Report

ENGLISHMAN RIVER WATER SERVICE

Technical Report #1

Completion of Phase 2
Aquifer Storage Recovery Testing Program

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SUMMARY

Aquifer Storage Recovery (ASR) is defined as the storage of water in an aquifer through a well during times when water is available, and recovery of the water from the same well when it is needed. There are many different applications of ASR technology and numerous advantages.

Specific benefits of ASR for Parksville and the Regional District of Nanaimo (RDN) are as follows:

- Enhanced water supply security; 3 water sources will be available – River Intake, Conventional wells and ASR wells.
- Withdrawals of water from Englishman River during low flow periods will be reduced.
- Cooler temperature water can be provided from ASR wells in the summer.
- Water treatment plant size/cost can be reduced.
- Operational advantage of running the treatment plant at a constant flow rate by recharging ASR wells with excess water, even in summer months.
- Water storage in an underground aquifer is safer and less costly than above ground storage.
- ASR recovered water quality is favourable compared to the river water with respect to colour, turbidity and corrosivity.
- Well sites de-activated because of water quality issues can be used with the application of ASR.
- Regions of the Englishman River Aquifer which are or may become brackish in the future can be developed using ASR technology.
- The ASR water storage strategy is well suited to alleviate concerns about climate change in BC which is trending toward wetter winters and longer summer dry periods.

Lowen Hydrogeology Consulting Ltd. (LHC), Victoria, BC, sub-consulting to Associated Engineering Ltd. (AE), Burnaby, BC, were retained by the Englishman River Water Service (ERWS) in February 2012 for this study. The work comprises a Phase 2 Aquifer Storage Recovery (ASR) Feasibility Study. Phase 1 which involved a desk-top study of ASR feasibility was completed in September of 2010 (Discussion Paper 5-2).

The study area covers part of the RDN electoral areas E and G, south of Parksville. The BCGS map sheets involved are: 92 F 029 and 92 F 030 south and east of Englishman River.

The main objectives of the feasibility study were as follows:

- Select drilling sites for ASR well development
- Exploration drilling and well testing to locate one suitable ASR well location
- Collect baseline hydrogeology information
- Design and construct an ASR well for cycle testing
- Conduct cycle testing to prove the ASR concept works in the selected aquifer
- Determine injection and production well capacities and water quality issues at the ASR well.
- Determine if ASR storage and production capacity targets can be met
- Provide cost estimates for ASR well field expansion.

To achieve the above objectives 5 test wells were drilled; DS 1, 2, 3, 5 and 6. The aquifer conditions proved favourable at DS#3 and marginally favourable at DS#5. Sites DS#1, 2 and 6 were not feasible for development due to low production capacity. DS#3 was selected to be the site of an ASR cycle testing well. Cycle testing at the completed 12-inch well has proven a minimum storage capacity of 76,205 m^3 and injection/production rates of 10 L/s and 9 L/s (0.78 ML/d) respectively.

An upper-aquifer monitoring piezometer was also completed at the DS#3 site and monitoring shows no impact on the Upper Aquifer from pumping or injecting in the ASR-1 well, located in the lower aquifer.

The original scope of the project was expanded to carrying out a preliminary ASR feasibility investigation at an existing RDN well. This well located near the intersection of Claudet Road and Northwest Bay Road has elevated ammonia and was not in use. A 13-day pumping test was carried out at the well and the well yields 15.3 L/s. This well site is a second candidate site for ASR development. Cycle testing must be carried out to confirm injection capacity and potential storage volume. Also any water quality issues would need to be resolved. Additionally there are four other wells (Nanoose wells 1-4) in this area that have been de-activated by the RDN due to water quality issues. These well sites are also potential ASR well sites.

Several challenges were encountered in meeting the project objectives. The challenges were and will be overcome with future work as follows:

- Geologic variability – subject aquifer has been mapped in detail to aid site selection. Also test well drilling in future will use lower cost test drilling techniques at many sites. Also ASR wells will be located as close as possible to the test wells.
- Well construction problems using a cable-tool rig for ASR well construction – In future a dual-rotary rig will be used for ASR well construction. The cable-tool gets good samples but dual-rotary may produce a more efficient well. The cable-tool rig also had difficulties installing the 20-inch construction casing.
- Water quality issues; Arsenic (As) and Manganese (Mn) in produced water – four options are proposed to eliminate this issue.

The first stage of ASR well development for the ERWS has a target combined well capacity of 69 L/s (6ML/d). Our work to date indicates that this objective can be met with 4 ASR wells on Kaye Road (capacity = 25 L/s) and 3 ASR wells at the Nanoose well field (capacity = 44 L/s). The estimated cost for 3 new ASR wells at; Kaye Road is $2,400,000. and $2,020,000. for 3 ASR wells at the Nanoose well field. GST and a 15% budget contingency should be added to those estimates.

It is recommended to continue the ASR testing and development work to attain this objective. The project aquifer mapping indicates that the ultimate project target of 172 L/s (15 ML/d) can also be met with additional exploration and testing.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF GRAPHS

LIST OF PHOTOS

LIST OF APPENDICES

LHC

Technical Report #1

ERWS Aquifer Storage Recovery Testing Program

1.0 INTRODUCTION

1.1 Background and Project Implementation

The Englishman River Water Service (ERWS) is a joint venture partnership with the City of Parksville (COP) and the Regional District of Nanaimo (RDN) which was formed to secure an upgraded bulk water supply from the Englishman River. The partnership aims to address concerns of declining groundwater levels in the region, especially in the high-demand summer months when river flows are at a minimum, and climate change impacts such as longer, drier summers. Additionally the Vancouver Island Health Authority has mandated treatment of surface water sources necessitating a water treatment plant for the river intake supply.

The ERWS initiated the "Englishman River Water Intake Study" in 2009 which included a "Groundwater Management" component. Lowen Hydrogeology Consulting Ltd. (LHC) was retained in June 2009 to undertake a review of regional groundwater resources that could be tapped to augment the river water supply. The LHC review identified Aquifer Storage Recovery (ASR) as the "greatest water management opportunity in the region". Further study of ASR was recommended (Ref. Discussion Paper 5-1). The proposed ASR wells would increase water supply yield and reliability especially during high demand periods.

Following-up on the recommendation a Phase 1 – Conceptual Planning Study was completed by LHC in September 2010 (Ref. Discussion Paper 5-2). This desk-top-study indicated that ASR was a good option that warranted continuing with a Phase 2 ASR feasibility testing program. This report presents the results of the Phase 2 testing now complete.

1.2 General Scope of the Project

The Phase 2 ASR Feasibility Study included:

- The exploration drilling phase with the completion of 6 wells;
- The selection and testing of the most promising well and the conversion of other test holes into monitoring wells;
- The construction, development and testing of the ASR well;
- The cycle testing of the ASR well (alternating cycles of injection and recovery).

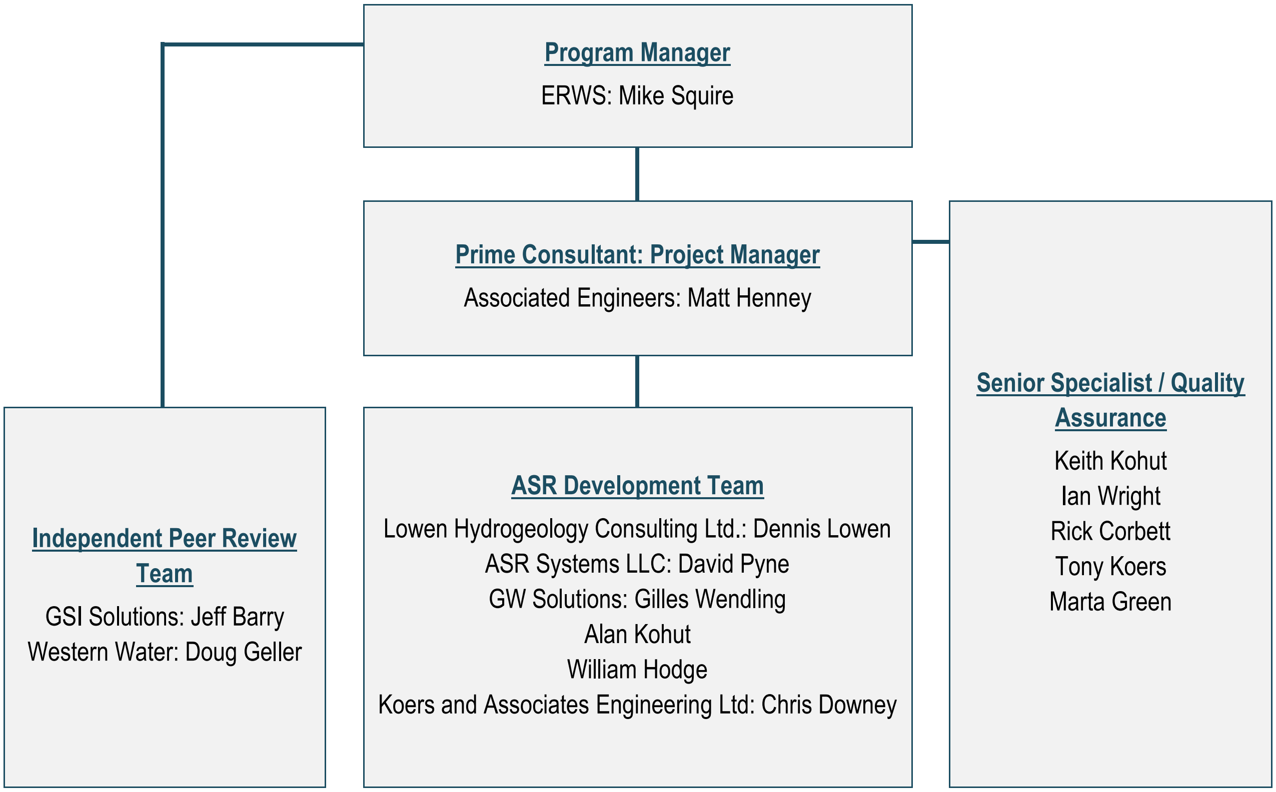
Aquifer Storage and Recovery may be defined as the storage of water in a suitable aquifer through a well during times when water is available, and recovery of the water from the same well during times when it is needed (D. Pyne, 1995).

The ASR project for Parksville is part of a new water intake on Englishman River plus a water treatment plant project. It is proposed to obtain drinking water from the water treatment plant and inject into the subject aquifer through the ASR wells. Excess flows in the river occur during the winter months, and high demand occurs in the summer months, May to October inclusive, when the river flow is reduced. The ASR wells will allow the storage of excess water when available and the recovery of the water during periods of high demand or when insufficient flow is available from the river or when a turbidity event precludes the use of the river intake. Figure A1 in Appendix A illustrates the supply/demand scenario.

The most suitable aquifer in the region was selected in 2010, and the drilling of 5 exploration wells took place from May to December 2012. These 5 test holes where called DS#1 to DS#6 (site DS#4 not drilled) and were concentrated in the Kaye Road area (see Figure A2 – Appendix A). The location around DS#3 was selected for the drilling of the ASR well. DS#3 and DS#5 were converted into monitoring wells and were re-identified as MW-1 and MW-2 respectively.

Two cycle tests were performed on the ASR well to assess long-term capacity under injection and production, and appraise the potential geochemical reactions within the aquifer from the injection of a non-native type of water.

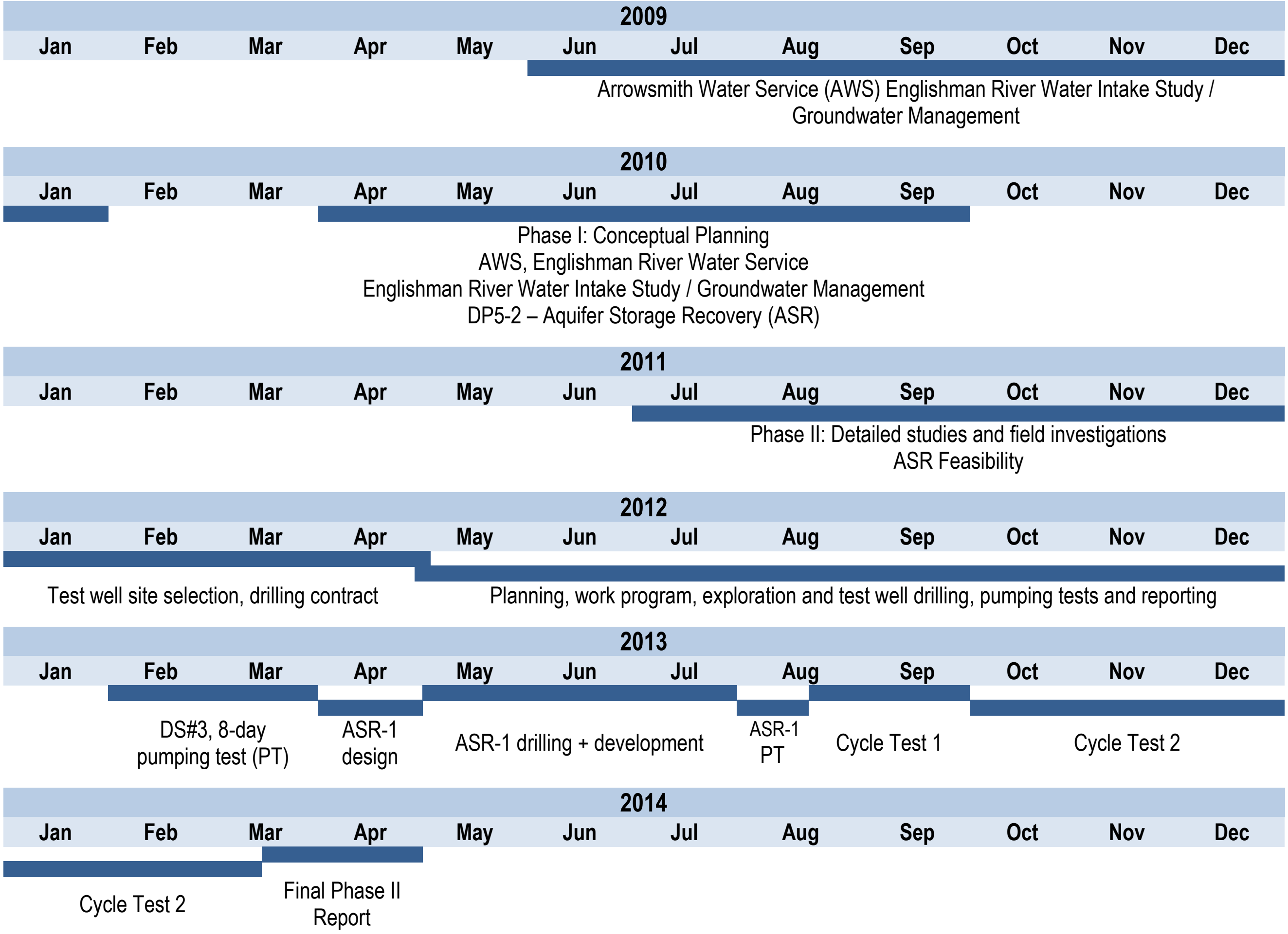
1.3 Project Team – Groundwater Component



From M. Squire, ERWS, 2012

LHC would like to thank all of the individuals referenced above for their support and invaluable input for the ASR testing program. This gratitude also applies to, Mike Donnelly (RDN), Scott Cherko (COP), Ted Belser and Tom Morris of ASR Systems and the drilling and pumping test contractors: Drillwell Enterprises and BC Aquifer.

1.4 Work Schedule - Englishman River Water Intake Study - Groundwater Component



1.5 List of Acronyms and Definitions

AO	Aesthetic Objective for Water Quality
ASR	Aquifer Storage Recovery
AWWA	American Water Works Association
BDL	Below Detection Limit
CDWS	Canadian Drinking Water Standards
COP	City of Parksville
CT	Cycle Test
DO	Dissolved Oxygen
DP	Discussion Paper
EM	Englishman River
ERWS	Englishman River Water Service
gpm	Gallon per Minute (US)
GW	Groundwater
K	Hydraulic Conductivity
LHC	Lowen Hydrogeology Consulting Ltd.
MAC	Maximum Acceptable Concentration, Water Quality
PT	Pumping Test
RDN	Regional District of Nanaimo
T	Transmissivity

This report refers to a number of hey hydrogeological terms and concepts that are defined as follows:

AQUIFER - An aquifer is a formation, group of formations or part of a formation containing enough saturated permeable material to produce significant amounts of water to wells and springs. (See also confined aquifers or artesian aquifers and unconfined aquifers.)

AQUIFER STORAGE AND RECOVERY (ASR) - Involves injecting water into an aquifer through wells and then pumping it out when needed. The aquifer essentially functions as a water bank. Deposits are made in times of surplus, typically during the rainy season, and withdrawals occur when available water falls short of demand (Department of Ecology, 2009). ASR as referred to in this document refers exclusively to systems where the same wells are used for recharging water to and discharging water from the aquifer.

BEDROCK - Rock underlying soil and other unconsolidated material.

CONFINED AQUIFER - Confined is synonymous with artesian. A confined aquifer or an artesian aquifer is an aquifer bounded both below and above by beds of considerably lower permeability than that existing in the aquifer itself. The groundwater in a confined aquifer is under pressure that is significantly greater than that existing in the atmosphere.

CONFINING BED OR LAYER - A bed of impermeable material stratigraphically adjacent to one or more aquifers. Confining bed is now used to replace terms such as "aquiclude", "aquitard" and "aquifuge".

DRAWDOWN - The variation in the water level in a well prior to commencement of pumping compared to the water level in the well while pumping. In flowing wells drawdown can be expressed as the lowering of the pressure level due to the discharge of well water

FLUVIAL DEPOSITS - Deposits related to a river or stream.

FRACTURE - A break or crack in the bedrock.

FLOWING ARTESIAN WELL - A well where the water level is above the ground surface.

GLACIAL DEPOSITS - Deposits related to the action of glaciers.

GROUNDWATER - Water in the zone of saturation underground, that is under a pressure equal to or greater than atmospheric pressure.

GROUNDWATER TABLE - That surface below which rock, gravel, sand or other material is saturated. It is the surface of a body of unconfined groundwater at which the pressure is atmospheric.

HETEROGENEOUS DEPOSIT - Non-uniform structure and composition throughout the deposit.

HOMOGENEOUS DEPOSIT - Structure or composition of the deposit is uniform throughout.

HYDRAULIC CONDUCTIVITY - Hydraulic conductivity is a measure of the ability of a fluid to flow through a porous medium determined by the size and shape of the pore spaces in the medium and their degree of interconnection and also by the viscosity of the fluid. Hydraulic conductivity can be expressed as the volume of fluid that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

HYDRAULIC GRADIENT - The slope of the groundwater level or water table.

HYDRAULIC HEAD - The level to which water rises in a well with reference to a datum such as sea level.

HYDROGEOLOGY - Study of groundwater in its geological context.

IGNEOUS ROCKS - Rocks that solidified from molten or partly molten material, that is from a magma or lava.

LITHOLOGY - All the physical properties, the visible characteristics of mineral composition, structure, grain size etc. which give individuality to a rock.

MARINE DEPOSITS - Mostly silt and clay materials deposited under a marine environment.

METAMORPHIC ROCKS - Any rock derived from pre-existing rocks by mineralogical, chemical, and/or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the earth's crust.

OBSERVATION WELL - A well constructed for the objective of undertaking observations such as water levels, pressure readings and groundwater quality.

PERMEABILITY - The property of a porous rock, sediment or soil for transmitting a fluid, it is a test of the relative ease of fluid flow in a porous medium.

PERVIOUS - The property of a porous medium to allow the easy passage of a fluid through it.

PIEZOMETER - Pressure reading and measuring instrument connected to a short sealed off length of a drill hole or hydrogeological unit.

PIEZOMETRIC SURFACE - Imaginary surface defined by the elevation to which water will rise in wells penetrating confined aquifers.

