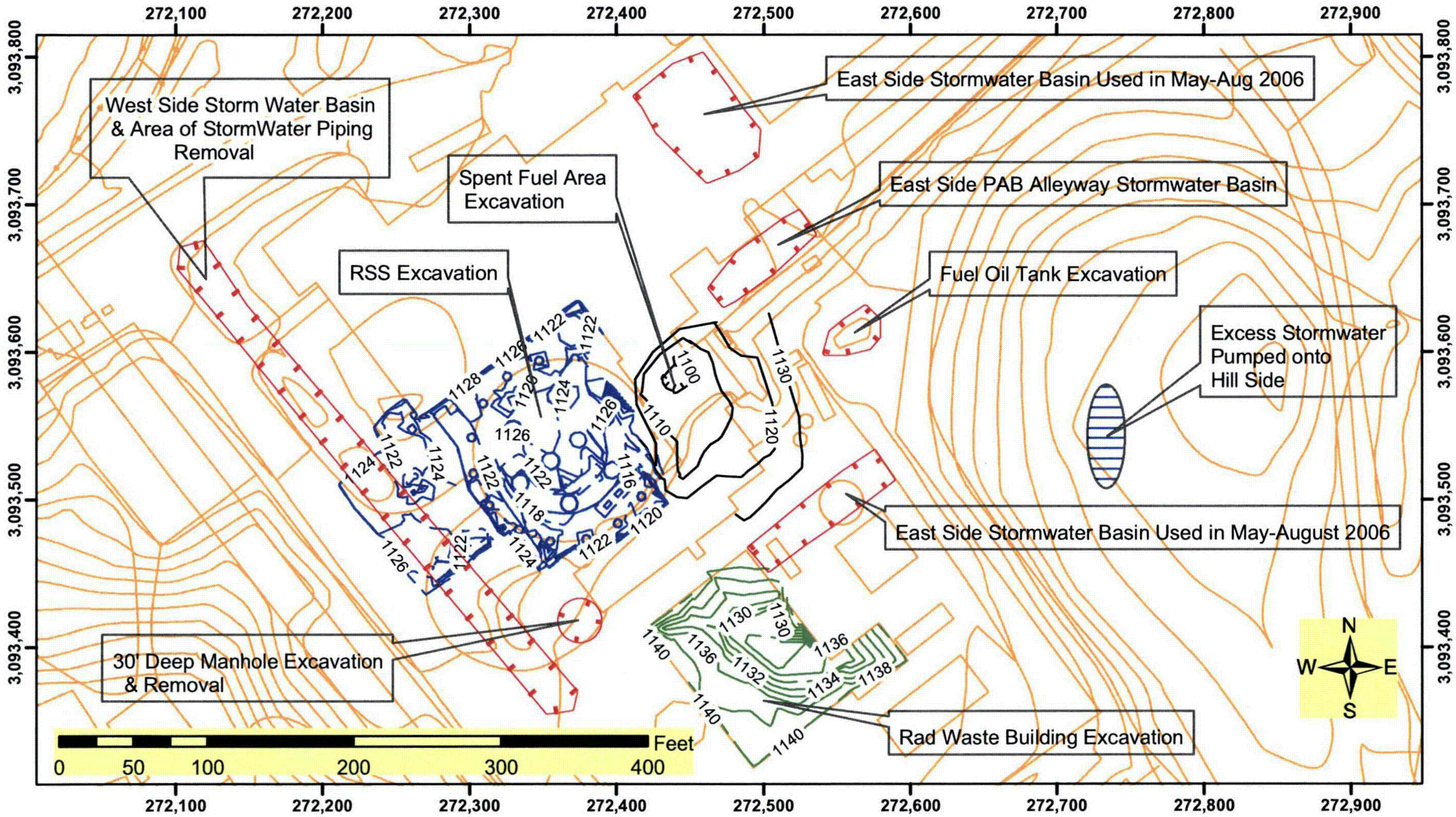
Yankee Nuclear Power Station Rowe, MA	***12/4/06 Groundwater Elevation in Lower Till & Glaciolacustrine and Data Points*** **Contour Interval 5' NAVD88, Ft.**	**1/24/07**	**Final Groundwater Condition Report** ***Figure 2-7***



