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PHELPS ENGINEERING, INC.
TOWN OF WAITSFIELD
Waitsfield, Vermont

SOURCE EVALUATION REPORT: WELL R-1

1.0 INTRODUCTION

On behalf of Phelps Engineering, Inc. and the Town of Waitsfield, Pioneer Environmental Associates, LLC. (Pioneer) presents this report summarizing well and aquifer testing conducted on Well R-1 in Waitsfield, Vermont. The well was tested in order to determine its yield and suitability for supplying water to a proposed new Public Community Water System (PCWS) to supply the town. On June 21, 2005, Pioneer submitted a Source Application for proposed Wells R-1 and R-2 to the Vermont Water Supply Division (WSD). The application was approved on August 30, 2005 following a three-week public comment period and a public hearing on August 24, 2005. Well R-1 was completed on September 8, 2006. Well R-2 was not drilled because it was determined not to be needed following the successful installation of Well R-1. Subsequently, Pioneer submitted a Source Testing Application for the testing of Well R-1 on November 21, 2006, which was approved on November 29, 2006. Source Testing was conducted during November and December of 2006, in accordance with the Source Testing Application.

Based on source testing conducted during November and December 2006, Pioneer has determined that Well R-1 has a stand-alone yield of 269 gallons per minute (gpm), but due to interference caused to, and caused by, Houston wells 2 and 3, the maximum approvable safe yield of the well is 186 gpm. At the recommended safe yield of 186 gpm, Well R-1 would not cause unacceptable interference to other water supply sources. Water quality is acceptable, and is not impacted by any potential contaminant sources in the watershed. The average age of the water in Well R-1 is between 40 and 50 years. A Source Protection Area (SPA) has been delineated for the well based on the pump test results. Pioneer recommends that a Source Permit be issued for the well approving a yield of 186 gpm.

2.0 HYDROGEOLOGIC SETTING

Well R-1 is located in the Town of Waitsfield, in the Vermont Green Mountain foothills. The well is situated at an elevation of 1,150 feet, on the lower slopes of Scrag Mountain in the Northfield Mountain Range. A deep layer of glacial till covers the bedrock in the vicinity of the well; bedrock is mapped as the Stowe formation, consisting of Ordovician-age schist and phyllite with interbeds of calcareous greenstone, containing primarily quartz-sericite and chlorite minerals (Vermont Geological Survey, 1961). The Source Location Map on page 1 of Appendix 1, and the Monitoring Map on page 1 of Appendix 3 show the well location over USGS topographic and orthophoto bases, respectively. Surficial and bedrock geology are shown on the Wellhead Protection Area (WHPA) Delineation map on page 2 and the Surficial Geology Map on page 3 of Appendix 1.

The well is situated in the Pine Brook watershed, and the upslope terrain slopes upwards towards the east, south, and west, forming the likely recharge area for the bedrock aquifer.

2.1 Well Details

Well R-1 was completed on September 8, 2006 by Spafford and Sons Water Wells, with an estimated yield of 250 gpm according to the driller. A specialized casing was installed by D.L. Maher as a subcontractor to Spafford, in order to seal the extremely high pressure from the artesian aquifer. The well completion report is on pages 4 through 5 of Appendix 1, and the Well ID Sheet is included on pages 6 and 7 of Appendix 1. The well consists of an eight-inch diameter hole in the bedrock, with 118.5 feet of casing. The casing comprises a 16-inch outer casing to 37 feet below grade, a 12-inch middle casing that extends 20 feet into the bedrock to 109 feet below grade, and an 8-inch inner casing to 118.5 feet below grade. All casings and annular spaces are grouted with neat cement, with IDP#381 additive. Bedrock was encountered at 89 feet below grade. The well is currently sealed to contain its artesian pressure, which was measured at 27 pounds per square inch (psi), corresponding to a static level of 62.1 feet above the top of the casing. The total depth of the well is 385 feet. The well's yield originates from a series of water-bearing fractures encountered between 145 and 370 feet below grade; testing indicated a hydraulic base of at least 270 feet below the top of the casing. The well tag number is 35251.

3.0 SOURCE TESTING

Source testing procedures adhered to the November 21, 2006 Source Testing Application that was approved by the WSD on November 29, 2006. Source testing procedures also conformed to the requirements of the 2005 Vermont Water Supply Rule (Rule), section A-3.3.

Source Testing included a step-discharge test, 48 hours of background monitoring, a 120-hour constant discharge test, 48 hours of recovery monitoring, and water quality analysis. Interference monitoring was conducted in seven water supply wells plus two monitoring piezometers that were installed specially for the testing. All wells within the required 3,000-foot monitoring radius were monitored, with the exception of two wells for which the owners did not grant permission. For the two wells that were not monitored, interference was predicted based on the nearest monitored wells. Page 1 of Appendix 3 shows the monitoring network. All available well logs, Source Approval information, and Well ID sheets for the monitored wells are in Appendix 1, pages 8 through 36.