PLEISTOCENE - The period following the Pliocene during which an ice sheet covered the greater part of North America. Named by Lyell in 1839.

POROSITY - The volume of openings in a rock, sediment or soil. Porosity can be expressed as the ratio of the volume of openings in the medium to the total volume.

POTENTIAL WELL YIELD - An estimate of well yield generally above the existing yield rate or test rate, but considered possible on the basis of available information, data and present well performance.

PUMPING INTERFERENCE - The condition occurring when a pumping well lowers the water level in a neighbouring well.

PUMPING TEST - A test conducted by pumping a well to determine aquifer or well characteristics.

QUATERNARY - The period of geologic time that follows the Tertiary. The Quaternary includes the Pleistocene and Recent Periods and is part of the Cenozoic Era.

RADIUS OF INFLUENCE - The radial distance from a pumping well to the point where there is no drawdown of the water table or piezometric surface. This point marks the edge of the cone of depression around the pumping well.

SATURATED ZONE - The subsurface zone in which all voids are ideally filled with water under pressure greater than atmospheric.

SEDIMENTARY ROCKS - Rocks formed from consolidation of loose sediments such as clay, silt, sand, and gravel.

SPECIFIC CAPACITY - The rate of discharge of a water well per unit of drawdown. Specific capacity can be expressed as L/s/m of drawdown.

STATIC WATER LEVEL - The level of water in a well that is not being influenced by groundwater withdrawals. The distance to water in a well is measured with respect to some datum, usually the top of the well casing or ground level.

STORATIVITY, STORAGE FACTOR OR STORAGE COEFFICIENT - Refers to the volume of water that is released from storage for a unit area of aquifer per unit decline in water level, it may be expressed as a percent. Unconfined sand and gravel aquifers, for example, may have relatively large storativity values in the range 10 to 25 percent while fractured aquifers have low storativity values, for example, <5 percent, depending upon bedrock type.

SURFICIAL DEPOSITS - Deposits overlying bedrock and consisting of soil, silt, sand, gravel and other unconsolidated materials.

SUSTAINED YIELD / LONG TERM YIELD - Rate at which groundwater can be withdrawn from an aquifer without long-term depletion of the supply.

TILL - Till consists of a generally unconsolidated, unsorted, unstratified heterogeneous mixture of clay, silt, sand, gravel and boulders of different sizes and shapes. Till is deposited directly by and underneath glacial ice without subsequent reworking by meltwater.

TOPOGRAPHY - The configuration of a surface including its relief and the position of its natural features.

TOTAL DISSOLVED SOLIDS (TDS) - Concentration of total dissolved solids (TDS) in groundwater expressed in milligrams per litre (mg/L), is found by evaporating a measured volume of filtered sample to dryness and weighing this dry solid residue.

TRANSMISSIVITY - Rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity values can be expressed as square metres per day (m^2/day), or as square metres per second (m^2/s).

UNCONFINED AQUIFER - An aquifer in which the water table is free to fluctuate under atmospheric pressure.

UNCONSOLIDATED DEPOSITS - Deposits overlying bedrock and consisting of soil, silt, sand, gravel and other material which have either been formed in place or have been transported in from elsewhere.

UNSATURATED ZONE - The zone between the land surface and the water table. The pore spaces, interstices, contain water at less than atmospheric pressure, and also air and other gases. Perched groundwater bodies (local saturated zones) may exist in the unsaturated zone.

WATER TABLE - See Groundwater Table.

WELL DEVELOPMENT - This operation helps make water enter the well more easily and can make the difference between a satisfactory and an unsatisfactory well. Different techniques for well development can be used, the aim is to remove the smaller sized particles from the aquifer surrounding the well screen and to provide a coarser filter zone around the screen. The smaller sized particles are drawn into the well screen and can then be removed by bailing or pumping.

WELL INTERFERENCE - When the area of influence, or the cone of depression around a water well comes into contact with or overlaps that of a neighbouring well pumping from the same aquifer and thereby causes additional drawdown or drawdown interference in the wells.

WELL SCREEN - A cylindrical filter used to prevent sediment from entering a water well. There are several types of well screens, which can be ordered in various slot widths, selected on the basis of the grain size of the aquifer material where the well screen is to be located. In very fine grained aquifers, a zone of fine gravel or coarse sand may be required to act as a filter between the screen and the aquifer.

WELL YIELD - The volume of water discharged from a well in litres per minute (L/min), litres per second (L/s) or cubic metres per day (m^3/day).

2.0 GEOLOGY AND HYDROGEOLOGY OF THE LOCAL AQUIFER

ASR testing has been carried out within the sand and gravel aquifer #219 mapped by the BC Ministry of Environment (BC Water Resources Atlas). A geology and hydrogeology report for this aquifer has been submitted to the Ministry of Environment in order to revise the aquifer mapping by dividing #219 into two distinct aquifers. Aquifer #219 is named the Nanoose Creek Aquifer and it is proposed to name the deeper aquifer the Englishman River Aquifer (LHC, March 28, 2014). The uppermost aquifer is unconfined and the deep aquifer is confined and is the target of this project.

2.1 Aquifer Formation

The Englishman River Aquifer is believed to occur in the deposits of the Muir Point Formation stratigraphic unit or a unit similar in age and lithology. This unit was deposited during the Sangamonian inter-glaciation (late Pleistocene ≈ 125 ka). It consists of "estuarine, floodplain, fluvial, alluvial fans and debris flow lithofacies" (S. Hicock, 1989) materials.

The Muir Point Formation is embedded between glacial deposits and is directly overlaid by the marine deposits of the Dashwood Drifts. It was described as containing five units, ranging from "rusty gravel with lenses of organic-rich silt and casts of logs and branches, to sandy gravel with lenses of coarse gravel and debris flow" (S. Hicock, 1989).

The predominant colour of the deposits is grey, while the upper aquifer developed in the Quadra Sands is mostly brown. The Englishman River Aquifer is extremely heterogeneous and the well logs usually report the following units in random order:

- Silty sand, silty sand and gravel, silty gravel, silty cobble/boulders
- Fine sand to coarse gravel
- Organic materials, mostly wood debris

Numerous well records suggest that the aquifer is highly heterogeneous, thus unpredictable, rather than uniformly layered. In fact, the layering and grain sizes in one hole is not necessarily found in another hole drilled a few meters away.

The ASR well was drilled with a cable tool drill rig, therefore, providing good reliable samples. Some layers of the aquifer contained coarse gravel to large boulders. The biggest boulder reported and able to be recovered through the construction casing without being crushed was over 30 cm in diameter (12-in). The grains within a single sample were from various origins; from sedimentary, to igneous to metamorphic, and their geometry ranged from sub-rounded to angular. This suggests that the materials were deposited by rivers from a relatively close-by source (i.e. limited transportation). The non-conventional shape of the aquifer boundary (See Figure A3 – Appendix A) suggests therefore that the productive layers consisting of mixed size elements follow the course of paleo-rivers. Numerous and remarkably well preserved fibered wood debris were observed at all depths of the aquifer, as well as a few shells in the gradual transition between the top of the aquifer and the confining layer of till (probably from the Dashwood Drifts). For that matter, the Muir Point Formation is rich in debris from Douglas fir and cedars, indicating general climatic conditions "at least as warm and dry as present "(S. Hicock, 1989).

The aquifer deposits occur where the bedrock is deep, generally from 0 to 80 m. below current sea level. An overview of the bedrock surface elevation suggests that the paleo-Englishman river/glacier might have flowed from west to east with an outlet in Nanoose Bay. The aquifer pinches out on the sides, mostly due to the bedrock becoming shallower. In the area directly east of the ASR well (see Figure A3 – Appendix A), the aquifer does not exist along a thin ridge-like zone due to a continuous transition of till - marine silt – till.

2.2 Recharge / Discharge

The main recharge zone of the Englishman River aquifer is located in the south-western region, where the highest water levels are observed. Recharge likely occurs through upland flow from precipitation runoff which infiltrates along the aquifer-bedrock contact. A connection between the aquifer and the Englishman River is unlikely considering geologic analyses completed to date (LHC, March 28, 2014). Furthermore, if a connection exists it would apply to a limited section of the river in the extreme south-west of the aquifers, in fact, bedrock outcrops in the river bed when progressing downstream. Minor recharge also occurs through leakage from the overlying aquifer. An additional recharge component may be provided by upward flow from the underlying bedrock. However in the Kaye Road region a confining till layer covers the bedrock and will limit upward flow. Water quality data were gathered from different locations in the aquifer and it appears that the wells located closer to the boundaries have lower TDS, sodium and chloride (see Section 6.0). These elements usually increase as the groundwater moves away from the recharge areas.

The two discharge zones of the aquifer are located in Craig Bay and Nanoose Bay. Groundwater flow paths divide to follow either a south to north direction, or a west to east course. A few wells are flowing artesian along the northern boundary.

The bedrock becomes very shallow at the northern boundary and it is not established whether or not the groundwater mounds along the boundary and eventually moves slowly towards the closest discharge area, or if it discharges slowly into the bedrock through fractures. A piezometric map showing groundwater flow paths is displayed in Figure A4 – Appendix A.

3.0 ASR WELL SITE SELECTION AND CONSTRUCTION

3.1 Test Wells

Five aquifer testing wells were drilled in order to locate the most suitable site for the ASR test well (ASR-1). The test wells, DS#1, 2, 3, 5 and 6 are plotted in Figure A2, Appendix A. The test wells were completed using the dual-rotary drilling method with 8-inch welded steel casings. Stainless steel well screens were installed in DS #1, 3 and 5 so that these wells could be pumped. DS#2 and 6 did not intersect the lower aquifer and therefore were not screened. A short pumping test at DS#1 indicated a yield of 3.21 L/s or not sufficient based on our 7^{+} L/s minimum target yield. Test well DS#5 had a yield estimated at 6.88 L/s or marginally sufficient. The DS#3 pumping tests (Sept 2012 and Feb 2013) indicated that DS#3 could yield 7.2 L/s and this site was selected for construction of a larger diameter ASR cycle testing well.

All of the test wells were drilled by the dual-rotary drilling method utilizing 8-inch diameter welded steel casings. This drilling method is relatively expensive but does allow for completion of an 8-inch screened well which is the optimum well size for testing aquifer yields in the 5-11 L/s range (Driscoll, P. 415).

For future exploration work required for ASR well field expansion a combination of drilling methods may be considered. A Sonic Drilling machine, Becker drill or dual-rotary with 6-inch screwed steel casing will be considered as lower cost options for aquifer exploration. These lower cost methods would be followed-up with 8-inch screened wells, to be used for pumping tests, only at sites with confirmed favourable geology.

3.2 Method of Drilling and Sampling

The ASR well, referred to as ASR-1, was drilled 8 m south-east of DS#3 (currently MW-1). The well was drilled between May 2 and May 24, 2013. The ASR well has a 12-inch diameter 304 stainless steel casing and screen and the construction casing was 20-inch diameter. The ASR-1 well was drilled with a cable tool drilling machine. This method was selected because of its advantage to recover relatively undisturbed samples compared to the rotary method of drilling. Drilling difficulties were encountered due to casing friction and the 20-inch construction casing became stuck at one point. This drilling problem caused a delay of about 2 weeks and the 20-inch construction casing was only freed by drilling rotary holes around it and injecting drilling fluid. Subsequent to this experience it was decided that in future the 20-inch casing should be installed by the dual-rotary drilling method. This method provides for rotating the casing which facilitates penetration of tight geologic layers. The hole was drilled to a depth of 165 ft (50.3 m).

Samples were taken every 5 ft. from 40 to 105 ft., and every 2 ft. from 106 to 156 ft. The samples were caught directly out of the bailer with a bucket, mixed and laid on the ground. A photo of each sample was taken and samples were bagged for sieve analysis. The cable-tool samples appeared very different than at the 8-inch test well. While we observed mostly gravel in the 8-inch well, the ASR-1 well samples were very sandy with cobbles (see Photos 1a and 1b). This may be due to the fact that the rotary method used in the 8-in well missed a fraction of the finer materials. It might also be a drastic change of the aquifer characteristics over a short distance. It was however noticed that a lot of sand was flushed-out during development of the test well.

Pictures of the samples at ASR-1 are attached in Appendix B.

Photo 1- Comparison of the samples at MW-2 and ASR-1

MW-2 (similar to MW-1) | **ASR-1**

Scale is different for the 2 pictures (MW-2 is a closer view)

The MW-2 samples above are from the dual-rotary drill and ASR-1 samples from cable tool drill. Apparently the larger boulders are broken-up by the rotary drill.

3.3 Well Log Record

The geological formations were described using the Guide for Using the Hydrogeologic Classification System for Logging Water Well Boreholes (T.M. Hanna, NGWA, 2006). The main components of the log are as follows:

- Upper pervious layer containing upper unconfined aquifer: [0′ ; 68′];
- Impervious, confining layer: [68′ ; 124′];
- Lower pervious layer containing lower confined aquifer: [124′ ; 150′].
- The full well log and details of the well construction are provided in Appendix B.

3.4 Well Plumbness and Alignment Test

Plumbness of the well was assessed on May 28, 2013. The cable tool drill bit was used for this purpose and was perfectly centered at surface. The casing was oriented and the rod was lowered down. A measurement of the cable position from the centre of the casing was recorded every 5 ft.

Plumbness of the well is excellent, with a final deviation from the center of 0.36 m at 47.8 m deep to the South-South-East (1.18ft/157ft). This corresponds to an angle of 0.0075°.

The maximum deviation allowed is calculated based on the AWWA Standard A100-066:

"The maximum allowable deviation (drift) from vertical shall not exceed 2/3 of the inside diameter of the well casing per 100 feet of depth".

Therefore, the maximum allowable horizontal deviation for the subject well is 2/3 of 20-inch I.D., or 1.11ft/100ft (0.34m/30.5m). This corresponds to and angle of 0.01°. With a horizontal deviation angle of 0.0075°, the ASR-1 well meets the standards set by AWWA. See Appendix B.

Ensuring that ASR wells are plumb and straight is important because this facilitates installation of pumping equipment and control valves. Additionally ASR wells can be used to generate power (electricity) in the recharge mode and this is best achieved with a line-shaft turbine pump which in-turn requires a straight and plumb well.

3.5 Sieve Analysis and Screen Design

The samples were sieved by Hodge Hydrogeology. Data from the sieve analysis were used to design the screen and the formation stabilizer. The sieve analysis report is attached in Appendix B.

The screen is designed as follows:

- [130' to 132']: Slot 40
- [132' to 138/']: Slot 80
- [138' to 144']: Slot 40
- [144' to 150']: Slot 20

3.6 Formation Stabilizer Design

The formation stabilizer was directly designed from the sieve analysis. The purpose of the stabilizer is to support the natural formation around the screen (Driscoll, P. 447). The stabilizer must therefore have the same characteristics as the natural aquifer formation, meaning that 50 to 60 percent of the stabilizer will be removed during development of the well. Therefore, the stabilizer was backfilled during development in order to maintain material above the top of the screen. The stabilizer design chosen was 8-16 gravel with a grain size range between 1.18 and 3.36 mm.

3.7 Piezometer Construction

A 1-in diameter piezometer was installed inside the annular space between the 12-in well and the 20-construction casing. The piezometer is a PVC pipe, schedule 80, completed at depth 131 ft. and slotted from 129 to 131 ft. The stick-up (above ground level) is 2 ft. The goal of this piezometer is to monitor the water level directly outside of the well without having to access the large diameter casing. Water levels in the piezometer were measured during pumping and followed the water levels inside the casing very closely which indicated the efficient flow through the formation stabilizer and into the well.

4.0 WELL FIELD / MONITORING WELLS

The ASR-1 well site is located at 1900 Kaye Road. It encompasses one ASR well called ASR-1, two monitoring wells, MW-1 located 8 m. north-west and MW-2 located 175 m. south-west of ASR-1. A 2-inch diameter piezometer (MW-1 Piezo) was installed in the upper aquifer to monitor pumping impacts on the upper aquifer. A close-up view of the well field is displayed in Figure A5 – Appendix A.

Table 1 – Well Information

Well Name	Well ID. Plate No.	Coordinates UTM (10 U)	Elevation*		Well Completion Depth		Static Water Level		Yield (driller's estimate)		Distance to ASR-1	
			m	ft	m	ft	m	ft	L/s	gpm	m	ft
ASR-1	38480	408,599 5,460,709	43	141	47.5	156	31.1	102	-	-	-	
MW-1 (DS#3)	36481	408,595 5,460,717	43	141	51.5	159	30.5	100	3.8+	60+	8	26
MW-2 (DS#5)	34713	408,506 5,460,556	44	144	46.6	153	24.1	79	6.3+	100+	175	574
MW-1 Piezo	-	408,595 5,460,719	43	141	15.9	52.2	10.5	34.4	-	-	11	36
DS#1	36734	409,373 5,460,863	48	157	36.0	118	28.6	94	0.95	15	785	2,575
DS#2	36480	408,569 5,461,040	40	131	19.2	63	12.8	42	(upper aquifer only)		330	1,083
DS#6	-	408,717 5,460,589	44	144	63.7	209	-	-	DRY		170	558

5.0 PRE PUMPING TESTS AND WELL DEVELOPMENT

5.1 Short Pumping Tests During Development

ASR-1 was heavily developed in July 2013 by Drillwell Enterprises Ltd. The well was developed by air lifting and the pump and surge method. Due to the great amount of clay in the vicinity of the well, a dispersant polymer was used to partially remove the clay (Nu-Well® 220). After injection of the product, the turbid water was pumped out of the well.

Regular short pumping tests were performed to monitor the efficiency of the well development. A total of eight 60-min short tests were recorded and showed steady improvement of the well capacity. The development was completed when almost no benefit was noted from further developing. Table 2 summarizes the data obtained from these pump tests. See Graph C1 in Appendix C.

Table 2 – Short Pumping Test Information at ASR-1 during Development

Pumping Test	Date	Pumping test length	Flow rate		Specific capacity at 100 days	Preliminary Capacity Estimate	
#	dd-mm-yyyy	min	USgpm	L/s	L/s/m	USgpm	L/s
1	27-06-2013	-	-	-	-	-	-
2	02-07-2013	60	59	3.7	0.398	59	3.7
3	05-07-2013	60	60	3.8	0.552	79	5.0
4	09-07-2013	60	61	3.9	0.665	96	6.0
5	12-07-2013	60	62	3.9	1.258	178	11.2
6	16-07-2013	60	62	3.9	1.437	206	13.0
7	18-07-2013	240	132	8.3	1.295	184	11.6
8	19-07-2013	60	62	3.9	1.482	206	13.0

Pumping test #1 gave erratic and unusable data.

The 60-min tests show a net improvement of the 100-day specific capacity and therefore the long-term capacity. Pumping test 7 was a 4 hours test and showed a lower specific capacity. This can be the result of more loss at the well due to greater pumping rate, and the presence of a negative boundary that was not reached with the shorter tests.

The development was stopped when the results from pump test 6 to 8 did not indicate a significant increase in the well performance.

5.2 Step Test

A step test was conducted on July 30, 2013. The purpose of the step test was to assess the optimal pumping rate for the long-term pumping test and assess the respective loss percentage resulting from well and aquifer media (see Graph C2 in Appendix C).