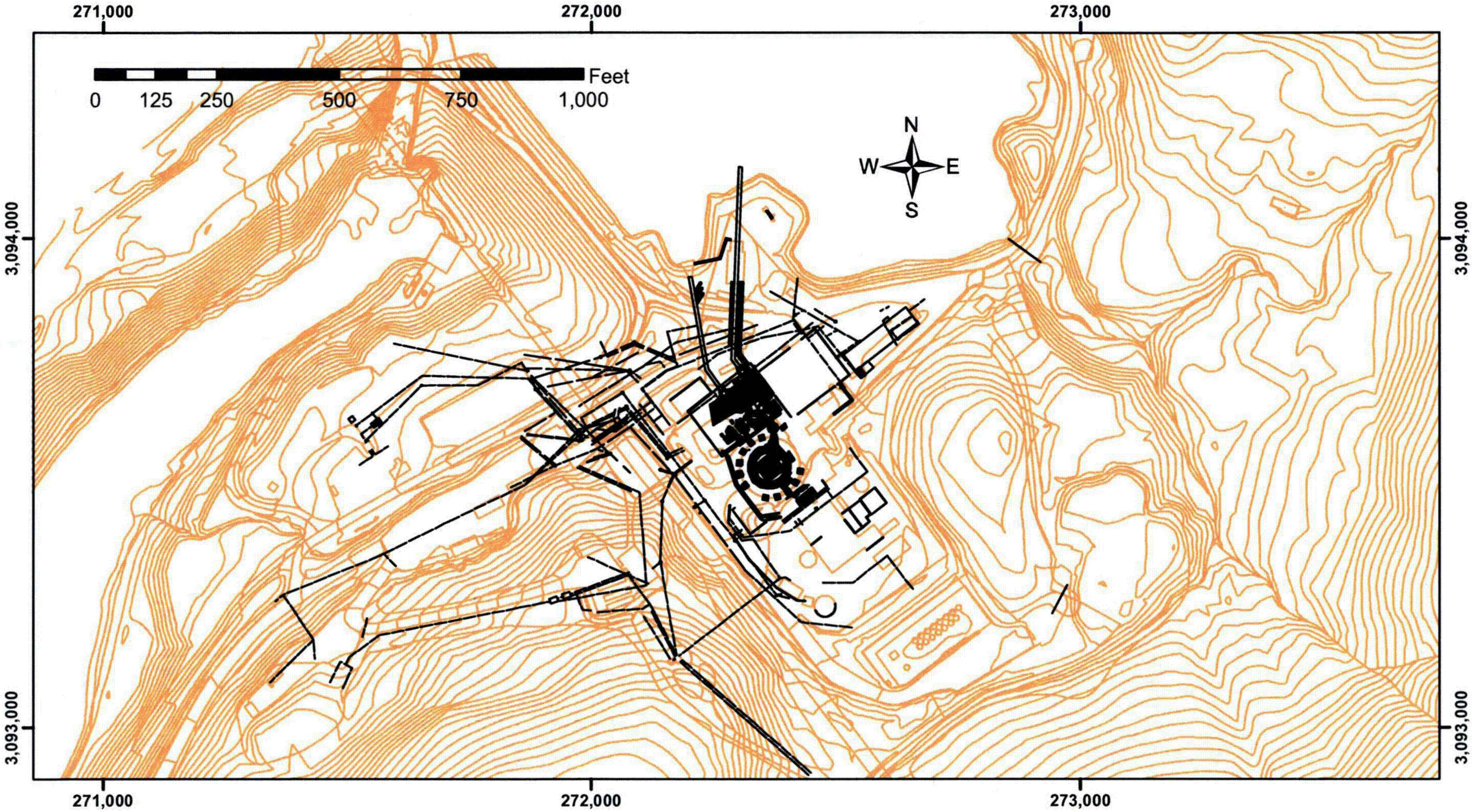
Yankee Nuclear Power Station Rowe, MA	***12/4/06 Groundwater Elevation in Bedrock and Data Points*** **Contour Interval 5' NAVD88, Ft.**	**1/24/07**	**Final Groundwater Condition Report** ***Figure 2-8***