Due to the substantial artesian pressure in Well R-1, the test pump installation included a seal so that no artesian flow occurred during the background or recovery monitoring phases. A pressure gage allowed the artesian pressure to be measured. During the step test and constant discharge test, the pumping rate from Well R-1 was measured using a totalizing water meter. In addition, a calibrated weir was used as a backup measurement device; all discharge water was routed through the weir to allow continuous measurement of the flow rate. To ensure that the pumped water did not recharge the aquifer, the discharge water from the weir was directed in a non-erosive manner into Pine Brook, located about 150 feet east of the well. The test pumping setup is depicted in the photographs on page 1 of Appendix 2.

Precipitation was monitored using a rain gage at the site in order to assess the potential for natural recharge during the testing. The constant discharge test was not significantly affected by recharge, as evidenced by hydrographs from the observation wells. Although rain fell during the testing period, the aquifer was not immediately affected, most likely due to the considerable residence time in the groundwater of at least 40 years, as will be discussed below in section 6.0. Weather data collected during the testing period are presented on pages 2 through 3 of Appendix 2.

3.1 Step Test

A step-discharge test with five, 60-minute steps was conducted on November 29, 2006. Steps were conducted at 172, 198, 247, 295, and 364 gpm. The deepest water level achieved during this test was 270 feet below the pipe (BTP). During all five steps, the drawdown slope was consistent, indicating that no significant water-bearing fractures were dewatered. Step test data were analyzed following standard techniques (Bierschenk, 1964), showing that the steps correlated very well (r^2 = 97%) on the graph of Sw/Q versus Q, indicating consistent hydraulic performance and confirming that the well can sustain pumping at rates up to 364 gpm. From the step test, a turbulent loss coefficient (C term) of 0.0018 was measured, which corresponds to a well with a low amount of turbulent head losses (see data on pages 4 through 11 of Appendix 2).

3.2 Background Monitoring

Background monitoring was conducted in all tested wells from November 29 to December 1, 2006. During this period, minimal recharge to the aquifer occurred, based on the steady water levels in the monitored wells. In the production well, water levels were rising gradually in recovery from the step test during this time (see hydrograph, page 12 of Appendix 2). Data and hydrographs from all observation wells are contained in Appendix 3.

3.3 Constant Discharge Test

The constant discharge test was conducted at an average rate of 237.6 gpm, and lasted 120 hours. The test began following recovery from the step test at 11:25 a.m on December 1, and ended at 11:25 a.m on December 6, 2006. Pages 13 through 15 of Appendix 2 present production well data from the constant discharge test.

The drawdown plot for Well R-1 indicates that no boundaries were encountered during the 120-hour test, and the aquifer was able to sustain pumping at the rate of 237.6 gpm. Semilog drawdown plots for Well R-1 are shown on pages 16 and 17 of Appendix 2. The straight-line plot of the test indicates radial flow and appropriate conditions for analysis of aquifer parameters. At 2,917 minutes into the test, a valve adjustment was performed in order to compensate for the declining water levels. After an immediate response to this increase in the discharge, water levels resumed drawing down at the previously established slope. Overall, the slope of the drawdown plot was remarkably consistent for a bedrock well.

3.4 Recovery Monitoring

Recovery monitoring was conducted 48 hours until Well R-1 had recovered by 92 percent. Recovery data from the production well were consistent with the drawdown data. Full recovery was projected to occur at a t/t' ratio of 1.3, which is close to the theoretical performance of an ideal aquifer: full recovery at t/t' = 1.0. The recovery data indicates that the aquifer at Well R-1 was neither overpumped nor subject to significant recharge during the testing period. See pages 18 through 20 of Appendix 2.

3.5 Yield Calculations

The recommended yield for Well R-1 is 186 gpm, based on an analysis of interference to and from existing wells. The well has a stand-alone yield of 269 gpm, which would cause unacceptable interference to the nearby Houston wells which are permitted, but unused, Public Community sources. Furthermore, should the Houston wells ever operate at their permitted yields, well R-1 could not be pumped at 269 gpm due to the drawdown that the Houston wells would cause to it. Yield was calculated for 180 days at average day demand, followed by a three-day peak. The recommended yield of 186 gpm is the average of four different calculation methods. Based on the peaking factor of 2.0, the recommended yield for Well R-1 equates to an average day demand of 133,920 gallons per day (gpd), and a peak demand of 267,840 gpd.

3.5.1 Hydraulic Base

The hydraulic base was determined to be at 270 feet below the top of the casing (BTC), based on the step testing results. This is the lowest level at which the well was proven to be able to yield water by the testing. The consistent drawdown to discharge ratio from the step test (see page 4 of Appendix 2) shows that the well's hydraulic characteristics are consistent down to at least the depth of 270 feet BTC.