Under laminar flow, the drawdown is proportional to the pumping rate. However, turbulence at and near the well can occur at sufficiently high rates. This brings losses at the well that adds up to the observed drawdown. The Jacob equation is used to assess the proportions of laminar loss and turbulent loss.

$$s/Q = BQ + CQ^2$$

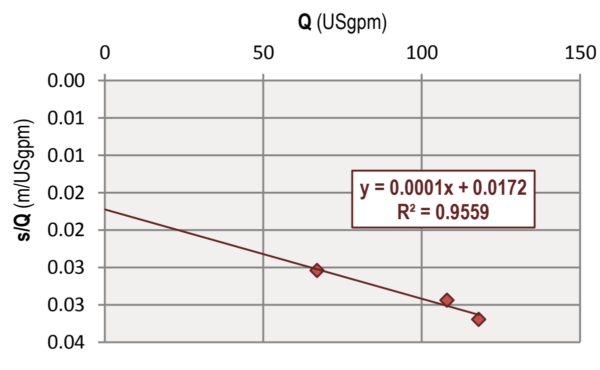
With:

- Laminar loss: $\Delta l = BQ$ (linear losses)
- Turbulent loss: $\Delta q = CQ^2$ (quadratic losses)
- Total loss: $\Delta t = \Delta l + \Delta q$

Results from the step test are shown in Table 3:

Table 3 – Summary of Step Test Data at ASR-1

Step	Time	Pumping rate	Drawdown	Specific drawdown
	t	Q	s	s/Q
#	min	USgpm	m	m/USgpm
1	90	67	1.700	0.0254
2	90	108	3.171	0.0294
3	90	118	3.766	0.0319



The equation obtained is: **y = 0.0001 x + 0.01752**

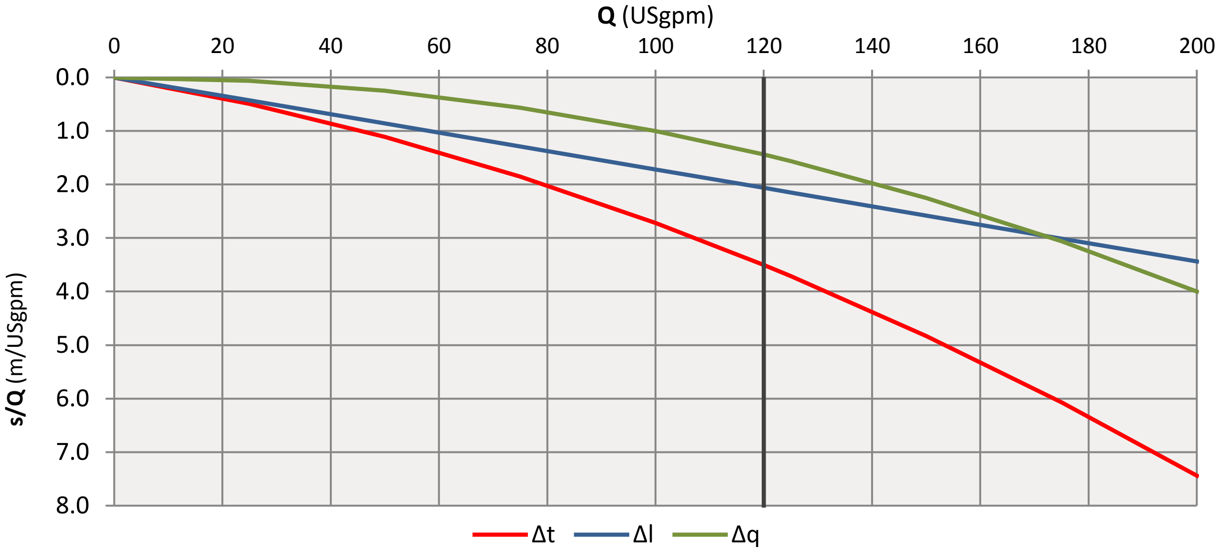
With:

- B = 0.0172 ⇨ ΔI = BQ = 0.0172 Q
- C = 0.0001 ⇨ Δq = CQ^2 = 0.0001 Q2

Graph 1 represents the percentage of loss due to laminar loss (blue line) and turbulent loss (green line); the total loss (red line) being the sum of the laminar and turbulent losses. The graph shows that at low pumping rates most of the loss is attributed to laminar loss (almost no turbulence). At high pumping rate, losses resulting from turbulence become dominant over laminar loss.

The choice of a pumping rate for the well determines the percentage of each loss type. For the 3-day test, the pumping rate was chosen where 60% of the loss is attributed to laminar loss and 40% to turbulent loss. These percentages correspond to a flow of 120 USgpm (grey dashed line).

Graph 1 - Step Test: Laminar and Turbulent Losses



5.3 3-day Pumping Test

A 72 hours (3 days) pumping test at constant rate was performed from July 31 to August 3, 2013. The pumping rate was set at 120 USgpm (7.57 L/s) following the step drawdown analysis (see section 5.2). The rate was held constant during the test following a short start-up phase (90 min) when small flow adjustments were made. Flow meter readings from 300 minutes until the end of the test were constant at 120 USgpm and the flow meter totalizer indicated an average flow of 124 USgpm. The well water level declined from 32.507 m to 38.454 m for a total drawdown of 5.947 m during the test. Manual water level readings as well as datalogger readings were recorded with good agreement. Total drawdown indicated by the datalogger was 5.885 m. The produced water was discharged to a ditch approximately 300 m north of the pumped well. Three days of recovery water levels were recorded following the end of pumping. See Graph C3 in Appendix C for a drawdown graph.

Long-term capacity of the ASR-1 well was calculated based on the following method:

Long-term Capacity = Specific capacity at 100 days x Safe available drawdown

With:

- Specific capacity = Pumping rate during the test / Extrapolated drawdown @ 100 days
- Safe available drawdown = Total available drawdown - Static Water Level to Top of Screen

Pumping rate during the test:	124 7.82	USgpm L/s
Extrapolated drawdown @ 100 days:	9.0	m
↳ Specific capacity:	0.869	L/s/m
Static water level:	30.32	m.bgl.
Depth to top of the screen:	39.62	m.bgl.
↳ Total available drawdown:	9.3	m
↳ Safe available drawdown:	9.3	m
Well long-term capacity:	**8.08** **128**	**L/s** **USgpm**

bgl = below ground level

The drawdown curve also shows the effect of a clear negative boundary reached between 1000 and 2000 minutes after pumping started. The boundary effect was expected as it was also observed at the test well DS#3). The other inflections in the drawdown curve are too limited to be considered as boundary effects. The transmissivity near the well is calculated from the Cooper-Jacob equation. The set of data used is during laminar flow (straight line on a log scale). Using the drawdown points from 40 to 125 min after pumping started give a R^2 of 0.9999, meaning that the condition during this time frame was perfectly laminar The equation is as follows: **$y = 0.3365 \ln(x) + 1.9922$** (Graph C3 – Appendix C). This corresponds to the transmissivity nearest to the well before the boundary effect.

Pumping rate during the test:	124 675.9	USgpm m^3/d
Drawdown at 10 min: s(10)	2.77	m
Drawdown at 100 min: s(100)	3.54	m
Δs	0.77	m
Transmissivity: T = 0.183 x Q / Δs	**160.6**	**m^2/d**

After the boundary effect, the equation is as follows: **$y = 1.163 \ln(x) – 3.8455$.**

Pumping rate during the test:	124 675.9	USgpm m^3/d
Drawdown at 10 min: s(10)	-1.17	m
Drawdown at 100 min: s(100)	1.51	m
Δs	2.68	m
Transmissivity: T = 0.183 x Q / Δs	**46.2**	**m^2/d**

The two results are significantly different and show the significant effect of aquifer boundaries. This is due to the limited extent of the aquifer to the west and the east. For the long term use of the well, the second result will apply (46.2 m^2/d).

6.0 CYCLE TESTING

6.1 Data Collection

The ASR well is connected to a SCADA system to monitor the well operations. This system records the flow rate at the well, the water level and the pressure in the casing. This allows the LHC team to assess the cumulative volume stored and recovered as well as the specific capacity of the aquifer under injection and production.

Solinst datalogger tools were deployed in the monitoring wells MW-1 and MW-2 to record the water levels and groundwater temperature. A barologger was also installed at MW-2 to apply correction to the water levels. Regular hand readings were performed to adjust the datalogger readings. Figure A6 – Appendix A show a simplified sketch of the data collected during the cycle tests at the ASR well field.

Table 4 displays the list of all the data collected and interpreted from the field.

Table 4 – Data Collected and Interpreted in the Field

ASR-1	MW-1 ; MW-2 ; MW-1 Piezometer
SCADA System	Solinst Datalogger / Barologger
Measured data Injection / extraction flow Groundwater level Wellhead pressure Interpreted parameters Mounding / drawdown Cumulative volume stored / extracted Transmissivity	Measured data Groundwater level Groundwater temperature Barometric data Interpreted parameters Mounding / drawdown Transmissivity
Hach Kit (ERWS)	
Temperature ; Total dissolved solids ; Conductivity / Specific conductance ; Salinity ; pH ; Chlorine ; Turbidity ; Dissolved oxygen / Dissolved oxygen saturated ; Oxygen reducing potential Eh / Chlorine residual	

6.2 Cycle Test 1

Cycle Test 1 extended from August 19 to October 1, 2013 according to the following schedule:

Table 5 – Cycle Test 1 Schedule

	INJECTION		STORAGE		PRODUCTION	
	Start	End	Start	End	Start	End
	19-08-2013	18-09-2013	18-09-2013	20-09-2013	20-09-2013	01-10-2013
Recharge / recovery volume (m^3)	21,976		-		5,568 (25.3%)	
Recharge / recovery rate (L/s)	9.0 *(average)* 8.9 *(geometric mean)*		-		7.6 [0 ; 7] h 6.4 [7 ; 74] h 6.0 [74 ; 96] h 5.5 [96 ; 168] h 5.2 [168 ; 266] h 5.0 [266 ; 270] h	
Phase duration (days)	30		2		12	

6.2.1 Injection Phase

Graphs showing the evolution of the water levels and mounding during the injection phase are shown in Graphs D1 and D2 in Appendix D. While the water level at ASR-1 rose significantly, the levels at the monitoring wells remained comparatively low. The MW-1 Piezometer located in the upper aquifer showed no interference.

The limited response at MW-1 located only 8 meters away from ASR-1 shows a low transmissivity zone between the two wells.

Table 6 – Mounding Response at the Wells during CT#1

	Maximum Mounding in m. (Cycle Test 1)	**Percentage**
ASR-1	39.6	100
MW-1	5.6	14
MW-2	0.5	1.3

6.2.2 Recovery Phase

The production phase at ASR-1 started on September 18, 2013, with a production rate of 7.6 L/s. The rate had to be reduced after 7 hours of pumping due to a quick drop of the water level. The pumps were shut down and recovery started on October 1, 2013. See Graph D3 in Appendix D for the drawdown plot and Graph D4 for the recovery plot.

The drawdown plot shows the effect of a boundary and/or well clogging, with steeper slopes during the test, even under decreasing pumping rates. The pumping rates started at 7.6 L/s and was lowered down to 5.0 L/s, the estimated long-term capacity ranging from 5.4 to 3.15 L/s at the end of the test.

The recovery graph (D4 – Appendix D) also shows the effect of a boundary. The extended curve cuts the X axis at a very low value (below 1), which indicates an aquifer of limited extent with no recharge occurring during the pumping phase.

Cycle test 1 showed that the well was not able to maintain a production rate of 8 L/s as estimated from the 3-day pumping test. This is indicative of well clogging which is common in ASR wells. Vigorous development before starting cycle test 2 was recommended.

The cumulative water stored curve is plotted on Graph D5 in Appendix D. 25% of the volume injected was recovered (5,567.5 m^3), therefore 75% of the water injected during cycle test 1 still remains in the aquifer (16,408.2 m^3).

6.2.3 Evolution of Aquifer Transmissivity

The transmissivity T is a parameter representing “the transmission capability of the entire thickness of an aquifer” (Sterrett, J. Robert - 2007). The unit is a measure of capacity of the aquifer per meter width of the aquifer, i.e. $m^3/d/m$, or m^2/d. The transmissivity can be assessed from pumping data with two methods: time/drawdown and distance/drawdown methods. The distance/drawdown method used data from ASR-1 and MW-1 (8 m NW) and compares the response of the wells at each time of injection and pumping. The time/drawdown method uses equations from specific time frames, therefore gives single point results. Graph D7 shows the evolution of the transmissivity during injection and production, with the two methods. It appears after injection started, that the value of transmissivity before the boundary effect found during the 3-day pumping test cannot be sustained (see section 5.3). The T quickly drops below the minimum value of T calculated with the 3-day test. The back-flushing recovered a value slightly above this low T, but decreased after a short period of time. The distance/drawdown method during production shows an increase in the transmissivity, although the time/drawdown method displays a decrease. This is due to the fact that the levels between ASR-1 and MW-1 tended to be closer to each-other with time. The overall transmissivity at the ASR-1 well decreased with time, as indicated by the time/drawdown method. Overall Graph D7 illustrates that the aquifer performs better (transmits water more efficiently) during recovery as compared to during injection. This is normal for ASR well.

6.3 Cycle Test 2

It should be noted here that the water injected in CT#2 was sourced from Parksville's wells. CT#1 injected water was sourced from the Englishman River Intake. This change was necessary because the river intake is shutdown in the wet season due turbidity issues.

Cycle Test 2 extended from October 11, 2013 to March 17, 2014 according to the following schedule:

Table 7 – Cycle Test 2 Schedule

	INJECTION		STORAGE		PRODUCTION	
	Start	End	Start	End	Start	End
	11-10-2013	03-01-2014	03-01-2014	21-01-2014	21-01-2014	17-03-2014
Recharge / recovery volume (m³)	66,924[1]		-		37,451	
Recharge / recovery rate (L/s)	9.0 *(average)* 7.2 *(minimum)* 12.2 *(maximum)*		-		8 L/s approximately form ASR-1 and MW-1	
Phase duration (days)	85		18		55	

[1] At the start of CT#2 there was also 16,408 m^3 of stored water remaining from CT#1

6.3.1 Injection Phase

Graphs showing the evolution of the water levels and mounding during the injection phase are displayed in Appendix E, Graphs E1 and E2. The Graphs overlap results from CT#1 and CT#2. At equal time after injection started, the mounding built at ASR-1 during CT#2 is significantly smaller than at CT#1.

An example at 710 hours after injection started is as follows:

- ASR-1 CT#1 @ 710h: Mounding = 33.006 m
- ASR-1 CT#2 @ 710 h: Mounding = 20.053 m

The mounding at MW-1 was however greater, with a maximum mounding of 44% of the mounding at ASR-1 (14% during CT#1). This is a clear indication of a better communication between the two wells, therefore an improvement of the transmissivity near to ASR-1.

Table 8 – Mounding Response at the Wells during CT#2

	Maximum Mounding in m. (Cycle Test 1)	**Percentage**
ASR-1	32.46	100
MW-1	14.56	44
MW-2	1.41	4.4

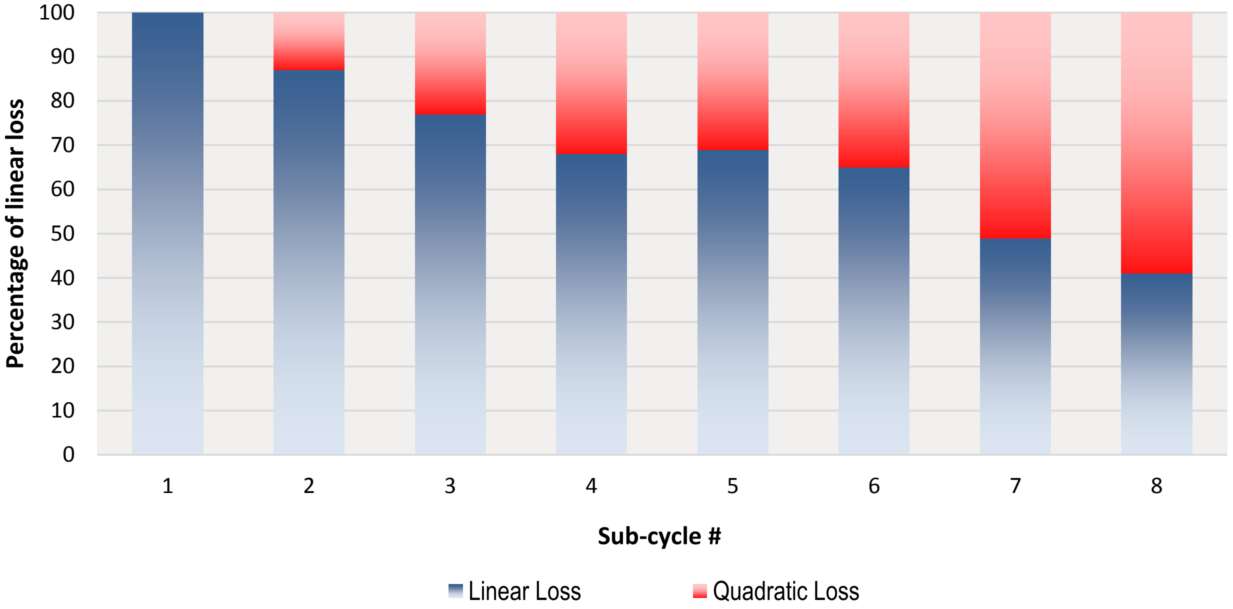
The ASR-1 well was regularly back-flushed in order to recover well efficiency. The periods of injection between each back-flush is called in this report "sub-cycle". The following table shows the mounding achieved after 50 hours on injection into each sub-cycle. A linear comparison between injection flow and mounding is made to compare each cycle. It is supposed that the first sub-cycle is the most efficient; therefore, all the head loss attributed at the well is linear. The mound after 50 hours is 9.8 m.bgl., corresponding to 100% of linear loss and 0% of other type of loss (quadratic loss or well loss, Driscoll, P 556). If the 2nd sub-cycle was as efficient, for the same average flow, the mound should reach the same value (9.8 m.), however, we observe a value of 11.4 m. The loss of efficiency is, according to this model, attributed to the quadratic type of loss (most likely well clogging, and introduction of turbulence in flow). The last column of the table compares the increase of quadratic loss from the previous sub-cycle. Graph 2 is an illustration of the data displayed in Table 9.

Table 9 – Details on Sub-cycles during CT#2

Sub-cycle	Average flow	Level reached 50h into the sub-cycle	Mounding reached 50h into the sub-cycle	Linear loss based on 1st sub-cycle		Quadratic loss based on 1st sub-cycle		Quadratic loss from previous sub-cycle
#	L/s	m.bgl.	m.bgl.	m	%	m	%	%
1	7.6	21.3	9.8	9.8	100	0.0	0	-
2	7.6	19.7	11.4	11.4	87	1.5	13	13
3	8.0	17.6	13.5	13.5	77	3.1	23	10
4	9.8	12.4	18.7	18.7	68	6.0	32	9
5	9.8	12.6	18.5	18.5	69	5.8	31	-1
6	9.8	11.6	19.5	19.5	65	6.8	35	4
7	11.9	-0.6	31.7	31.7	49	16.3	51	17
8	9.6	0.6	30.5	12.4	41	18.1	59	8

Graph 2 shows a slow increase of the quadratic losses, that could be attributed to well clogging, i.e. loss in efficiency. Cycle #4, 5 and 6 showed a stabilization of the losses. This could be attributed to an optimal injection flow. These cycles had an average injection flow of 9.8 L/s. However, the injection flow was increased to 11.9 L/s at the sub-cycle #7, resulting in a great increase of quadratic losses (17%). Well clogging most likely occurred during this cycle because the well kept losing efficiency even after reducing the flow on sub-cycle #8. This is also illustrated in the Well Performance graph showing the mounding/injection rate path followed by the well between the sub-cycle. If no losses occurred, the increase or decrease of the flow should lead the mounding to follow the same path back and forth. However, it is observed that the plot gets further from the ideal curve as the sub-cycling goes on. For the same injection rate, the mounding is higher and higher, which clearly demonstrate a loss in performance over time.

Graph 2 - Well Efficiency Compared to 1st Sub-cycle



Graph E7, Appendix E shows the evolution of the transmissivity during the period of injection. The slow decrease of the transmissivity illustrates the same effect as the above graph, due to an increase of the quadratic losses. A vigorous re-development of ASR-1 could make the well more efficient.