Figure 2-9
Ambient Air Temperature at YNPS Site

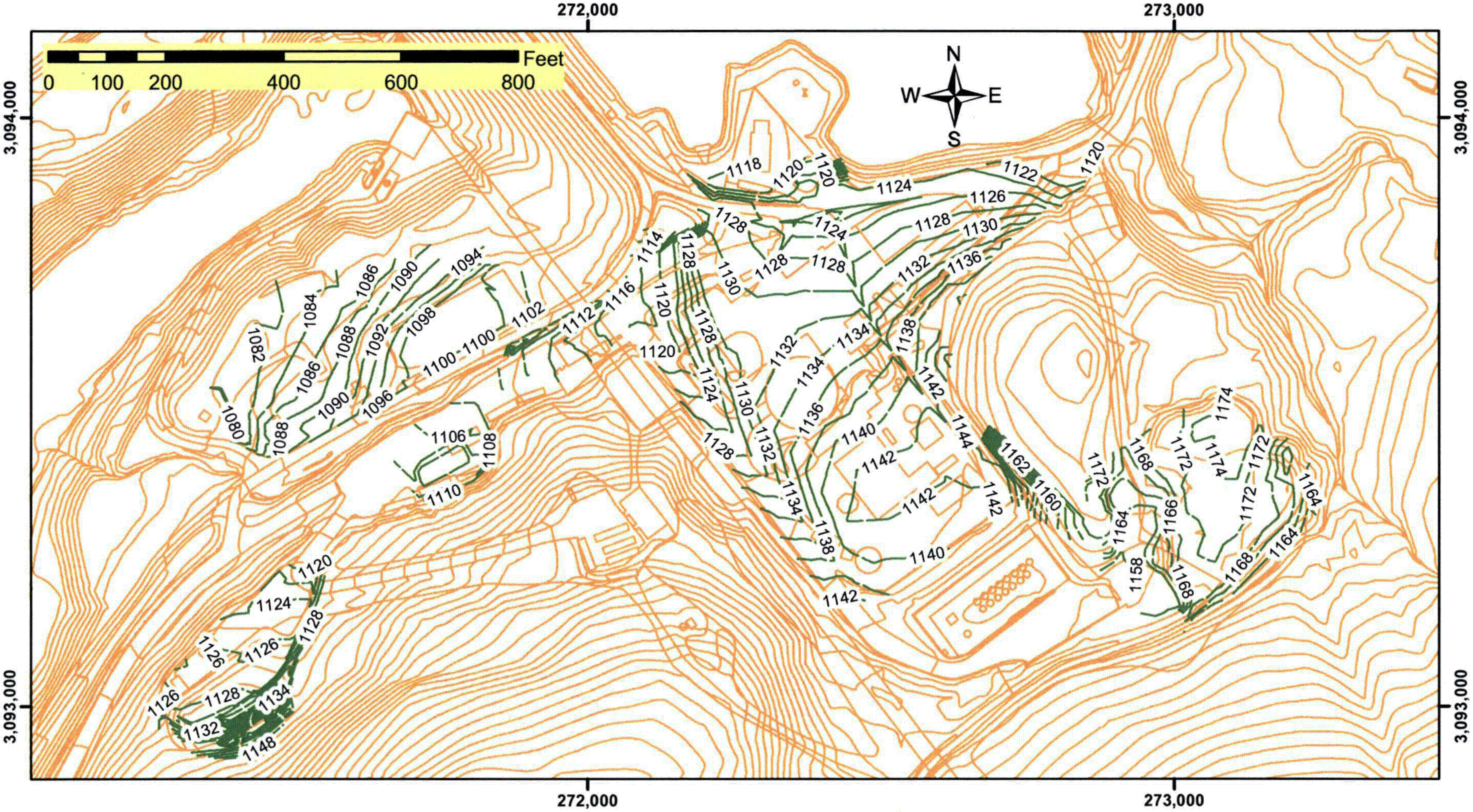




Yankee Nuclear Power Station Rowe, MA	**Deep Excavations for Utility and Soil Removal and Locations of Temporary Stormwater Basins During 2006** The contours of the RSS, Spent Fuel, and Rad Waste Building Excavations were surveyed by Cianbro to NAVD88, Feet 1/29/07	**Final Groundwater Condition Report** ***Figure 2-10***



Yankee Nuclear Power Station Rowe, MA	**Concrete Slabs, Foundation Walls, and Underground Utilities Left in Place, Post Demolition** 1/29/07	**Final Groundwater Condition Report** ***Figure 2-11***



Yankee Nuclear Power Station Rowe, MA	Final Site Ground Surface Contours in Post-Demo State Contours referenced to NADV88 datum 1/29/07	Final Groundwater Condition Report ***Figure 2-12***