3.5.2 Static Level and Total Available Head

A static level of 27 psi of artesian pressure, as measured in November of 2006, was used in the yield analysis. This pressure equates to a static level of 62.1 feet above the top of the casing. Total available head was determined to be 332.1 feet, equal to the difference between the static level and the hydraulic base.

3.5.3 Yield Calculation #1 – Cooper-Jacob method, drawdown data

The yield of Well R-1 was analyzed using the standard Cooper-Jacob method (Todd, 1980). Aquifer parameters were determined from the semilog drawdown plot (page 17 of Appendix 2). A transmissivity of 348.8 ft^2/day and an r^2S of 7.09×10^{-5} ft^2 were measured; the resulting safe yield was 270.0 gpm. See page 21 of Appendix 2 for calculations.

3.5.4 Yield Calculation #2 – Cooper-Jacob method, Recovery Data

Aquifer parameters were determined from the semilog recovery plot (page 20 of Appendix 2). A transmissivity of 270.1 ft^2/day and an r^2S of 1.69×10^{-3} ft^2 were measured; the resulting safe yield was 256.0 gpm. The aquifer parameters measured from the recovery data were similar to those measured from drawdown, indicating fairly isotropic conditions. The consistency of the measurements from the different phases of testing confirms the accuracy of the test data. See page 22 of Appendix 2 for calculations.

3.5.5 Yield Calculation #3 – B-Plot method

Formation loss coefficients (B values) were plotted to compensate for the slight variations in pumping rate during the pump test (see page 23 of Appendix 2). Based on the B-plot data and the turbulent loss coefficient measured from the step test, the Jacob well loss equation (Driscoll, 1986) was used to determine a safe yield of 284.5 gpm. See page 24 of Appendix 2 for calculations.

3.5.6 Yield Calculation #4 – Sen method

The Sen linear fracture flow method was used because Well R-1 appears to be influenced by a large fracture or set of fractures (Sen, 1986). Aquifer parameters were determined from curve matching, based on the semilog drawdown plot (page 25 of appendix 2). A transmissivity of 349 ft^2/day, an

r^2S of 7.10 x 10^{-5} ft^2, a fracture length of 560 feet, and an effective radius of 51 feet were measured; the resulting safe yield was 266.0 gpm. See page 26 of Appendix 2 for calculations.

3.6 Stand – Alone Yield

All four yield analysis methods produced similar results, confirming the reliability of the testing and of the calculations. The accuracy of each method was checked by using the measured aquifer parameters and the analysis method to calculate the drawdown caused by the pump test; this theoretical drawdown was compared to the actual drawdown measured during the testing. Accuracies of 94.4 percent, 98.5 percent, 98.6 percent, and 95.6 percent, respectively, were determined, indicating that all four methods were reliable. The average of the four methods, 269 gpm, is the stand alone yield for Well R-1.

However, a yield of 269 gpm is not proposed, because Well R-1 would cause unacceptable interference to the unused, but permitted Houston Wells #2 and #3, if it was pumped at the rate of 269 gpm (detailed interference information is presented below in section 4.0). Also, if the Houston wells were to be used at their permitted rate, they would cause too much drawdown to Well R-1 for it to be able to produce 269 gpm. Therefore additional analysis was performed in order to determine an interference-limited yield for well R-1.

3.7 Interference – Limited Yield

A safe yield of 186 gpm was determined to be the maximum pumping rate for Well R-1 that would not cause unacceptable interference to any other well, and that would be possible if the Houston wells were operating at their permitted yield of 600 gpm, combined. Calculations on page 27 of Appendix 2 predict that the Houston wells would cause 109.35 feet of drawdown to Well R-1, from use at their permitted yields. Reducing the total available head in Well R-1 by the 109.35 feet of drawdown, we re-calculated the yield of Well R-1 using the four methods described above. Yields of 181.0, 171.0, 214.1, and 178.0 gpm were determined, resulting in an average yield of 186 gpm. The yield of 186 gpm was determined not to cause unacceptable interference to any other well, and therefore is the recommended yield for Well R-1.

4.0 INTERFERENCE

Use of Well R-1 at the proposed rate of 186 gpm would not cause adverse interference to any well. Pumping of Well R-1 does cause drawdown to five wells, including two permitted but unused public wells, two unused private wells, and one in-use private well. Monitoring indicated that the four wells on the Houston property experienced drawdown due to the pumping of Well R-1. The two permitted Houston wells will be able to meet their permitted yields under the effect of Well R-1 pumping at 186 gpm; the other two Houston wells are not permitted for use. Also, the private well serving the Schaffer residence experienced a slight degree of interference, and will be able to yield sufficient water to meet its owners' needs with Well R-1 pumping at 186 gpm.