6.3.2 Storage Phase

The storage phase extended for a period of 18 days. The well was re-developed with the Nu-Well® 220 well conditioner to remove the fines and unclog the well.

According to the data gathered during cycle test 1, it was suggested for better efficiency to pump the stored water from ASR-1 and MW-1 simultaneously. During the storage period, the ERWS team installed a pump in MW-1 and connected it to the main piping system.

6.3.3 Recovery Phase

The recovery started on January 21, 2014 and ended on March 17, 2014. ASR-1 and MW-1 were pumped at an average flow of 7.86 L/s (a minimum of 7.60 L/s and a maximum of 8.60 L/s). The flow was equally divided between the two wells; therefore each produced on average 3.93 L/s. Both wells were pumped to increase the yield from the ASR well site. Pumping only ASR-1 limits production capacity to approximately 5L/s, however using both ASR-1 and MW-1 increased the potential yield to 9 L/s.

The drawdown plot is shown in Graph E3, Appendix E. The drawdown plots for the two wells are very close to each other and roughly follow the same trend. The small variations in the drawdown match with small variations of the flow, proving that the wells are very sensitive to the fluctuations in flow.

The drawdown at ASR-1 and MW-1, extrapolated to 100 days does not reach the maximum available drawdown. The extraction flow may therefore be slightly increased according to the following calculations:

ASR-1: $y = 1.4793 \ln(x) - 3.7565$			**MW-1:** $y = 1.4388 \ln(x) - 3.2108$		
$Q_{average} = 7.91$ L/s[1]					
Average flow	Q_{ASR-1}	= 3.955 L/s	Average flow	Q_{ASR-1}	= 3.955 L/s
Drawdown at 100 days	s_{100d}	= 7.00 m	Drawdown at 100 days	s_{100d}	= 7.25 m
Specific capacity at 100 days	SC_{100d}	= 0.565 L/s/m	Specific capacity at 100 days	SC_{100d}	= 0.546 L/s/m
Total available drawdown	TAD	= 9.382 m	Total available drawdown	TAD	= 8.547 m
Approximate interference[2]	s_{int}	= 0.655 m	Approximate interference	s_{int}	= 0.452 m
Safe available drawdown[3]	SAD	= 8.291 m	Safe available drawdown	SAD	= 7.690 m
Adjusted flow	Q_{max}	= 4.7 L/s	Adjusted flow	Q_{max}	= 4.2 L/s
$Q_{total} = 8.9 \approx 9.0$ L/s					

[1] *$Q_{average}$ is the average of the flow from the set of data used to create the extrapolated trendline. It is therefore slightly different from the average of the flow of the whole pumping phase.*

[2] *The estimation of the interference between ASR-1 and MW-1 is detailed further.*

[3] *An extra safety factor using 95% of the total available drawdown has been applied to address the possible variations of the start water level.*

According to the cycle test 2 data, the combination of the two wells can produce a safe yield of 9.0 L/s. ASR-1 has a greater available drawdown so can pump at a slightly higher rate than MW-1 (53% from ASR-1 and 47% from MW-1).

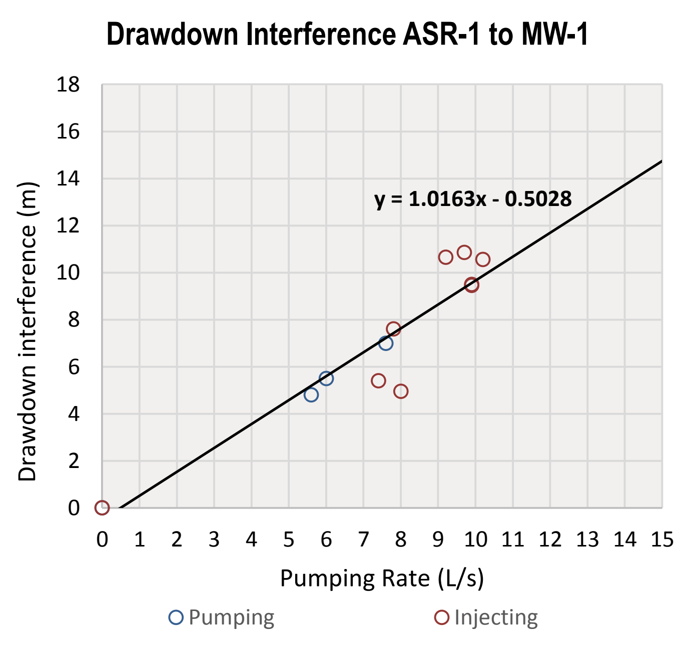
The mounding effect was plotted on a map using the following control points: ASR-1, MW-1, MW-2 and #50036 (Weigh Scale well). The map is displayed in Figure A7 Appendix A. The response in pressure is higher at the weigh scale than at MW-2, although the latter is closer to ASR-1. This shows a displacement of the pressure response to the north. However, the modeling shows that this pressure does not significantly expand beyond a radius of 400 m from ASR-1 along the North-South axis.

Method for the estimation of the interference between ASR-1 and MW-1:

Data from Cycle Test 1 and the injection phase of Cycle Test 2 were collected to get of each pumping rate a corresponding drawdown at ASR-1 and at MW-1. See Table 10:

Table 10 - Estimation of the Interference between ASR-1 and MW-1

Pumping Rate	Drawdown ASR-1	Drawdown MW-1	Δs
L/s	m	m	m
Pumping			
0.0	0.00	0.00	0.00
5.6	9.20	4.40	4.80
6.0	9.50	4.00	5.50
7.6	9.00	2.00	7.00
Injecting			
0.0	0.00	0.00	0.00
7.8	11.10	3.50	7.60
7.4	8.60	3.20	5.40
8.0	8.90	3.95	4.95
9.9	14.70	5.25	9.45
9.9	14.60	5.10	9.50
10.2	15.80	5.25	10.55
9.2	16.40	5.75	10.65
9.7	16.50	5.65	10.85



6.3.4 Back-flushing

Back-flushing (reversing the flow from injection to production) once per week was used effectively during Cycle 2 to limit water level mounding. The water level at ASR-1 was maintained below ground level for essentially all of the injection period. This was a significant improvement over cycle test one.
The back-flushing is carried out to dislodge fine material trapped around the well screen which "clogs" the well. The back-flush protocol that we designed and proved effective is described as follows:

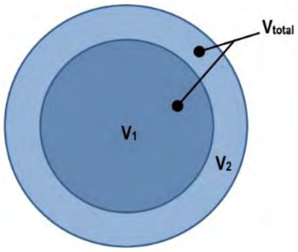
- Shut-down injection flow.
- Pump well at up to 11 L/s to draw down the water level to just above the screen.
- Immediately reverse the flow to inject 9 – 10 L/s and bring the water level up to ground surface.
- Repeat above two steps in quick succession until the produced water comes completely clear (no turbidity).

7.0 WATER QUALITY MONITORING

Water chemistry parameters were regularly measured according to specific schedules. On-site analysis with a field water chemistry kit was conducted on regular basis and more complete laboratory analyses were applied according to the schedules attached in Appendix F – Water Sampling Programs and Schedule. All field and laboratory water chemistry testing results are presented in Appendix F.

7.1 Conservative Elements for Groundwater Tracing

Considering the stable water quality at MW-2, it can be confirmed that the injected water never reached this well. Further calculations corroborate this conclusion: the aquifer transmissivity is lower towards the south (i.e. towards MW-2) than towards the north; the injected water may flow preferentially to the north. The theoretical extent of the water bubble is 133 m, Cycle test #2 (see Graph E6 – Appendix E), while MW-2 is at a distance of 175 m from ASR-1. Therefore it would take an additional 73% of the total volume injected to create a storage bubble that would reach MW-2. The volume calculations are as follows:



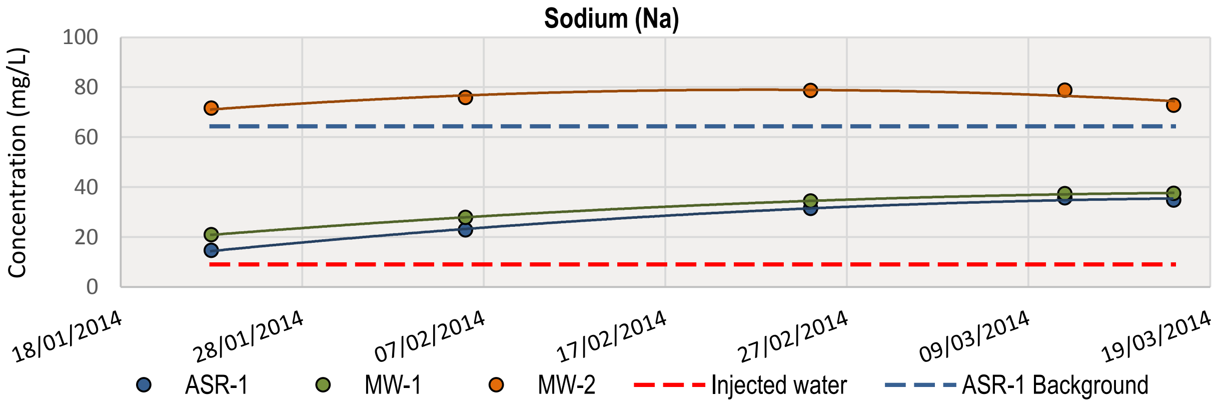
Parameters:

Aquifer porosity = 0.25
Aquifer thickness = 6 m

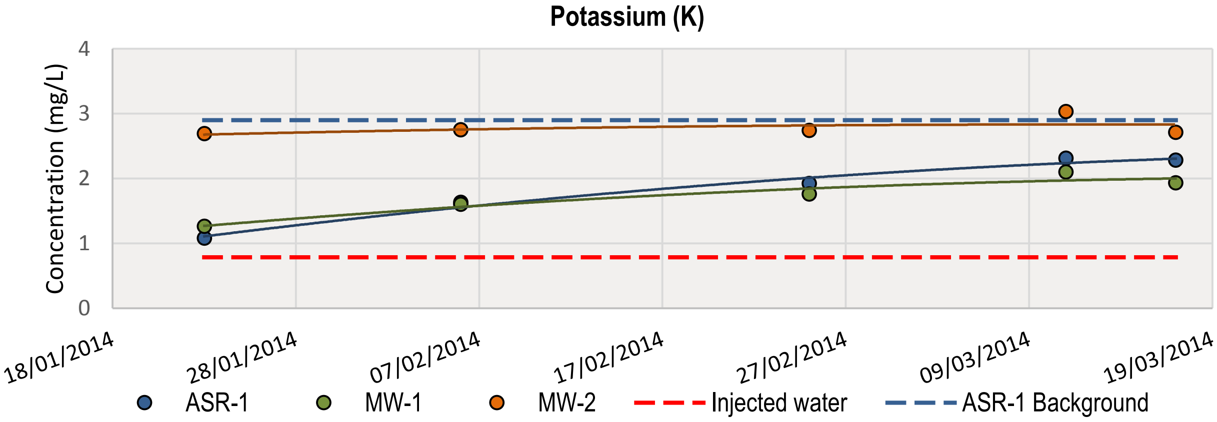
$V_2 = V_{total} - V_1$
$= 0.25 . 6 . [(\pi.175^2) - (\pi.133^2)]$
$= \mathbf{60,959\ m^3}$ (= 73% extra volume needed to reach MW2)

Considering the above we conclude that MW-2 can be used as a background or reference well when looking at water quality changes at ASR-1, due to injection and production. Graphs 3, 4 and 5 show the evolution of selected conservative elements at ASR-1, MW-1 and MW-2.

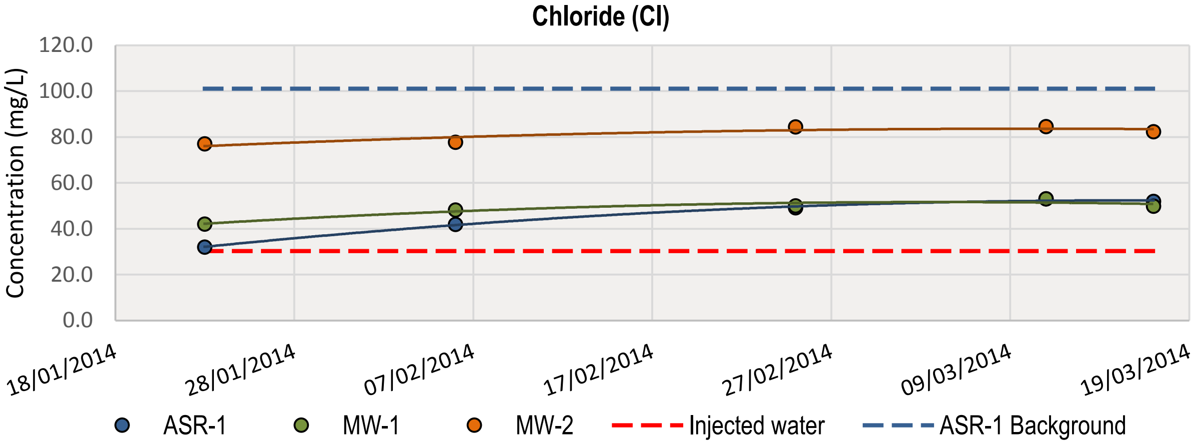
Graph 3 - Evolution in Sodium Concentration



Graph 4 - Evolution in Potassium Concentration



Graph 5 - Evolution in Chloride Concentration



The above graphs indicate that the recovered water includes some native groundwater which is normal for ASR wells. Chloride is considered the best tracer element (pers. Comm. D. Pyne) and the trend of the Cl graph indicates that recovery of water over the 100-120 days dry season, with acceptable quality, is feasible.

7.1.1 Extent of Stored Water Bubble

The actual extent of the stored water bubble varies from the theoretical extent because; the aquifer has boundaries near ASR-1, aquifer transmissivity varies from north to south and the water table slope which extends the bubble in the downstream direction. The actual extent of the stored water bubble has been modeled using the available data and the cycle test #2 cumulative injection volume (66,924 m^3). The modeled extent is shown in Figure A8, Appendix A.

The stored water bubble likely extends 275 m to the north and 170 m to the south of ASR-1 with a maximum width (east-west) of approximately 145 m. The projected annual storage at the ASR-1 site is approximately 76,000 m^3 and this volume of water would only produce a marginally larger storage area. Water level observations at the Weight Scale well, 350 m north the ASR-1, indicates significant drawdown from the ASR-1 pumping. Therefore ASR-1 can draw water from distances greater than 350 m and the water storage bubble remains sufficiently close to be extracted during recovery.

7.2 Geochemical Reactions

7.2.1 Arsenic

Levels of arsenic prior to cycle testing were below the MAC value in the aquifer (MW-1 As = 4.24 µg/L and ASR-1 = 3.25 µg/L; 02/2013). The background Arsenic level at MW-2 (not affected by the injection) is 0.94 µg/L and is 0.25 µg/L in the injected water from Englishman River. The recovered water shows high levels of arsenic, exceeding the drinking water quality guidelines (MAC = 10 µg/L). The highest value recorded at ASR-1 is 39.1 µg/L on February 19, 2014, and 16.2 µg/L at MW-1 on March 17, 2014. The general trend at ASR-1 regarding arsenic is an increase in the concentration up to 50% of target volume recovered, followed by a slow decrease. MW-1 shows an increase in the concentration up to 50% recovered and then a stabilization. However MW-1 has lower general levels (see Graph 6).

Graph 6 - Arsenic Concentration (CT#2, production)

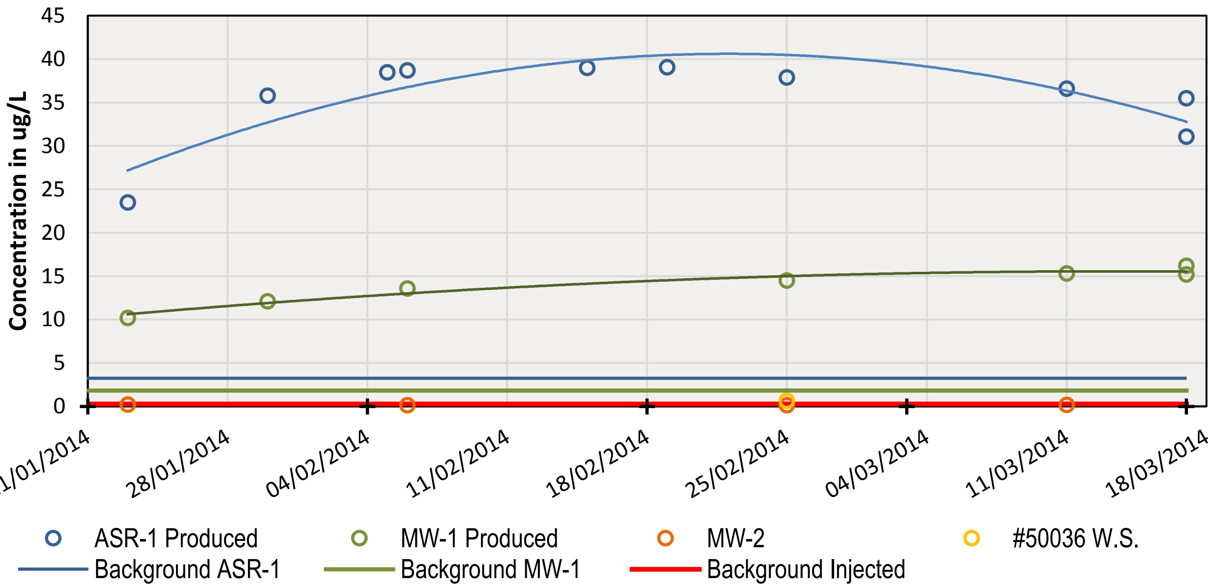


Table 11 - Arsenic Concentrations in µg/L

	Bckg	23-01	30-01	05-02	06-02	15-02	19-02	25-02	11-03	17-03	
ASR-1	*3.23*	23.5	35.8	38.5	38.7	39.0	39.1	37.9	36.6	35.5	31.1
MW-1	*1.8*	10.2	12.1		13.6			14.5	15.3	15.2	16.2
MW-2	*0.94*	0.22			0.12			0.15	0.18	0.15	
#50036								0.66			
EM	*0.25*										

Values in grey are from MB Lab. Other values are from Maxxam Analytics. (MAC: Arsenic = 10 µg/L)

Iron and manganese oxides are the principal matrix compounds controlling the mobility of heavy metals by the process of adsorption (McLean J.E. et al., 1992). Heavy metals are adsorbed on Fe and Mn oxide surface (Martin S.T. 2003). The dissolution of these oxides therefore leads to the release of heavy metals in groundwater. The decrease of pH (towards the acidic pole) is a factor in dissolution of these oxides. The native groundwater pH in the subject aquifer is on average 8.8, with a maximum value recorded of 9.5 (data taken at MW-2); the injected water has an average pH of 7.4, with a minimum value recorded of 6.5. There is then a significant difference (± 2) in pH values between native and injected waters.

Dissolved oxygen (DO) however is the main factor in the dissolution of the Fe and Mn oxides. The injected water has a much higher DO than the native groundwater. However, the produced water shows a very low DO (see Item 3 in Appendix F). This suggests that the DO was consumed by oxidation processes (see Appendix F for DO measurement on the produced water at ASR-1 and MW-1 on Mach 17, 2014).

The arsenic concentrations at ASR-1 are between 2 and 3 times higher than at MW-1, located only 8 m away. The injected water was introduced in the aquifer only through ASR-1. It is believed that the DO decays fast from oxidation processes, and therefore is less abundant at MW-1. This may explain the difference of As concentrations between the two wells. See the website www.asrforum.com, select “Final Position on ASR”, for a discussion on Arsenic at pages 10-15.

7.2.2 Manganese

Manganese is the other parameter found in excess in the recovered groundwater. As explained in the previous section, the release of manganese ions in the groundwater may be due to the dissolution of manganese oxides present in the aquifer matrix. It is therefore expected to observe high levels of manganese along with high levels of heavy metals adsorbed on the oxide surface.