Appendix 3 contains interference monitoring information. The Monitoring Map on page 1 of Appendix 3 shows the locations of all wells within the required 3,000-foot monitoring radius. Pages 8 through 39 of Appendix 1 contain available well completion reports and Well ID sheets for the wells involved in the interference monitoring. All wells that are known to exist within the monitoring radius were monitored during the pump test, with the exception of the private well serving the Burbank residence, because permission was not granted. Page 2 of Appendix 3 presents spreadsheet calculations of well specifications, interference, demand, and yield based on the recommended permit yield of 186 gpm. Page 3 of Appendix 3 presents the same analysis, but based on the stand-alone yield of 269 gpm, to show the impact that Well R-1 would have to surrounding wells at its maximum yield. Note that at the stand-alone yield, use of Well R-1 would not adversely affect any well that currently is in use. Page 4 of Appendix 3 presents calculations of aquifer coefficients from the monitoring data. Raw data are presented on pages 5 through 49 of Appendix 3. Below, each well in the monitoring radius is discussed.

4.1 Monitored Wells

Piezometers

A pair of piezometers were installed in the overburden 200 feet from Well R-1 in order to evaluate the possible presence of a hydraulic connection between the bedrock aquifer and the overburden water table, to determine the hydraulic gradient in the overburden, and to assess whether that gradient is affected by the pumping of Well R-1. This evaluation was performed in accordance with section A-3.3.1.2 of the Rule, in order to determine whether a reduction in the Source Isolation Zone to a 125-foot radius could be justified. The piezometer locations are shown on the

Monitoring Map on page 1 of Appendix 3. A schematic of the piezometers, showing construction details, is shown on page 37 of Appendix 1. The shallow piezometer (PZ-S) was screened in the water table at 14 to 15 feet below grade, and the deep piezometer (PZ-D) was screened at 32 to 33 feet below grade. Soil Boring logs from the piezometer installation are shown on pages 38 and 39 of Appendix 1, and indicate that the soils consisted of glacial till, comprising very fine sand to gravel with cobbles. Due to the very dense till, the drill rig was unable to proceed deeper than 33 feet below grade in the deeper piezometer; this dense material acts as a confining layer above the bedrock aquifer. A layer of clay may exist below the till, but could not be reached during piezometer installation. Both piezometers are located uphill from well R-1, where they were not affected by discharge from the test.

The piezometers indicated that a strong upward gradient exists in the overburden soils in the vicinity of Well R-1. Water levels in the deep piezometer were consistently about five feet higher than those in the shallow piezometer (see data and graph on pages 5 through 7 of Appendix 3). Monitoring indicated no effect to either piezometer from the pump test; water levels in the shallow piezometer rose due to precipitation, but otherwise the water levels in both piezometers were very steady and showed no drawdown. Noting that the shallow piezometer responded to the precipitation but the deep piezometer did not, we conclude that the dense glacial till, in which the deep piezometer is screened, is a confining layer. Also, we conclude that due to this confining layer, the deeper overburden layers as well as the bedrock aquifer were not influenced by precipitation during the test. Finally, as will be discussed below in section 7.2, the piezometer results support a reduction in the Source Isolation Zone to 125 feet.

Houston Well #1

This drilled bedrock well was abandoned and partially sealed with fill material inside the wellbore, but has a measurable water level within the casing. Water level monitoring indicated that the water inside the well casing is perched above the seal inside the well and thus is not connected to the aquifer. However, water leaks around the outside of the Houston Well #1 casing at a significant rate, forming a deep "pool" surrounding the well. During the pump test of Well R-1, this pool dried up, and the pool returned during recovery monitoring, indicating that the aquifer at Houston Well #1 is indeed hydrologically connected to Well R-1. More significantly, this observation indicates that water loss is occurring and the aquifer is being partially depressurized due to leakage from Houston Well #1. The leaky seal around the well may also enable potential contaminants from the ground surface to enter the aquifer. See pages 8 through 13 of Appendix 3 for a hydrograph and data.

Houston Well #2

This drilled bedrock well is one of two permitted but unused wells on the Houston property. Houston Well #2 is 349 feet deep. Houston Wells #2 and #3 have a combined permitted yield of 600 gpm as bottled water sources; individual yields for the two wells are not specified in the permit (see well completion report and Source Permit, pages 13 through 20 of Appendix 1). Like Well R-1, Houston Well #2 has a strong artesian pressure. During background monitoring, a static level of 19.5 psi

(44.85 feet above the casing) was measured. Compared to a static level of 66 psi (153 feet above the casing) reported from December of 1990 (Wagner, Heindel, & Noyes, 1995), the current static level in Houston Well #2 points to depressurization of the aquifer, most likely due to the substantial leakage nearby at Houston Well #1. Note that Well R-1 was sealed with grout, capped, and had not been flowing or leaking since it was completed in September of 2006, and therefore could not have caused any depletion of pressure.

Houston Well #2 experienced 71.83 feet of drawdown during the pump test. Based on the recommended permit yield of 186 gpm for Well R-1, long-term use is predicted to cause 92.89 feet of drawdown to Houston Well #2, causing a 33 percent decrease in available head based on the static level measured in 2006. Houston Well #2 has already lost 108.15 feet of head compared to the conditions under which it was permitted, for reasons unrelated to Well R-1. Under the effect of the interference that Well R-1 would cause at 186 gpm, Houston Well #2 could still yield 375.8 gpm. In combination with Houston Well #3, the two Houston wells can produce in excess of their 600 gpm permitted yield. Therefore, the interference is acceptable. Note that the interference evaluation incorporated an analysis of the interference between the Houston Wells themselves; Houston Well #3 is predicted to cause 115 feet of drawdown to Houston Well #2 and this drawdown was taken into account in the calculation of the resulting yield of Houston Well #2. See page 21 of Appendix 1 for information on the interference between the Houston wells. Finally, use of Well R-1 at its stand-alone yield of 269 gpm would cause 134.35 feet of drawdown to Houston Well #2, equal to a loss of 48 percent of available head as of 2006, with a resulting yield of 292 gpm. See pages 14 through 18 of Appendix 3 for hydrographs and data; interference calculations are on pages 2 through 4 of Appendix 3.

Houston Well #3

This drilled bedrock well is the second of two permitted but unused wells on the Houston property. Houston Well #3 is 349 feet deep. Houston Wells #2 and #3 have a combined permitted yield of 600 gpm as bottled water sources (see well completion report and Source Permit, pages 13 through 20 of Appendix 1). Houston Well #3 has a modest artesian overflow. During background monitoring, a static level at the top of the casing with no measurable pressure was recorded. The report of the original testing of this well (Wagner, Heindel, & Noyes, 1995) states that the well overflowed in 1990, but that pressure was not measured.

Houston Well #3 experienced 55.85 feet of drawdown during the pump test. Based on the recommended permit yield of 186 gpm for Well R-1, long-term use is predicted to cause 70.10 feet of drawdown to Houston Well #3, causing a 33 percent decrease in available head. Under the effect of the interference that Well R-1 would cause at 186 gpm, Houston Well #3 could yield 291.2 gpm. In combination with the 375.2 gpm yield of Houston Well #2 under this scenario, the Houston wells could still produce more then the 600 gpm permitted yield for the two wells combined. Realistically, Houston Well #3 would be expected to produce 291.2 gpm and Houston Well #2 would be expected to yield 308.8 gpm. Therefore, the interference is acceptable. Note that the interference evaluation incorporated an analysis of the interference between the Houston Wells themselves; Houston Well #2 is predicted to cause 115 feet of drawdown to Houston Well #3, and this drawdown was taken into account in the calculation of the resulting yield of Houston Well #2. See page 21 of Appendix 1 for information on the interference between the Houston wells.

Finally, use of Well R-1 at its stand-alone yield of 269 gpm would cause 101.38 feet of drawdown to Houston Well #3, equal to a loss of 49 percent of available head, with a resulting yield of 222.8 gpm. See pages 19 through 25 of Appendix 3 for hydrographs and data; interference calculations are on pages 2 through 4 of Appendix 3.

Houston Well #4

This drilled bedrock well is not in use and is not permitted. It is 374 feet deep and has a yield estimated by the driller of 125 gpm (see well completion report, pages 17 and 18 of Appendix 1). During source testing of Well R-1, a static level of 13.7 feet BTC was measured. In contrast, a static level of 12.46 feet was measured on December 20 of 1990 (Wagner, Heindel, & Noyes, 1995). The change in static level from 1990 to 2006 at Houston Well #4 is very minor compared to the change seen at Houston Well #2. This observation suggests that the lowering of static pressure is localized around the leakage at Houston Well #1.

Houston Well #4 experienced 51.02 feet of drawdown during the pump test. Based on the recommended permit yield of 186 gpm for Well R-1, long-term use is predicted to cause 68.97 feet of drawdown to Houston Well #4. In combination with the predicted drawdown from Houston Wells #2 and #3, no available head and no yield would remain in the well. See pages 26 through 31 of Appendix 3 for data; interference calculations are on pages 2 through 4 of Appendix 3.

Database Design Well

This drilled bedrock well supplies a private residence. It is 110 feet deep and has an unknown yield. Monitoring indicated no effect from the pump test; water levels in the Database Design well were fluctuating due to the operation of its own pump to supply household water demands, but without any lowering of static levels that could indicate interference due to the pump test. See pages 32 through 37 of Appendix 3 for a hydrograph and data.

Norris Well

This drilled bedrock well supplies a private residence. It is 80 feet deep and has yield of 30 gpm according to the driller. The well completion report is on pages 22 and 23 of Appendix 1. During the testing of the Houston wells in 1990, this well was identified as the Rivers Well, and monitoring indicated no hydraulic connection with the Houston wells. A static level of 4.8 feet BTC was measured during December of 2006; compared to the static level of 5.96 feet reported during 1990 (Wagner, Heindel, & Noyes, 1995), no lowering of static levels has occurred at this location. Monitoring during the Well R-1 pump test indicated no effect from the pump test; water levels in the Norris well were fluctuating due to the operation of its own pump, but without any lowering of static levels that could indicate interference due to the pump test. Static levels rose slightly, suggesting an effect from rainfall during the test. See pages 38 through 43 of Appendix 3 for a hydrograph and data.