Levels of manganese in ASR-1 are higher than in MW-1, supporting the same theory as for arsenic, of a higher dissolution closer to the injection well. Levels of manganese in ASR-1 and MW-1 have shown a constant decrease since the beginning of the recovery on Cycle Test 2 (see Graph 7).

Graph 7 – Manganese Concentration (CT#2, production)

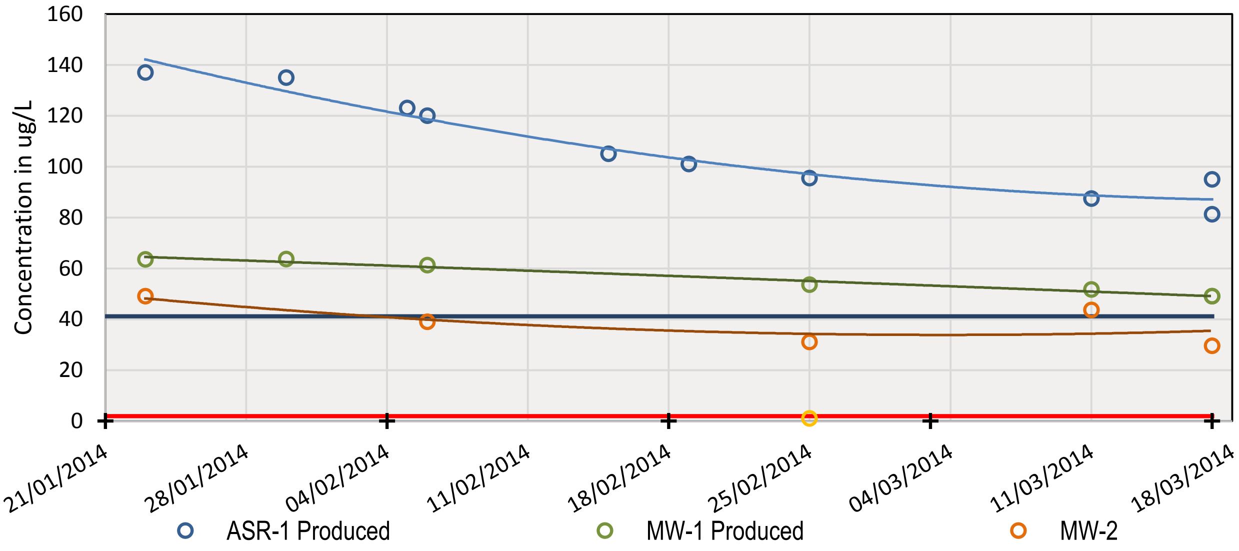


Table 12 – Manganese Concentrations in µg/L

	Bckg	23-01	30-01	05-02	06-02	15-02	19-02	25-02	11-03	17-03	
ASR-1	*41.2*	137	135	123	120	105	101	95.4	87.4	81.3	95.0
MW-1		63.5	63.6		61.2			53.6	51.7	49.0	
MW-2		49.0			39.0			31.0	43.6	29.5	
#50036											
EM	*1.85*										

Values in grey are from MB Lab. Other values are from Maxxam Analytics. (AO: Manganese = 50 µg/L)

The injection of a different type of water in the native aquifer has caused the dissolution of soils matrix on which heavy metals such as arsenic are adsorbed. These oxides are believed to be mainly iron and manganese oxides. Water chemistry results from Cycle Test 2 has only highlighted high concentrations of manganese, but no iron. However, iron oxides are slower to dissolve than manganese oxides (Martin S.T., 2003). If all oxides have already dissolved, the general trend will be a decrease in arsenic concentration to an acceptable limit, as the pumping extracts the remaining arsenic. The time to reduce As to acceptable levels is unknown.

7.3 90-minute Pumping of the Observation Wells

The monitoring wells MW-1 and MW-2 were sampled with a bailer on October 24 and November 7, 2013 and showed high levels of iron and manganese. It was suggested by LHC that these odd values were locally introduced in the groundwater by the steel well casings. To confirm this hypothesis, the two wells were pumped for 90 minutes each on December 18, 2013 and sampled at the end of the pumping period. The levels of iron and manganese, as well as turbidity significantly dropped below the maximum limit required (see Table 13). It was therefore confirmed that the well casings locally introduced iron and manganese in the water column. The pumped sample provides representative values for Fe & Mn in the aquifer, whereas the bailer samples were non-representative.

Table 13 – Turbidity Level, Iron and Manganese Concentration before and after 90-Min Pumping

		Turbidity **(NTU)**	**Iron** **(total in µg/L)**	**Manganese** **(total in µg/L)**
			AO* = 300 µg/L	**AO = 50 µg/L**
24-10-2013	MW-1	32	2480	151
	MW-2	50	7720	79.4
07-11-2013	MW-1	3	2780	238
	MW-2	22	5690	77.4
		18-12-2013 : Wells sampled after 90 min of pumping		
18-12-2013	MW-1	0.3	116	11.9
	MW-2	0.2	72.4	25.6

**MAC= Maximum Acceptable Concentration*

The metals scan of the MW-2 sample showed some anomalous values of some metals. The following table shows the average value for these selected metals from the injected water (from the Englishman River), and at MW-2. The presence of these spikes in the pumped water proves that the 90-min pumping brought injected water into MW-2 whereas bailer sampling did not. Two types of results can be found:

- A value between the injected water and the well background water: this shows a mixing with dilution of the elements.
- A value higher than both injected water and well background: this shows a dissolution of the elements formerly stable in the aquifer matrix.

Table 14 – Dissolution and Dilution of Selected Elements in the Aquifer

	Arsenic As	Barium Ba	Silicon Si	Strontium Sr	Calcium Ca	Magnesium Mg
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
MAC* =	10	1000	NL	NL	NL	NL
EM: Injected average	0.25	11.1	12,050	98	31.5	14.6
MW-2: Background average	0.17	5.7	139	109	5.5	4.20
MW-2: Value on 18/12/2013	4.05	24.3	5870	321	27.9	6.73
Type of element transfer	Dissolution	Dissolution	Dilution	Dissolution	Dilution	Dilution
Concentration increase from MW-2 background	x 24	x 4	x 42	x 3	x 5	x 1.6
Concentration increase from EM background	x 16	x 2	x 0.5	x 3	x 0.9	x 0.5

**MAC= Maximum acceptable Concentration   NL = No Limit*

From these results, it appears that the elements leaching from the rock matrix are principally arsenic, barium and strontium.

8.0 RECOMMENDED WELL OPERATION

8.1 Recharge and Recovery Rates

It was observed during cycle test #2 that a recharge rate of 10 L/s caused a loss of well efficiency. The well was most efficient at an 8 L/s injection rate and this is more than sufficient to establish the annual recharge target of 76,205 m^3.

Annual Recharge Calculation:

- Withdrawal period = 14 weeks (98 days)
- Maximum withdrawal at ASR-1; 98 days at 9 L/s continuous flow = $98\ x\ 9\ x\ 86{,}400 = 76{,}204{,}800\ \mathrm{L}\quad \mathrm{or}\quad 76.205\ \mathrm{ML}\quad \mathrm{or}\quad 76{,}205\ m^3$
- 76.205 ML must be recharged each year to balance the estimated well site withdrawal.

8.2 Target Storage Volume (TSV)

As discussed in DP 5-2, Sept. 2010 there will be a minimum period of 26 weeks per year (182 days) in which ASR well recharge can occur. For ASR-1 in the first year of injection we recommend a storage volume equal to the target recovery volume of 76,205 m^3 plus 60 days of recovery capacity as a buffer zone for improvement of water quality. Then the volume injected should be $76{,}205 + (0.6\ x\ 76{,}205) - 46{,}000 = 75{,}928\ m^3\ \ (75.9\ ML)$. Note[1]

At an injection rate of 8 L/s this will take a minimum of 110 days to achieve. It is recommended to inject the water early in the injection window of 182 days. If the first 110 days of the window is used for injection then 72 days is available for storage. This over 2 month storage period would help improve recovered water quality. During storage periods it is also recommended to maintain a trickle flow to the ASR well (0.4 L/s) of chlorinated water to prevent bacterial growth around the well screen.

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[1] Note: 46,000 m^3 is the cumulative volume stored from CT 1 & 2.

8.3 Back-flushing

The back-flushing protocol outlined in the section 6.3.4 should be followed. The once-per-week back flushing schedule is working and should be maintained. Well performance will be continually monitored and adjustments to the back-flush program made if necessary. It is recommended to add remote well controls to the wellhead SCADA system so that back-flushes can be initiated from the Parksville Engineering offices.

9.0 ASR WELL FIELD EXPANSION

9.1 Kaye Road

The numerous test wells drilled in the Kaye Road area helped refine the knowledge of the local aquifer boundary and thicknesses. It appears that ASR-1 is located within a narrow channel, where the aquifer is limited to the west and east. Further well exploration may extend to the south. Thicker sections of aquifer are found in the southern section of Kaye Road. See Figure A9, Appendix A where it shows potential sites for ASR Well Field expansion on Kaye Road.

9.2 Claudet Road

The ASR team also considered developing an ASR well field in the eastern region of the aquifer near the intersection of Northwest Bay Road and Claudet Road, Nanoose Bay. The Claudet Road well in this area was pumped for 13 days (ID.14506). The facilities at the site are already built (pump chamber, piping system, etc.), and the production well has a monitoring well ID.15436 located 4.15 m. to the west. The pumping test proved a substantial yield of 15.3 L/s. The wells in this region have not been put in use or have been de-activated due to a high level of ammonia, iron and manganese in the aquifer here. See Figures A10 and A11 Appendix A for the well field plan.

The potential of the Claudet well to be used as an ASR well was considered in 2013, see the LHC well report of Dec. 13, 2013. The well sites identified as Nanoose 1, 2, 3 and 4 will also be considered for ASR well development.

9.2.1 General Comments and Observations on the Claudet Well Pumping Test

The well ID.14506 was pumped from October 30, 2013 to November 12, 2013. The flow rate ranged from 168 to 200 USgpm. Groundwater level at the observation well ID.15436 located 4.15 m. west of the pumped well was also recorded during the pumping phase and the recovery. See Graph G1 Appendix G for the drawdown graph.

In the very beginning and late phases of the pump test, it appears that the groundwater level dropped below the top of the aquifer (as described in the well log record). However, the drawdown curve does not respond by a steepening of the drawdown curve, as it is typically the case when the upper section of the aquifer is dewatered. It is therefore assumed that the uppermost layers of the aquifer have probably a low transmissivity and do not contribute significantly to well yield. The well log record described the layer from 51.82 to 55.78 m. (170 to 183 ft.) as “fine sand and gravel, clay wash”. This has been considered when setting up the total available drawdown.

The time/drawdown curve is affected by a boundary effect. This effect is not significant as it does not lead to a sharp deflection of the drawdown graph, but shows a slight effect before 1000 minutes after the pumping started. It is also visible in the recovery. This will be discussed further.

The observation well shows a very good response to the pumping and follows the pumped well drawdown curve.

9.2.2 Transmissivity and Hydraulic Conductivity

Close to the well [12 – 200 min]

- Pumping rate during selected time frame: Q = 925.14 m^3/day
- Drawdown at 10 min: s(10) = 4.86 m
- Drawdown at 100 min: s(100) = 4.96 m
- ➩ Δs = 0.10 m
- Aquifer thickness: e = 12.1 m
- ➩ Transmissivity: T = 0.183 x 925.14 / 0.104 = **1,627.9 m^2/day**
- ➩ Hydraulic conductivity: K = 1,627.89 / 12.1 = **134.5 m/day**

Farther from the well [700 – 2780 min]

- Pumping rate during selected time frame: Q = 926.67 m^3/day
- Drawdown at 10 min: s(10) = 4.24 m
- Drawdown at 100 min: s(100) = 4.71 m
- ➩ Δs = 0.47 m
- Aquifer thickness: e = 12.1 m
- ➩ Transmissivity: T = 0.183 x 926.67 / 0.47 = **360.8 m^2/day**
- ➩ Hydraulic conductivity: K = 360.8 / 12.1 = **29.8 m/day**

Farther from the well [5692 – 11212 min]

- Pumping rate during selected time frame: Q = 915.77 m^3/day
- Drawdown at 10 min: s(10) = 3.69 m
- Drawdown at 100 min: s(100) = 4.46 m
- ➩ Δs = 0.77m
- Aquifer thickness: e = 12.1 m

- ➩ Transmissivity: T = 0.183 x 915.77 / 0.77 = **217.64 m^2/day**
- ➩ Hydraulic conductivity: K = 217.64 / 12.1 = **18.0 m/day**

Table 15 – Summary of Transmissivity and Hydraulic Conductivity Results Compared with Well ASR-1

	Time – Drawdown Method			
	Transmissivity in m^2/d		Hydraulic Conductivity in m/d	
	ID.14506	**ASR-1**	**ID.14506**	**ASR-1**
Early	1,628	160	134	20
Middle	361	-	30	-
End	218	46	18	6

9.2.3 Long-term Capacity

The long-term capacity of the well is calculated with and without the 30% safety factor. This safety factor (standard for S.F. conventional wells) would not apply if the well is used as an ASR well.

	No S. F.	With S. F.	
Pumping rate during the test:	175.5	-	USgpm
	11.1	-	L/s
Extrapolated drawdown @ 100 days:	7.80	-	m
↳ Specific capacity:	1.42	-	L/s/m
↳ Total available drawdown:	11.20	7.84	m
Well long-term capacity:	**15.3**	**11.13**	**L/s**
	242	**176**	**USgpm**

bgl = below ground level

* *The top of the aquifer is logged at 7.2 m. of drawdown, however the dewatering of the section [7.2 - 8] m showed no effect on the drawdown cone. This upper section is probably a marginal layer of the aquifer that can be dewatered.*

9.2.4 Conclusion

The Claudet Road aquifer around the tested well (ID 14506) has better transmissivity than the aquifer at Kaye Road where exploration for ASR has started. The subject well has an excellent yield capacity of 15.3 L/s, one of the most productive wells in the region. The aquifer in the vicinity of the well has a 12 m. thickness, hence, a storage zone with 150 m. radius around the well could store 255,000 m^3. That is more than enough to meet the ERWS project objectives for one ASR well site. The ultimate storage volume target for this project is 1,000,000 m^3.

There is more aquifer thickness that can be screened at this well. In our opinion 2 meters more screen could be installed which will increase the well specific capacity Furthermore the 30% safety factor for standard wells does not strictly apply to ASR wells (because artificial recharge negates the need to allow for seasonal recharge variations or drought years) so this has been considered in the well rating. In conclusion the subject well site should be feasible for construction of an ASR well, subject to Cycle testing with water quality monitoring. The next step is to conduct an ASR cycle testing program at the site. A new 12-inch ASR well would also be recommended.

9.3 Other Potential ASR Well Locations

Figure A12 in Appendix A shows the potential location for other ASR wells in the Englishman River Aquifer. Fifty-five (55) locations are mapped based on preliminary information on aquifer thickness and boundary. The water volume stored in the aquifer is estimated to be 16,000,000 m^3 (using an average porosity of 0.25).

10.0 CONCLUSIONS

1. Parksville ASR-1 is a feasible ASR well with an injection capacity of 8-10 L/s and production capacity (with DS#3) of 9 L/s. At least 76,205 m^3 of water can be stored at this well.
2. Work to date indicates that the stage 1 project objective of 69 L/s (6 ML/d) can be obtained from 3 or 4 ASR wells on Kaye Road (8-10 L/s wells) and 3 or 4 ASR wells in the Claudet Road area (10-15 L/s wells). Aquifer mapping and analysis also indicates that the ultimate ASR well capacity – 15 ML/d and storage of 1,000,000 m^3 of water per year is achievable.
3. Arsenic and manganese dissolution occurs in the aquifer due to injection of water with different dissolved oxygen and pH levels. As is approximately 3 times the drinking water standard (MAC) and Mn is up to 2 times the Aesthetic Objective (AO) in ASR-1. As and Mn only marginally exceed the MAC and AO in MW-1 even though it is being pumped and is only 8.0 m. from ASR-1. Further testing is required to confirm if operational measures can reduce As and Mn to acceptable levels and eliminate the need for treatment.

4. Arsenic is an issue that must be addressed at the ASR-1 well site. Options for addressing this issue are provided in 11.1 below. Arsenic may also be an issue for any ASR wells constructed in the Claudet Road area. However it is possible that As will not be an issue at Claudet Road. The natural levels of As in groundwater at ASR-1 have been recorded in the range of 4.0 – 7.0 ug/L. However the natural As level at the Claudet Road well is 0.25 ug/L or 16 times less than ASR-1. This is encouraging as naturally occurring As is much less prevalent at Claudet Road.
5. ASR wells in the Claudet Road area should be able to overcome the ammonia issue in recovered water. Additionally the natural ammonia levels at ASR-1 were more than halved by injection. ASR projects in the U.S.A. have shown ammonia levels greatly reduced with increased volume of the buffer zone and length of time that injected water is stored. See the reference, Kohut, 1980 for a description of the ammonia issue in the Claudet Road region.
6. The target aquifer shows great variability in thickness and transmissivity (T). T can vary significantly over a short distance as we experienced with ASR-1. This is common throughout the aquifer as recent work at the Fairwinds Resort (LHC, Jan. 2014) well field on N.W. Bay Road has confirmed.
7. Our drilling experience at ASR-1 has shown the Cable-Tool drilling method is not suitable for large diameter wells in this aquifer, we will use the Dual-Rotary drilling method in future.
8. The MW-1/ASR-1 well site has proven feasible but better sites for ASR wells can be developed. The aquifer lies in a narrow channel at this site which limits yield and storage. Also ASR-1 hit a lower T patch in the aquifer. We can expect better results with future development. Also ASR-1 has a deep static water level and limited available drawdown which limits capacity. The south Kaye Road area and Claudet Road areas are better in this respect.
9. The background (natural) water quality at ASR-1 is good and met all drinking water standards. However the ASR-1 site may be anomalous in this respect as surrounding wells have high TDS and other issues like H_2S gas. A standard production well developed here may tend to have decreasing water quality. However ASR water quality will be stable. TDS and H_2S in the native aquifer is not a problem for ASR wells.
10. The ASR-1 well showed much better performance in Cycle 2 compared to Cycle 1. However when the injection rate was raised from 8 L/s to 10 L/s mounding increased 66%. The well is most efficient at an injection rate of 8 L/s. An 8 L/s injection rate is sufficient to meet the annual recharge target considering injection can occur over a 6 month period (LHC – Discussion Paper 5-2).
11. In Cycle 2 weekly back flushes lasting 1 – 1.5 hours were sufficient to control mounding at or generally below ground surface.
12. Storage capacity at the site is not an issue. The mounding from injection is only a small fraction at MW-1 what it is at ASR-1. The aquifer accepted the injection rate with ease and indicates it could take more.
13. Water quality monitoring indicates there is a noticeable increase in TDS soon after injection. This may be due to leaching of minerals from the aquifer matrix. The fine sand at the margins of the aquifer likely provide a large surface-contact area for mineral leaching. TDS however is not an issue with recovered water from ASR-1.
14. The upper aquifer at the ASR-1 site is not affected by injection or pumping. ASR-1 is completed in a well confined aquifer with marine clay above and glacial till below. The ASR target aquifer is safe from pollution from surface sources.
15. ASR wells could be used to reduce the water treatment plant size. ASR wells could supply 172 L/s (15 ML/d) or more with a total of 14-16 wells. Aquifer mapping for this project has identified

a previously undifferentiated aquifer which has been submitted to the Ministry of Environment for revision to existing mapping (Ref. LHC Let. Report, Mar. 2014). The aquifer is 17 km^2 in area and has a total water storage volume of 16,000,000 m^3. The thicker sections of this aquifer are potential zones for ASR well development. A map of the aquifer (named "Englishman River Aquifer") is shown in Figure A12. In this figure 55 preliminary ASR well test sites are plotted. The 14-16 wells we foresee providing 15 ML/d will be located in these areas. The target annual storage volume for ASR is 1,000,000 m^3; only a fraction of the total aquifer water volume.