Shaffer Well

This drilled bedrock well supplies a private residence. It is 172 feet deep and has yield of 10 gpm according to the driller. The well completion report is on pages 26 and 27 of Appendix 1. During the testing of the Houston wells in 1990, this well was identified as the Mannix Well, and monitoring indicated no hydraulic connection with the Houston wells. A static level of 15.0 feet BTC was measured during December of 2006; compared to the static level of 19.55 feet reported during 1990 (Wagner, Heindel, & Noyes, 1995), no lowering of static levels has occurred at this location. Monitoring during the Well R-1 pump test indicated a slight effect from the pump test; water levels in the Shaffer well declined gradually during the 120-hour test, and rebounded following the end of the pumping. See pages 44 through 49 of Appendix 3 for a hydrograph and data.

The Shaffer well experienced 6.24 feet of drawdown during the pump test. Based on the recommended permit yield of 186 gpm for Well R-1, long-term use is predicted to cause 14.15 feet of drawdown to the Shaffer well, corresponding to a loss of 9 percent of available head. Based on one-half the driller's yield, this predicted interference would result in a yield of 4.6 gpm, which significantly exceeds the demand for the Shaffer residence. At the stand-alone yield of 269 gpm, Well R-1 is predicted to cause 20.47 feet of drawdown to the Shaffer well, corresponding to a loss of 13 percent of available head, and resulting in a yield of 4.4 gpm which exceeds demand. See interference calculations on pages 2 through 4 of Appendix 3.

4.2 Non-Monitored Wells

Burbank Well

This drilled bedrock well supplies a private residence, and was not monitored during the testing because the owner did not grant permission. It is 245 feet deep and has yield of 4 gpm according to the driller. The well completion report is on pages 8 through 10 of Appendix 1. During the testing of the Houston wells in 1990, this well was monitored, and no interference was identified. A static level of 0.9 feet was reported during 1990 (Wagner, Heindel, & Noyes, 1995). Based on the lack of any interference in the nearby Norris well, we conclude that Well R-1 does not affect the Burbank well.

Richards Well

This drilled bedrock well supplies a private residence, and was not monitored during the testing because the owner did not grant permission. Although the Richards well is located slightly outside the 3,000-foot monitoring radius, we offered to monitor the well in order to address any potential concerns about interference. It is 605 feet deep and has a yield of 2 gpm according to the driller. The well completion report is on pages 24 through 25 of Appendix 1. During the testing of the Houston wells in 1990, this well was monitored, and no interference was identified. A static level of 43.3 feet was reported during 1990 (Wagner, Heindel, & Noyes, 1995). Based on the location of the Richards well and the lack of any interference with the Houston wells, we conclude that Well R-1 does not affect the Richards well.

4.3 Static Level Trends

Static levels measured during testing of the Houston Wells in 1990 were compared against static levels from 2006 to determine whether any long-terms changes have occurred in the aquifer. As shown in Table 1, static levels in four out of five wells were at similar or slightly higher levels in 2006 compared to 1990. Only Houston Well #2 showed a significant decline in static level. Because this change is confined to this one well, it is believed to be a localized phenomenon that is the result of the leaky seal at Houston Well #1. Overall, the static level data show that the aquifer has not been depressurized since 1990.

Table 1: Static Level Trends

Well ID	Static Level, December 1990	Static Level, December 2006	Comments
Houston #2	66 psi (153 feet above the casing)	19.5 psi (44.85 feet above the casing)	Local depressurization of aquifer due to leakage around Houston Well #1 casing
Houston #3	0 feet (pressure not measured)	0 feet (overflow, no measurable pressure)	No apparent change
Houston #4	12.46 feet	13.7 feet BTC	No significant change, within normal fluctuation for a bedrock well
Norris (formerly Rivers)	5.96 feet	4.8 feet BTC	No significant change, within normal fluctuation for a bedrock well
Shaffer (formerly Mannix)	19.55 feet	15.0 feet BTC	Slight rise in water level

5.0 WATER QUALITY ANALYSIS

Water quality in Well R-1 is excellent and is suitable for a Public Community source well. All water quality parameters are within the limits of the Safe Drinking Water Act and Vermont standards. To summarize water quality, Table 2 shows all detected analytes only. All parameters required by the Vermont Water Supply Rule were tested for; any substance not shown in the table was not detected. Appendix 4 contains all laboratory reports.

Table 2: WELL R-1
SUMMARY OF DETECTED ANALYTES,
DECEMBER 2006 PUMPING TEST

Note: All contaminants required for initial source testing by the Vermont Water Supply Rule (4/2005) were analyzed. This table shows only those contaminants which were detected. Refer to appendix 4 for complete laboratory data.