16. ASR-1 lost injection and production capacity apparently due to well clogging. Re-development work may restore this capacity.

11.0 RECOMMENDATIONS

11.1 We recommend the following plan to address the arsenic issue:

1. We monitored As at ASR-1 and MW-1 and both of these wells were pumped at 4 L/s each for the production phase of Cycle 2. These two wells are only 8 m. apart. The ASR-1 As concentrations started at 25, peaked at 40 at the mid-point of Cycle 2 and trended down ending at 30 ug/L on Mar. 17. MW-1 As concentrations started at 10 and trended up to 15 by the mid-cycle and are stable at 15 ug/L now. It appears as has been observed before that the As issue occurs only very close to the injection/production well, confirmed by a 50% drop in As concentration just 8.0 m. away from ASR-1. This occurs because the dissolved oxygen (from the injected water), which causes As dissolution, is consumed as it moves away from the injection well. Therefore all the As is derived from a zone very close to the ASR well. The affected zone is relatively small in volume and has a limited quantity of As that it can supply.

   Considering this we propose to flush out the As with many short cycles. Two day injection cycles would create a bubble of 20 m. radius and we could do 10 cycles (2 days injection followed by 2 days recovery) in 40 days and observe what happens with the As concentrations with a weekly metals scan analysis. This procedure could be completed within 6 weeks. The number of cycles may be increased if improvement is observed but acceptable As levels are not reached after 10 cycles.

2. After this multiple cycle test, if it is unsuccessful, we could monitor during 2 months of storage and just take samples over time to observe the trend in As concentrations. At some existing ASR well sites a few weeks or months have been effective to attenuate As to acceptable levels.

3. The third option is to simply increase the volume of the stored water "buffer zone" because this can solve the As problem. Our original estimate of a buffer zone size = 30% of the Target Storage Volume was only preliminary (Discussion paper 5-2, Sep 22, 2010). Experience in Tampa, Florida demonstrated that a buffer zone equal to 70 days of design recovery of the stored water volume was sufficient to alleviate the As issue. In that case study it was also noted that up to 10 cycles may be required to resolve all issues, we have just completed Cycle #2 on ASR-1.

4. If Nos.1-3 above were not successful we would recommend treatment (proven for As removal) of the recovered water as a positive solution to the As issue. It is expected that treatment at the wellhead will be <u>temporary only</u> as As concentrations should decrease over successive injection/production cycles and as an adequate buffer zone is established. To achieve this option a mobile treatment plant (contained in a standard shipping container) can be set-up at the wellhead. The plant could be moved to the next ASR well site(s) if necessary. We have contacted a mechanical contracting company (Tiger Purification Systems Ltd.) that has designed a similar plant recently for a mining company client in Australia. They have provided a cost estimate for treatment of As, Mn and the system would also reduce ammonia and provide

disinfection. The treatment system consists of a 2 chlorine feed pumps, 1 - 100 gallon solution tank for 12% chlorine, in-line flow meter, 3 - contact – mixing 317 gallon tanks, 3 – 36 inch self-cleaning NextSand pre-treatment filters, followed by Arsenic reduction filters by MetSorb. The plant cost is estimated at $140,000. plus $50,000. for filter media changes every 65,000 m^3 volume produced. The treatment of recovered water will allow for use of the water produced during successive cycles and avoid having to discharge more water to waste. This would be easier for VIHA to approve as the issue would be fixed at the wellhead.

11.2 The injected water at future ASR wells should be filtered. Testing at ASR-1 indicated slugs of turbid water were injected likely due to an iron floc (rust) from the distribution piping.

11.3 Both, the Kaye Road area and Claudet Road area appear viable for ASR well development. Both areas are likely needed to meet the first stage project well capacity objective (69 L/s). ASR development work can progress in both areas. There are other suitable sites for exploration along Northwest Bay Road that are close to the existing large Nanoose watermain and would be cost-effective to develop.

11.4 Recommended next steps:

A. Implement recommendation 11.1 above.
B. Construct an ASR well at the Claudet Road well site and undertake a cycle testing program.
C. Expand the Kaye Road well field to include up to 3 more ASR wells.
D. Construct 2 or 3 more ASR wells at the Nanoose well sites and undertake cycle testing.
E. Conduct exploration drilling in the Northwest Bay Road Region to locate additional ASR well sites if necessary.

11.5. For new ASR wells in this aquifer start injection in a staged approach beginning with lower flow rates. Back flush frequently in the initial injection phase, at least daily. Do surging with the back flushing. As iron bacteria are present a high dosage chlorination is also recommended before injection.

11.6. Future exploration at new sites should consider alternate drilling technologies to help lower costs. The strategy would be to log test wells and do grain size analyses for several sites before completing an 8-inch screened test well at the best site(s). These exploration test wells may cost about $8,000 each compared to $20,000 for an 8-inch well.

11.7. Do some core drilling in the aquifer for better determination of the aquifer geochemistry.

11.8. Age date the aquifer water and wood fragments to better understand the local geologic history.

11.9. Build a groundwater computer flow model to aid in design/management of the well fields.

11.10. Re-development work should be considered for ASR-1. The next phase of ASR development will include a plan for ASR-1 re-development.

11.11. The estimated costs for the recommended follow-up work at ASR-1 and ASR well field expansions are as follows.

▪ LHC and ERWS cost for 11-1, 2 and 3	$90,000.
▪ LHC and ERWS cost for 11-4	$200,000. (if necessary)
▪ LHC and ERWS cost for 3 ASR wells on Kaye Rd.	$2,400,000.
▪ LHC and EWRS cost for 3 ASR wells in the Nanoose well field	$2,020,000.

The Kaye Road and Nanoose well field expansion costs include an allowance for temporary As treatment which may not be necessary. If not needed both cost estimates can be reduced by $304,000. For Kaye Road and $154,000. For the Nanoose wells. This assumes the same mobile treatment plant would service all the wells. The estimated costs do not include GST and a 15% contingency should be added to the above to cover exploration uncertainty.

CLOSURE / DISCLAIMER

This report has been prepared in accordance with generally accepted groundwater engineering practices. The opinions expressed herein are considered valid at the time of writing. Changes in site conditions can occur, however, whether due to natural events or to human activities on these, or adjacent properties. In addition, changes in regulations and standards may occur, whether they result from legislation or the broadening of knowledge. This report is therefore subject to review and revision as changed conditions are identified.

Well yields and water quality can vary over time due to climate change, recharge area modification, or earth movements (earthquakes and blasting). Water quality standards also evolve over time and future revisions of the standards may necessitate changes to the recommendations for water treatment or testing.

In formulating our analyses, conclusions and recommendations we have relied on information supplied by others; well drilling contractors, pumping test contractors and a certified water testing laboratory. The information provided by others is believed to be accurate but cannot be guaranteed. If the recommendations in this report are not implemented, we assume no responsibility for any adverse consequences that may result.

If you have any questions or require any further information, please contact the undersigned.

Respectfully Submitted,

LOWEN HYDROGEOLOGY CONSULTING LTD.

D. A. LOWEN

D. A. LOWEN

Dennis Lowen

Dardare

Dennis A. Lowen, P. Eng., P.Geo.
Senior Hydrogeologist

Marion Dardare, M.Sc.
Hydrogeologist

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- Discussion Paper 5-2, Sep. 2010 – *AWS, Eng. River Water Intake Study – Aquifer Storage Recovery*
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- Letter Report, March 28, 2014 - *Mapping of a New Sand and Gravel Aquifer in the Parksville/ Nanoose Bay Region* NTS Map Sheet 92F29

Reports

- M. Squire, Program Manager, ERWS – May 2012 – Aquifer Storage and Recovery Work Program

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- Sterrett, J. Robert – 2007 – *Groundwater and Wells*, Third Edition, Johnson Screens (ISBN 978-0-9787793-0-6)

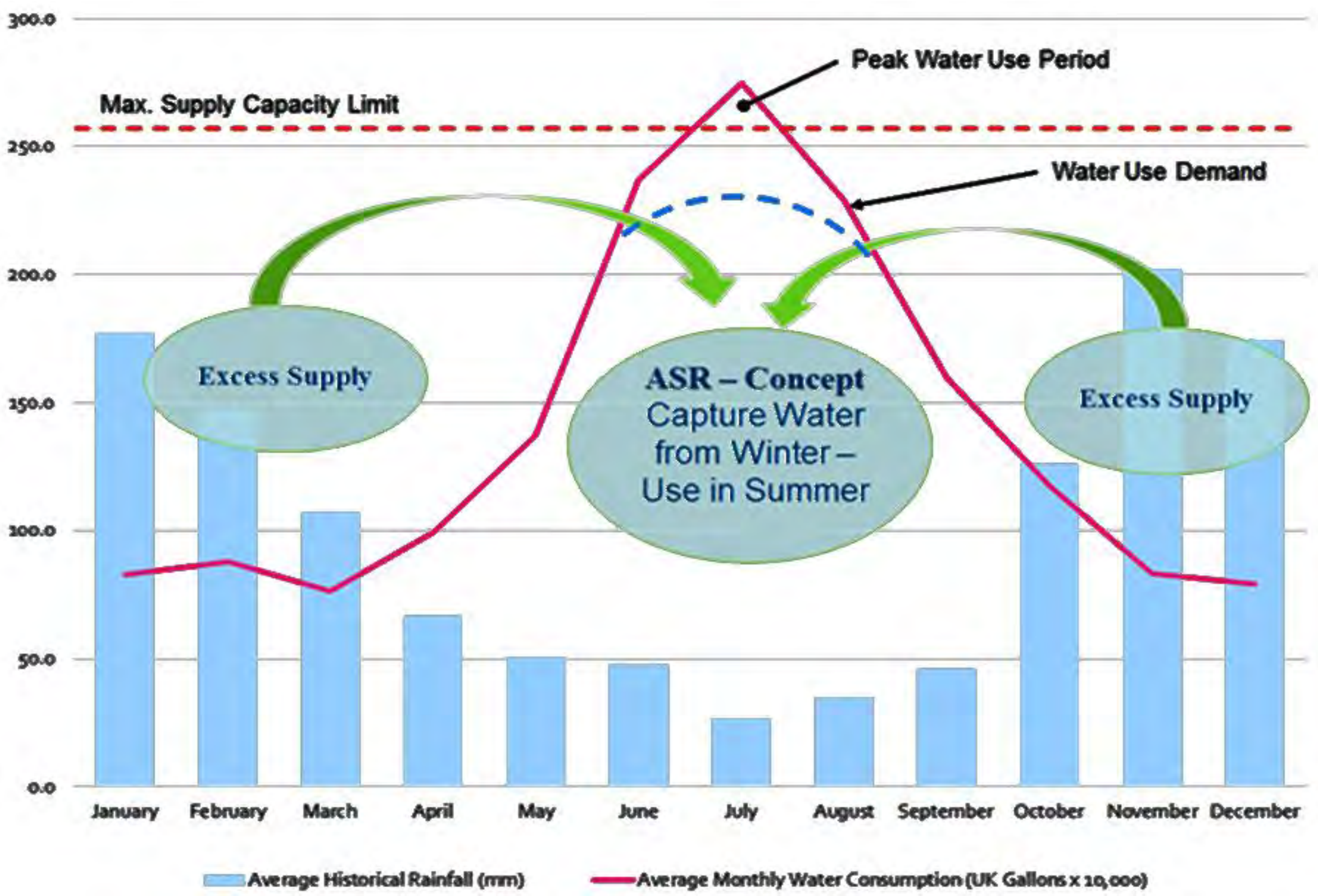
Websites

- Englishman River Water Service: www.englishmanriverwaterservice.ca
- RDN Water Map: https://rdnweb.com/watermap/
- BC Water Resources Atlas: www.env.gov.bc.ca/wsd/data_searches/wrbc
- ASR Forum: www.asrforum.com

APPENDIX A

Figures

Figure A1 - Illustration of Average Monthly Rainfall vs. Monthly Water Consumption



From M. Squire, ERWS, 2012

Figure A2 - Drilling Sites Locations

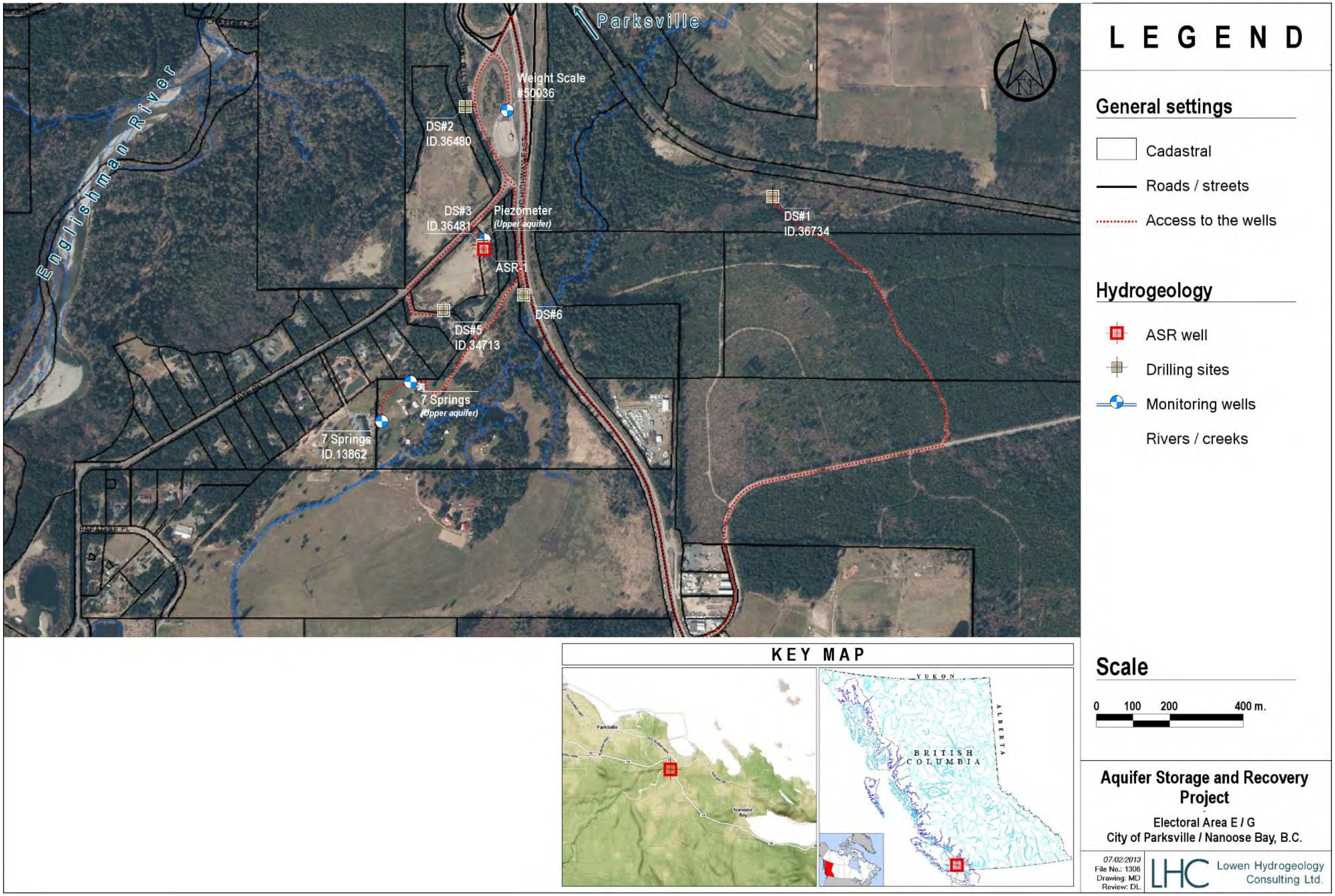
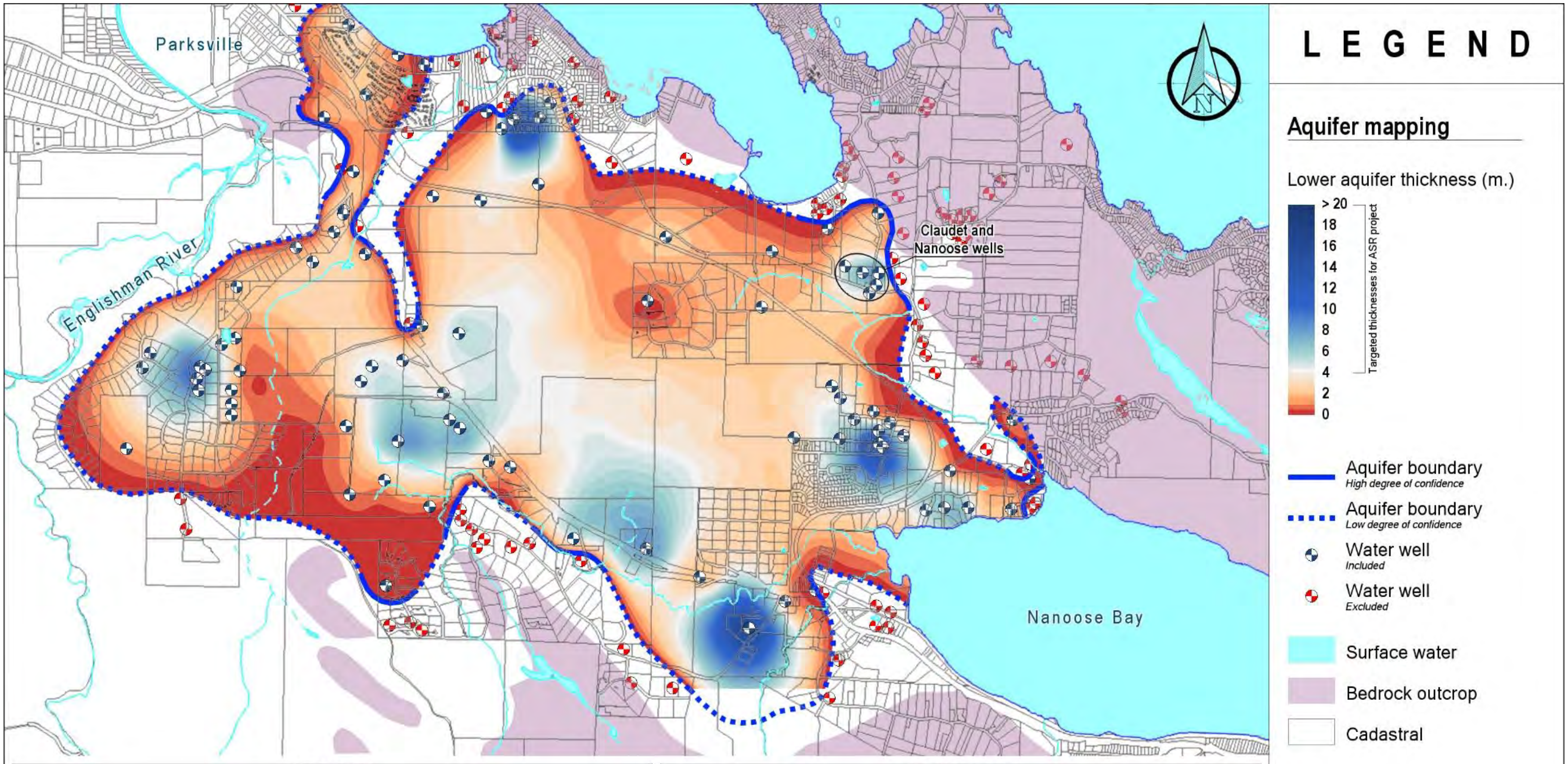


Figure A3 - Aquifer Boundary and Thickness

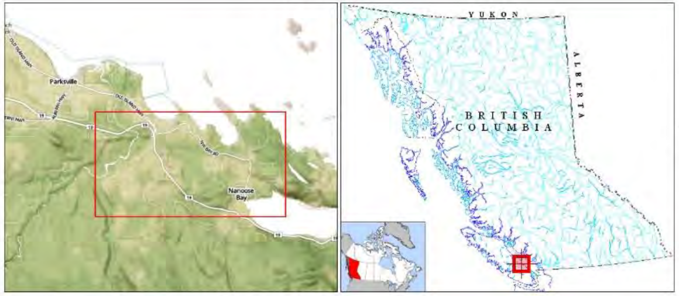


NOTES

Kriging interpolation was used in this model. Manual corrections were applied where necessary.