Analyte	Concentration	MCL
Corrosivity	-1.95	noncorrosive (1)
PH	6.20	6.5 - 8.5 (1)
TDS	180 mg/L	500 mg/L (1)
Turbidity	0.06 NTU	5 NTU
Gross Alpha Radioactivity	1.66 pCi/L	15 pCi/L (2)
Uranium	3 µg/L	20 µg/L
Nitrate	0.382 mg/L	10.0 mg/L
Sodium	4.9 mg/L	250 mg/L (1)
Total Hardness	80.8 mg/L	NS (3)

(1) Secondary MCL
(2) The reported Gross Alpha activity of 1.66 pCi/L, and the MCL of 15 pCi/L are both for the adjusted Gross Alpha excluding uranium
(3) NS = No Standard

Analysis of a water sample obtained at the end of the pump test showed that most natural and background contaminants were not detected in the water. Iron, manganese, radium, barium, and other common naturally occurring minerals were not detectable in the water from well R-1. The pH is slightly acidic and below the secondary MCL range, however the water is non-corrosive as indicated by the negative Langelier's index result. The pH is a secondary, or aesthetic, water quality standard and therefore acceptable. If necessary, pH may be increased with chemical addition.

5.1 Groundwater Under the Direct Influence of Surface Water

Well R-1 qualifies for an exemption from Microscopic Particulate Analysis (MPA) testing for Groundwater Under the Direct Influence of Surface Water. The well has over 50 feet of watertight casing below grade, is not subject to flooding, has no construction defects, and is protected by a confining layer. The completed MPA exemption form is provided on pages 40 through 43 of Appendix 1.

6.0 GROUNDWATER AGE ANALYSIS

The age of the water from Well R-1 was determined by analysis of tritium. Tritium is an isotope of hydrogen, with a half-life of 12.32 years. Water falling as precipitation contains tritium that was formed in the atmosphere, both naturally and due to man-made nuclear activities. Once precipitation has entered the ground, the tritium decays. Tritium is naturally formed in the atmosphere at a level of about 5 tritium units (TU). Additional tritium was formed from above-ground hydrogen bomb testing beginning in 1952; tritium levels peaked in 1964 at 6000± TU, and have been decreasing since then. Knowing the half-life of tritium, the initial concentration in precipitation at various times, and the tritium content of a groundwater sample, the age of the groundwater can be determined (Mazor, 1991). The tritium concentration of water from Well R-1 was measured to equal 3.08 Tritium Units, corresponding to an age of 50 to 53 years (see pages 32 to 37 of Appendix 2). This age most likely represents the average age of the water, which may be a mix of older and more recent recharge.

Similarly, during the testing of the Houston wells, a water sample from Houston Well #2 was analyzed in 1990 and found to contain 2.8 Tritium Units, corresponding to an age of 37 to 38 years (Wagner, Heindel, & Noyes, 1995 – see pages 38 to 44 of Appendix 2). By rounding this measurement and the tritium measurement from Well R-1 in 2006, we consider the average age of the groundwater in Well R-1 to be 40 to 50 years.

Based on the age of the groundwater of approximately 40 to 50 years, the water in Well R-1 is a renewable resource that is not likely to be significantly affected by short-term weather extremes such as droughts. The long residence time of the water should buffer the resource from variations in precipitation and recharge that may occur from year to year.

7.0 SOURCE PROTECTION

Well R-1 is not threatened by contamination sources. A wellhead protection area has been delineated based on the pump test results.

7.1 Wellhead Protection Area

The proposed WHPA is shown on pages 2 and 3 of Appendix 1 on the WHPA Delineation Map and Surficial Geology Map. Fracture trace lineations, the locations of the wells monitored during the pump test, surficial and bedrock geology, and topography were used in the delineation, and are also shown on the maps.

First, the overall WHPA was delineated to represent the area under the pumping influence of well R-1, and all land topographically upgradient. The well's zone of influence was mapped using the distance-drawdown plot results (see page 4 of Appendix 3) and the distribution of the affected and non-affected wells that were monitored during the pump test. This approach created an elongated oval, with the long axis following the fracture trace lineation on which the well was sited. The remainder of the WHPA was delineated as the area topographically upgradient from this zone of influence (see WHPA delineation map, page 2 of Appendix 1).

Next, a two-year travel boundary was delineated, based on flow within the bedrock and the overburden soils. Calculations (pages 45 through 48 of Appendix 2) show that groundwater would flow 1,613 feet within two years. Because groundwater flow within the rock fractures inside the pumping zone of influence is expected to be extremely rapid, the two-year travel boundary extends to 1,613 feet upgradient from the edge of the well's zone of influence. Where the confining layer exists over the bedrock, the surface environment is isolated from the aquifer, and therefore, areas closer to the well where the confining layer exists are excluded from the two-year travel zone.