Water volume estimation: V = 16,000,000 m^3

KEY MAP



Scale

0 0.5 1 2
kilometers

Aquifer Storage and Recovery Project

-

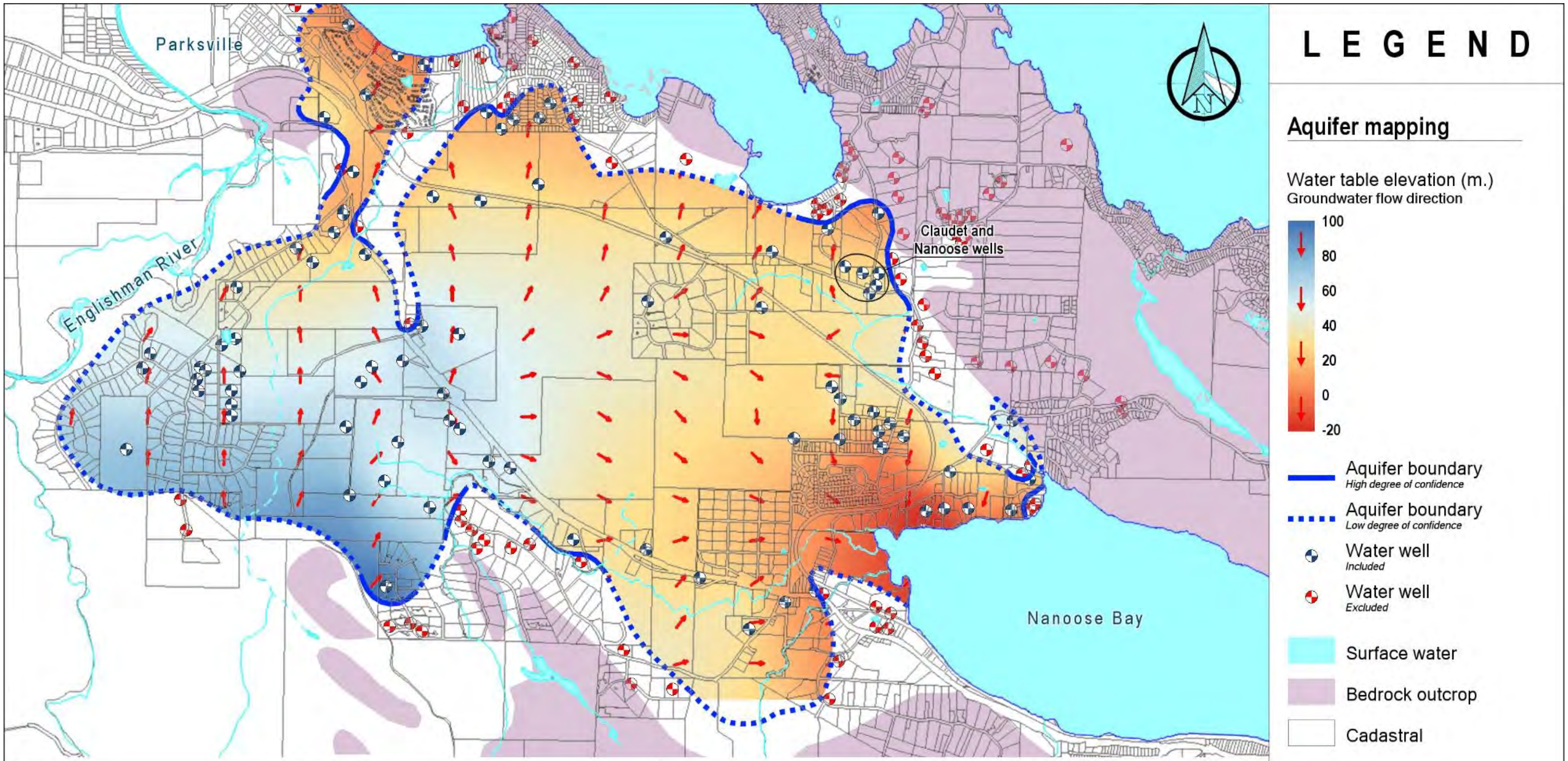
Electoral Area E / G

City of Parksville / Nanoose Bay, B.C.

09/04/2014
File No.: 1306
Drawing: MD
Review: DL

LHC Lowen Hydrogeology Consulting Ltd.

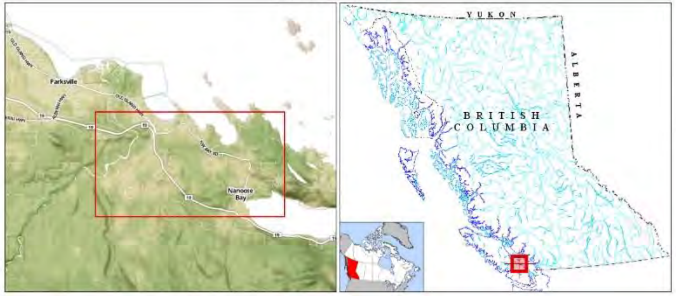
Figure A4 - Piezometric Map of the Deep Aquifer #219 (Englishman River Aquifer)

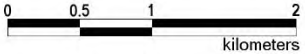


NOTES

Kriging interpolation was used in this model.

KEY MAP



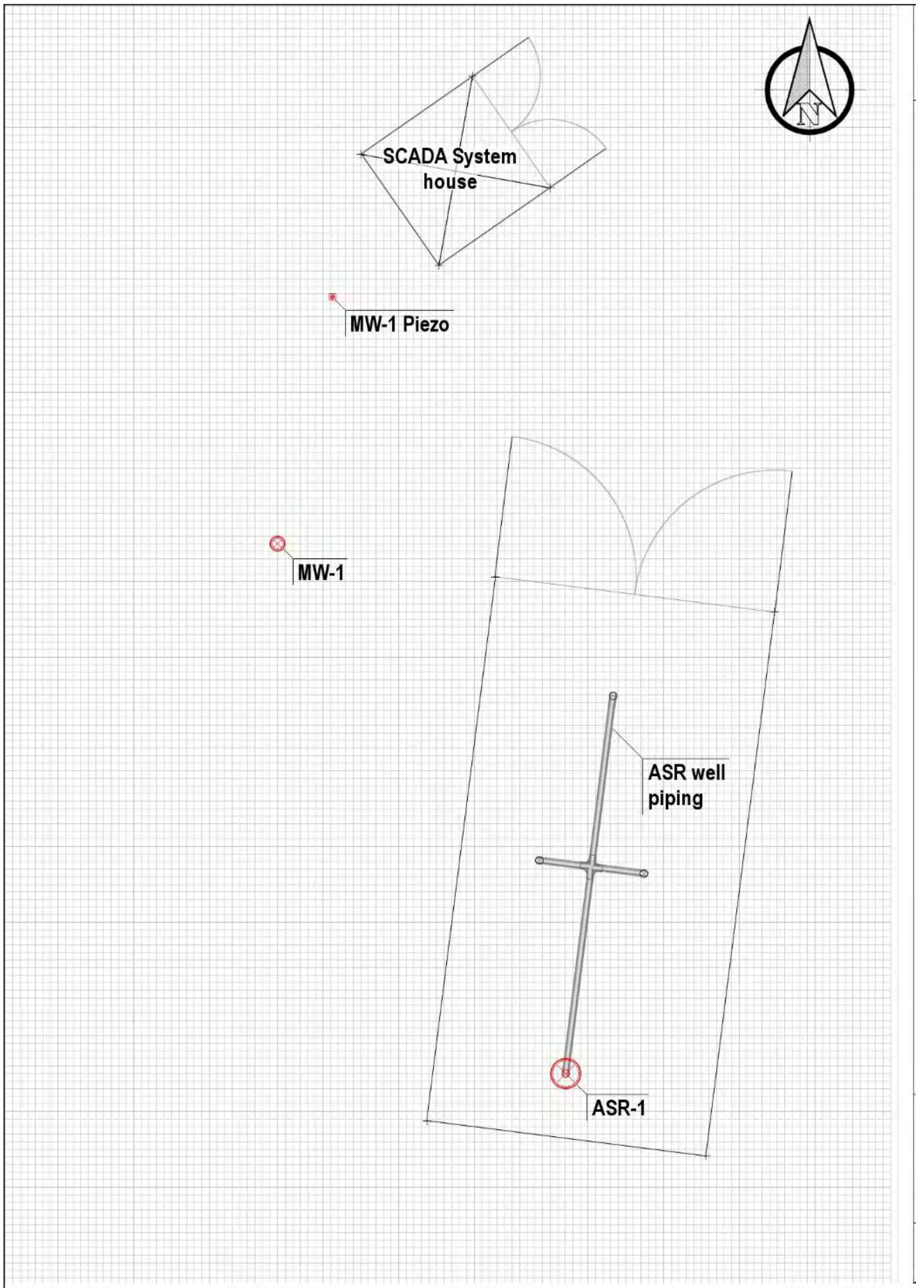


Aquifer Storage and Recovery Project
-
Electoral Area E / G
City of Parksville / Nanoose Bay, B.C.

09/04/2014
File No.: 1306
Drawing: MD
Review: DL

Lowen Hydrogeology Consulting Ltd.

Figure A5 – ASR-1 Well Site



LEGEND

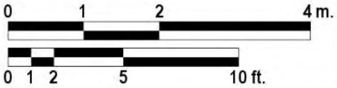
ASR-1
Parksville ASR well #1
Lower aquifer

MW-1 (DS#3)
8" test well
Lower aquifer

MW-1 Piezo
Piezometer
Upper aquifer

SCADA
ASR well controls and monitoring

Scale



ASR-1 well site plan

1900 Kaye Rd, Parksville, B.C.

09/09/2013
File No.: 1306
Drawing: MD
Review: DL

LHC Lowen Hydrogeology Consulting Ltd.

NOTES

Well diameters are at scale.

The pipes are drawn with a 4-in diameter although in reality some sections are 3-in.

KEY MAP

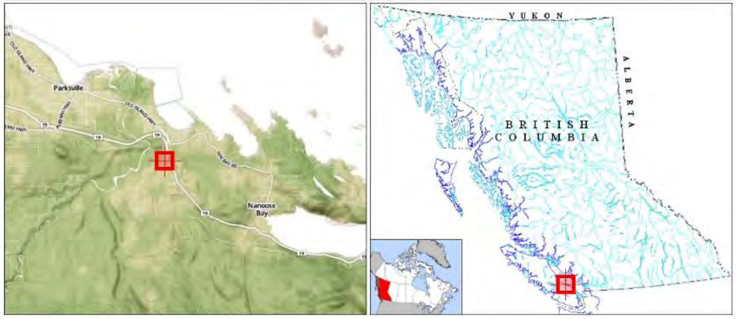


Figure A6 – Data Collection during Cycle Testing at the ASR Well Field

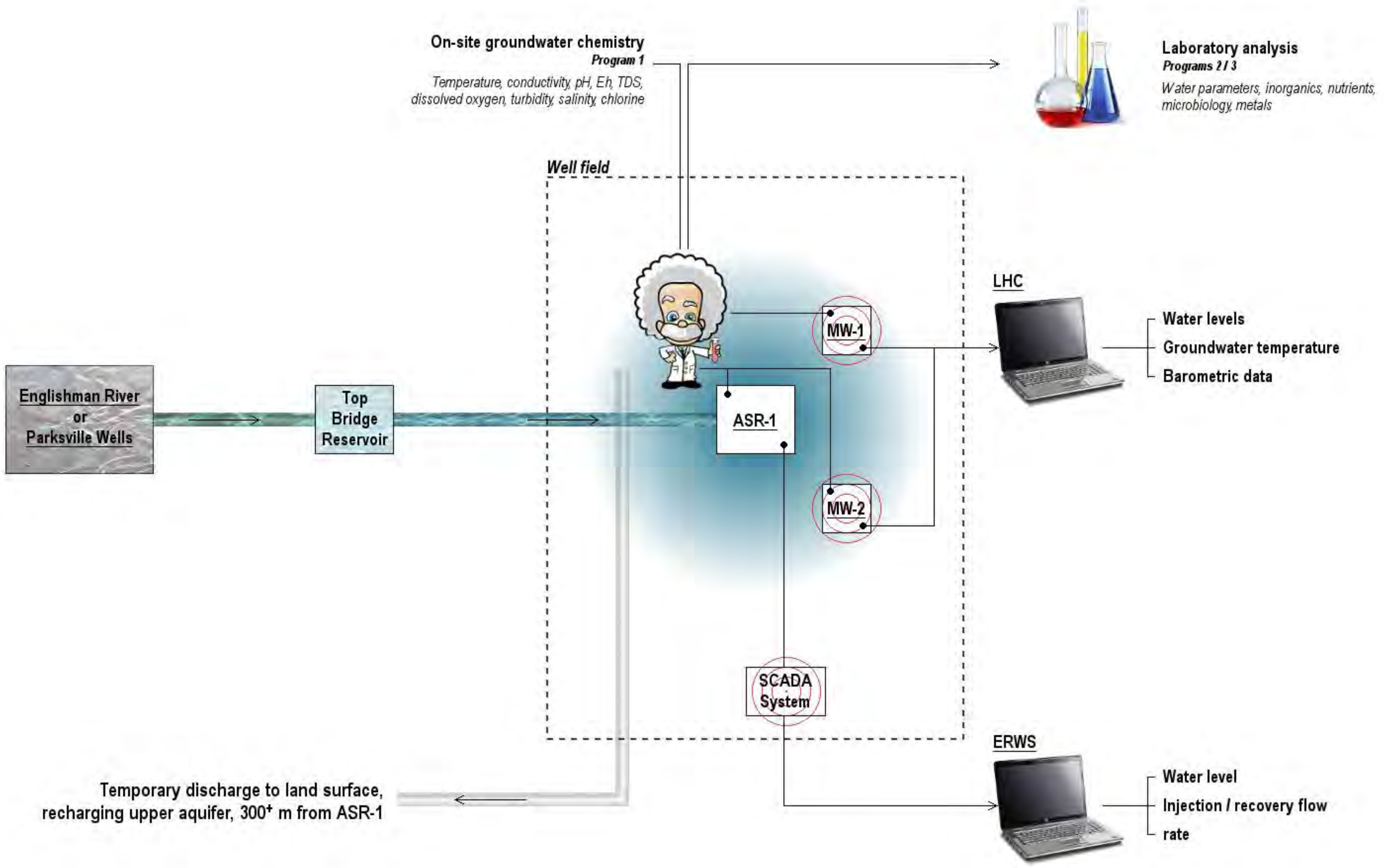


Figure A7 - Pressure Response in the Aquifer at the End of Cycle Test 2

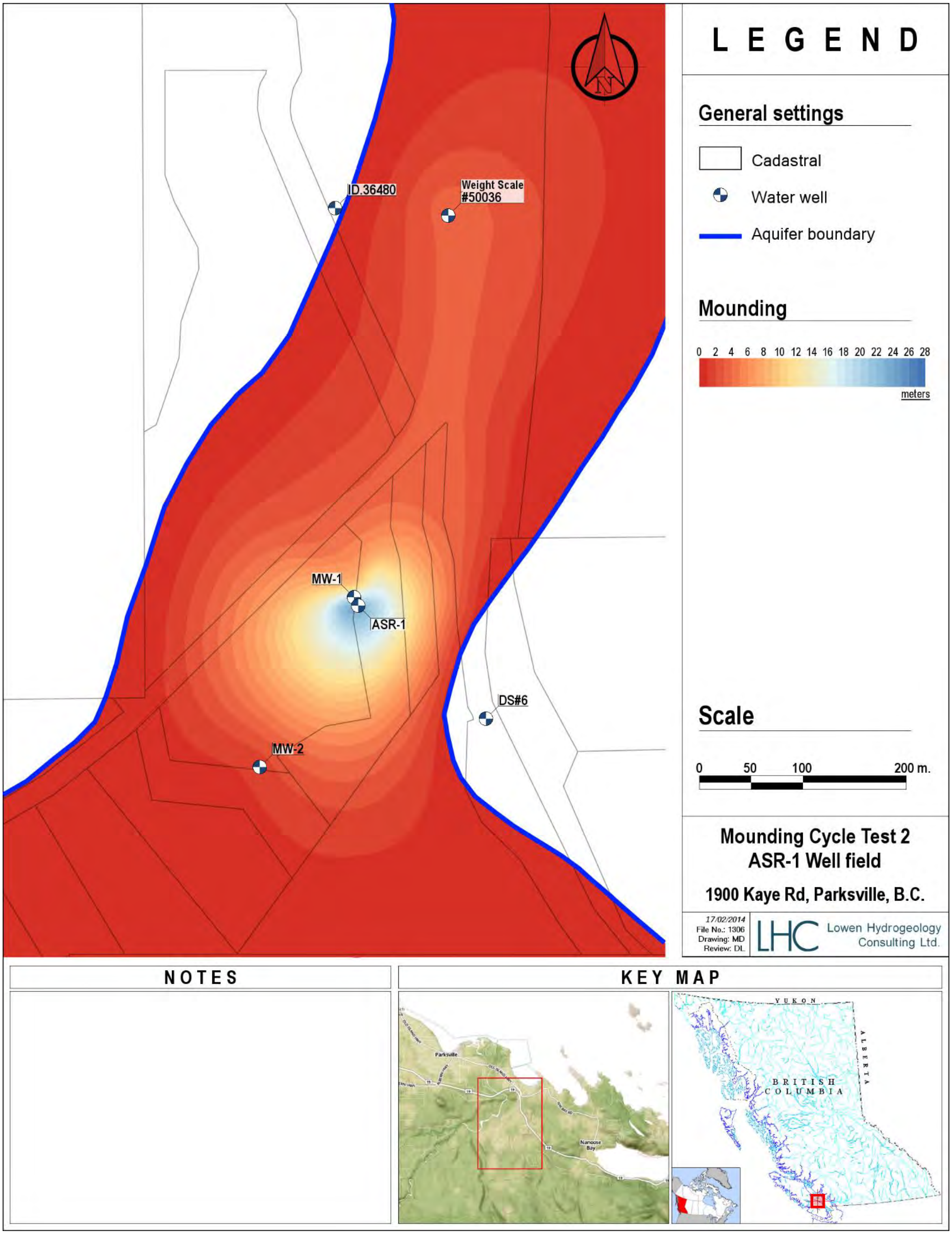
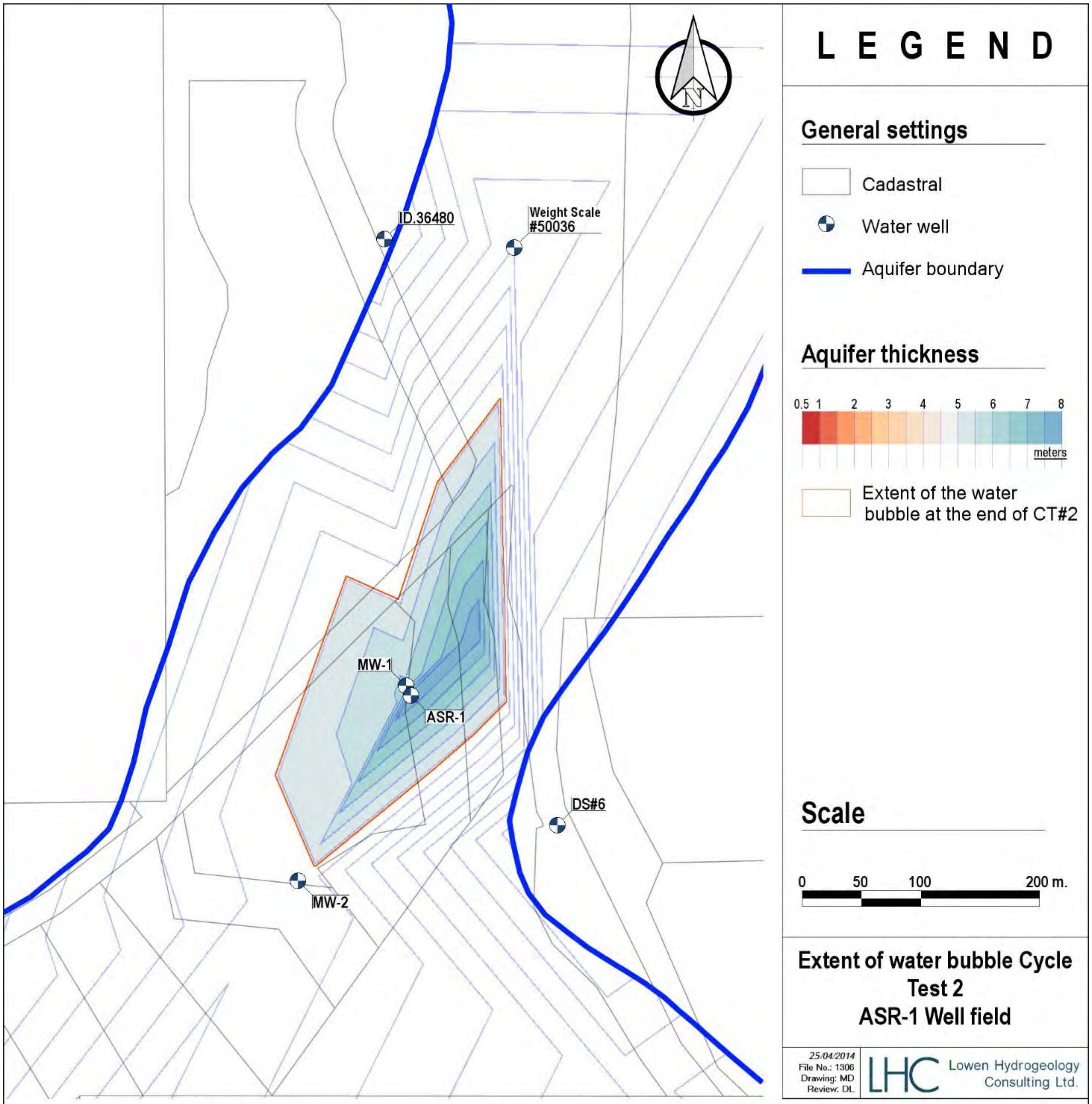