Zone 2 of the proposed WHPA is the area where direct recharge to the bedrock aquifer most likely occurs, based on surficial geologic information. As indicated by the strong upward gradient at the piezometers near Well R-1, the confining layer, and the well's artesian flow, recharge is not likely to occur in the vicinity of Well R-1 itself. Therefore, the area beneath the confining layer was delineated as Zone 3. The extent of the confining layer was inferred from well logs in the area, and was estimated to correspond to the 1,320 foot elevation contour. Well completion reports for the Houston and Shaffer wells indicate the presence of the confining layer, whereas the Norris and Burbank well logs only indicate six to ten feet of soil covering the bedrock. Land area upgradient from the 1,320-foot contour, as far as the two-year travel boundary, was delineated as Zone 2. Any area beyond a two-year travel distance to the well is not considered "one where there will be probable impact from potential sources of contamination," as defined in section A-3.3.6.3 of the Rules, and therefore was delineated as Zone 3.

Zone 3 consists of land areas within the WHPA where the confining layer prevents direct recharge to the aquifer, and all land area topographically upgradient from the two-year travel boundary.

A recharge analysis was performed to assess the size of the proposed WHPA. Based on typical rates of recharge for the glacial till soils that are identified as the predominant soil type throughout the WHPA (see surficial map, page 3 of Appendix 1), an annual average recharge to the WHPA of approximately 37,347,000 cubic feet of water was estimated. In comparison, operation of Well R-1 at the recommended yield would result in an annual groundwater withdrawal of only

6,540,000 cubic feet of water, or about 18 percent of the estimated annual average recharge volume. Because the average annual recharge rate significantly exceeds the annual withdrawal, the WHPA is adequately sized and the aquifer has ample recharge to sustain the proposed yield. An additional recharge estimate was performed to take the permitted pumping rate of the Houston wells into account; this calculation determined that the overlapping WHPAs for the wells can provide sufficient recharge. Calculations are presented on page 49 of Appendix 2.

7.2 Source Isolation Zone Reduction

Zone 1 of the proposed WHPA is a 125-foot radius circle. In accordance with the requirements of section A-3.3.1.2(b)(1) of the Rule, our testing has demonstrated that a source isolation zone reduction to 125 feet is appropriate. The requirements of the Rule are addressed as follows:

> *An impeding layer of soil is present and located at least 200' around the source, with no significant hydraulic connection to the proposed aquifer.* Well logs from the piezometers, and area water wells indicates the presence of the extensive layer of clay and dense glacial till that surrounds the source. See pages 4 through 27 of Appendix 1 for well logs, and pages 37 through 39 of Appendix 1 for piezometer logs. Piezometer monitoring during the pump testing showed no hydraulic connection in the impeding layer to the proposed aquifer.

Hydraulic connection, or lack thereof, between aquifers must be determined by standard pumping test methods including:

i) stressing the production well or proposed aquifer: The pump test stressed the aquifer, as it lasted for 120 hours, was conducted at a higher rate than the recommended yield, and caused drawdown to bedrock wells located up to 1800 feet from the production well.

ii) monitoring the aquifer's response in multi-level piezometers: A pair of two multi-level piezometers was used to monitor the response to the pump testing. As discussed in section 4.1 above, no response to the pumping was detected in either piezometer, and a strong upward gradient was maintained at the piezometers throughout the testing.

and

iii) mapping areas of influence of the source in overlying unconfined aquifers: All monitoring points in the overlying unconfined aquifer, within the 3,000-foot monitoring radius, were isolated from the influence of the source.

7.3 Public Notice

The Proposed WHPA Map on page 50 of Appendix 2 shows the proposed WHPA with property parcel boundaries, for public notice. Page 51 of Appendix 2 list all landowners within the WHPA, indexed by the parcel numbers as shown on the map.

8.0 CONCLUSIONS

Pioneer recommends a yield of 186 gpm for Well R-1. The well will not cause unacceptable interference to other water supply sources. Water quality is acceptable, and is not impacted by potential contaminant sources in the watershed. The well qualifies for an exemption from MPA testing. A wellhead protection area has been delineated based on the pump test results. Testing documents the appropriateness of a reduction in the Source Isolation Zone to 125 feet. A recharge analysis indicates that adequate recharge occurs within the proposed WHPA to sustain the use of Well R-1 at the recommended yield. The aquifer is a renewable resource that is not likely to be significantly affected by short-term weather extremes such as droughts, due to a long residence time of approximately 40 to 50 years. Table 3 summarizes key details of the well.

Table 3: Town of Waitsfield, Well R-1 Summary Information	
Stand-Alone Safe Yield, gallons per minute	269
Recommended Permit Yield, gallons per minute	186
Recommended Permit Average Yield, gallons per day	133,920
Recommended Permit Peak Yield, gallons per day (3-day peak, peak factor = 2)	267,840
Total Depth, Feet below grade	385
Hydraulic Base, Feet below top of casing (Recommended minimum pump depth)	270
Borehole Diameter, inches	8
Static Pressure, psi	27

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