Figure A8 – Estimated Extent of the Stored Water Bubble at the End of Cycle Test #2



NOTES

The total volume of water injected during Cycle Test 2 is V_{tot} = 66,924 m^3

The aquifer thickness map obtained with triangulation interpolation was used, and water volumes were calculated until V_{tot} was reached.

The area delineated above contains V_{tot} considering an aquifer porosity of 0.3.

KEY MAP

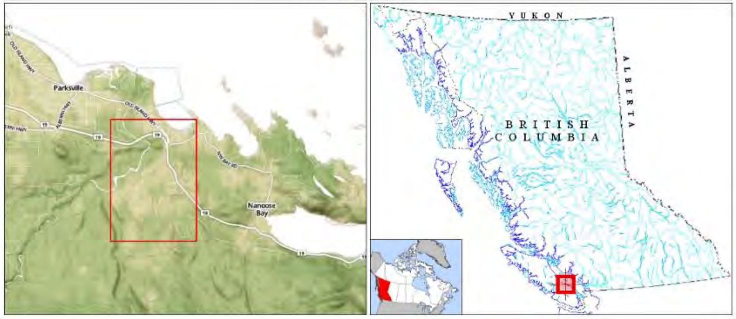
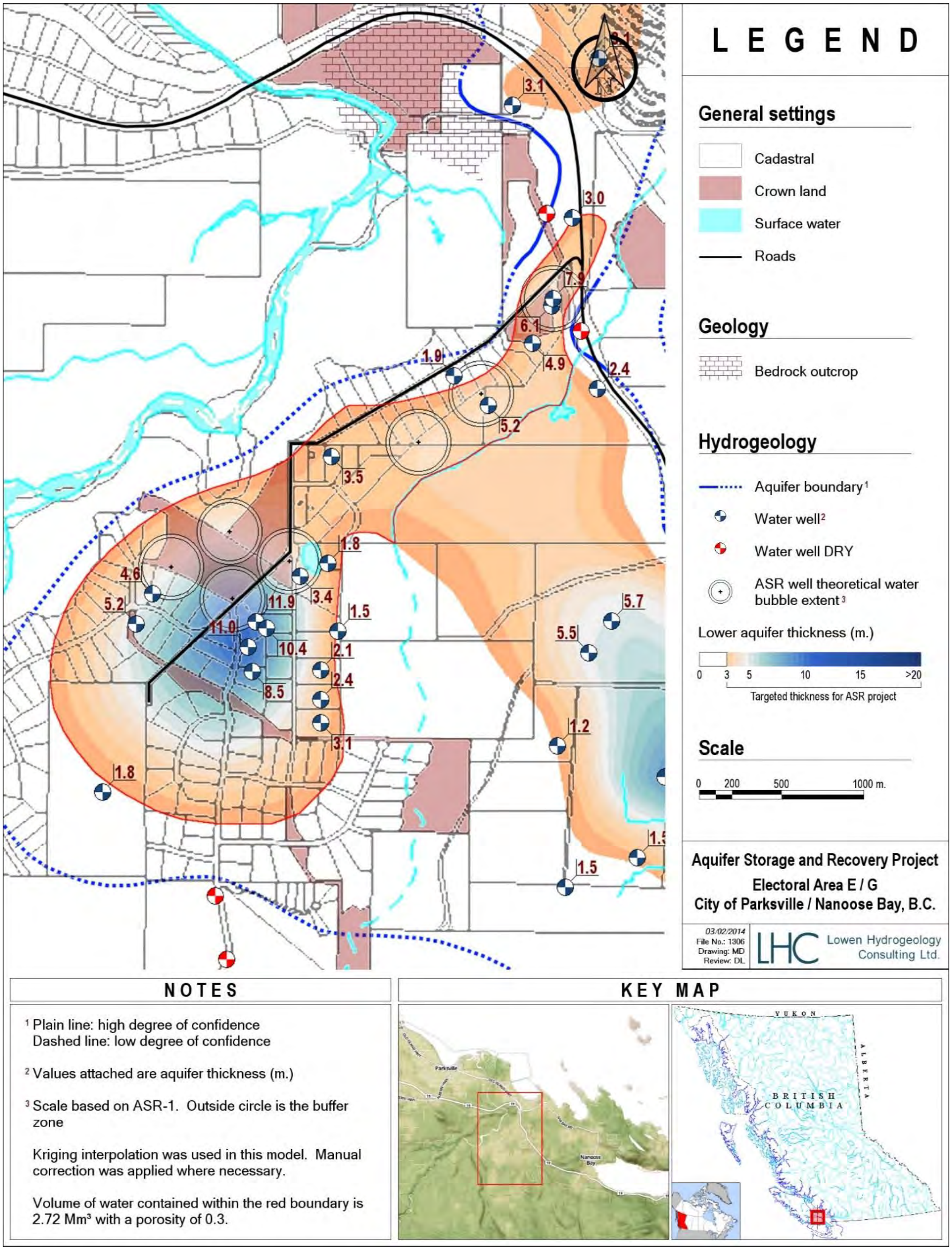


Figure A9 – Potential ASR Field Expansion along Kaye Road



NOTES

¹ Plain line: high degree of confidence
Dashed line: low degree of confidence

² Values attached are aquifer thickness (m.)

³ Scale based on ASR-1. Outside circle is the buffer zone

Kriging interpolation was used in this model. Manual correction was applied where necessary.

Volume of water contained within the red boundary is 2.72 Mm³ with a porosity of 0.3.

Figure A10 - Claudet Road Well Site

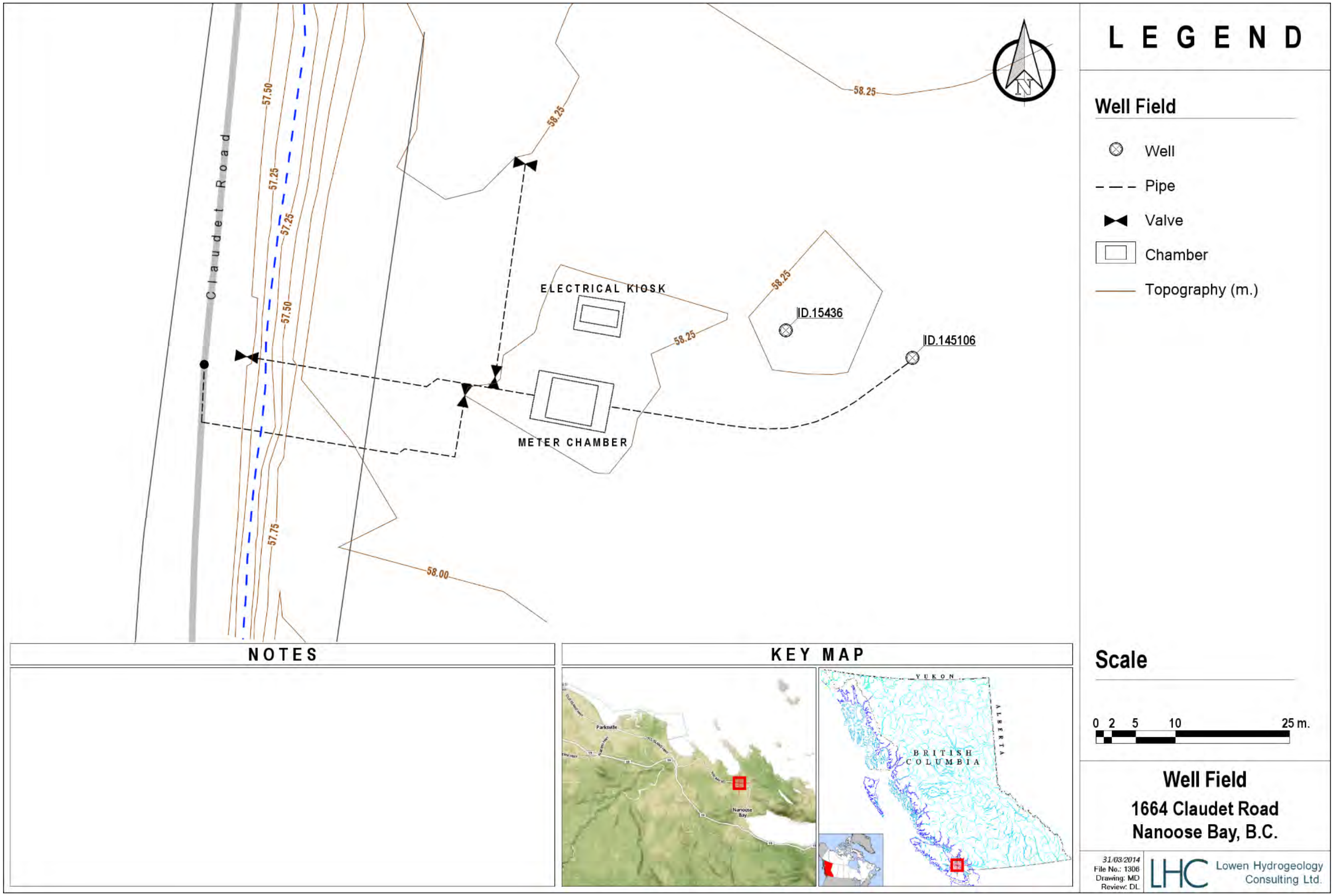
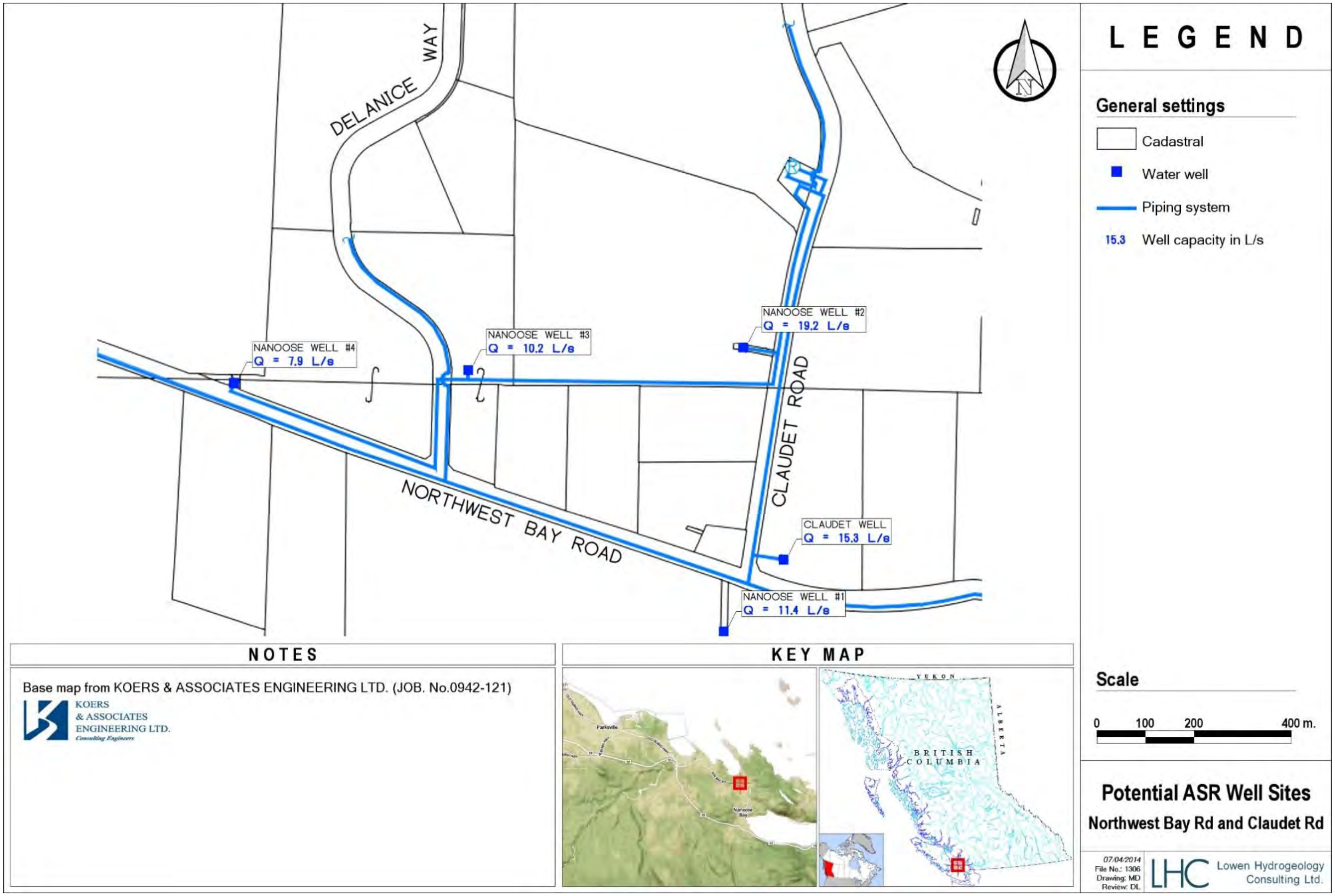
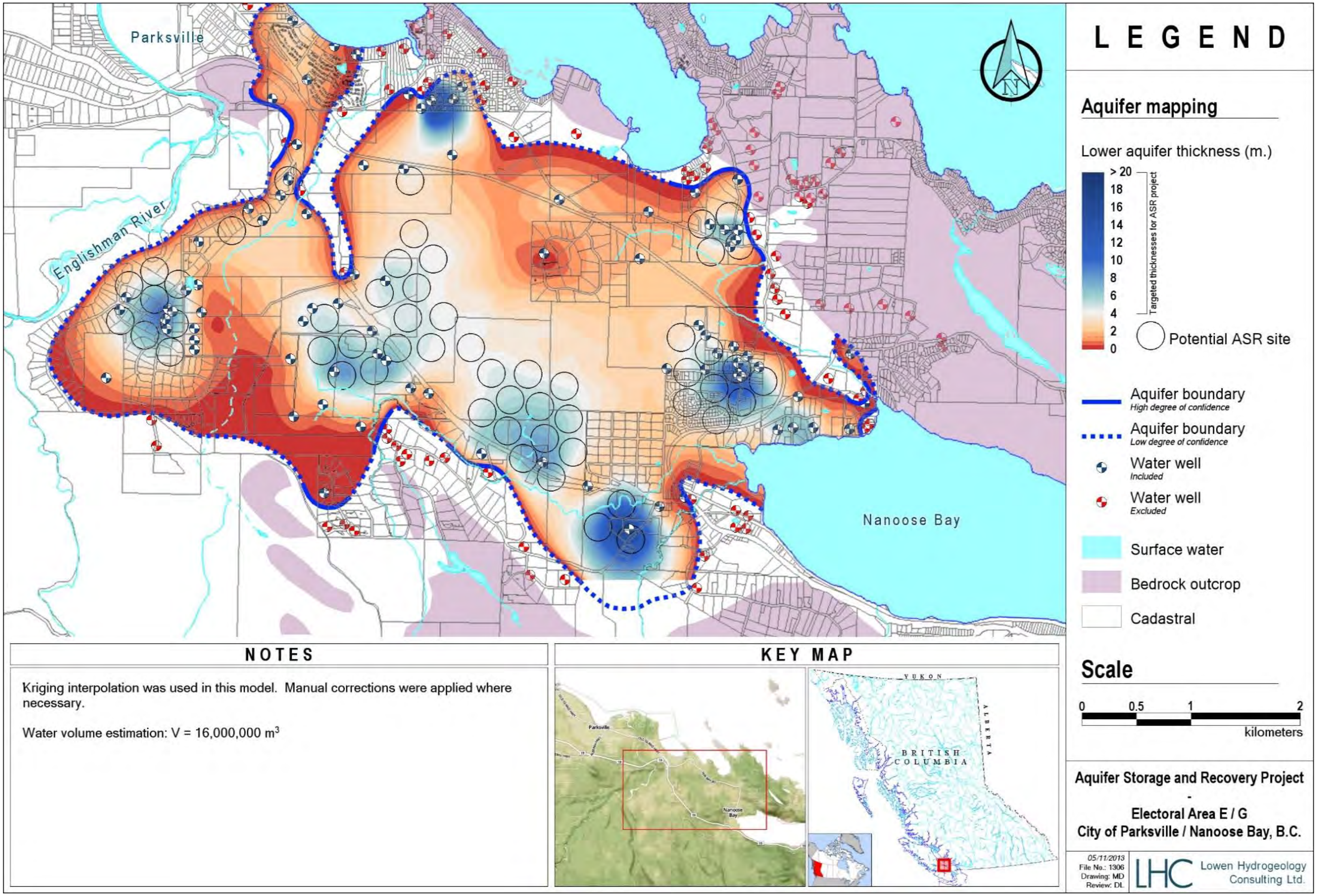


Figure A11 - Potential ASR Well Sites, Nanoose Well Field



Base map from KOERS & ASSOCIATES ENGINEERING LTD. (JOB. No.0942-121)

Figure A12 - Potential ASR Sites in the Englishman River Aquifer



NOTES

Kriging interpolation was used in this model. Manual corrections were applied where necessary.

Water volume estimation: V = 16,000,000 m^3

APPENDIX B

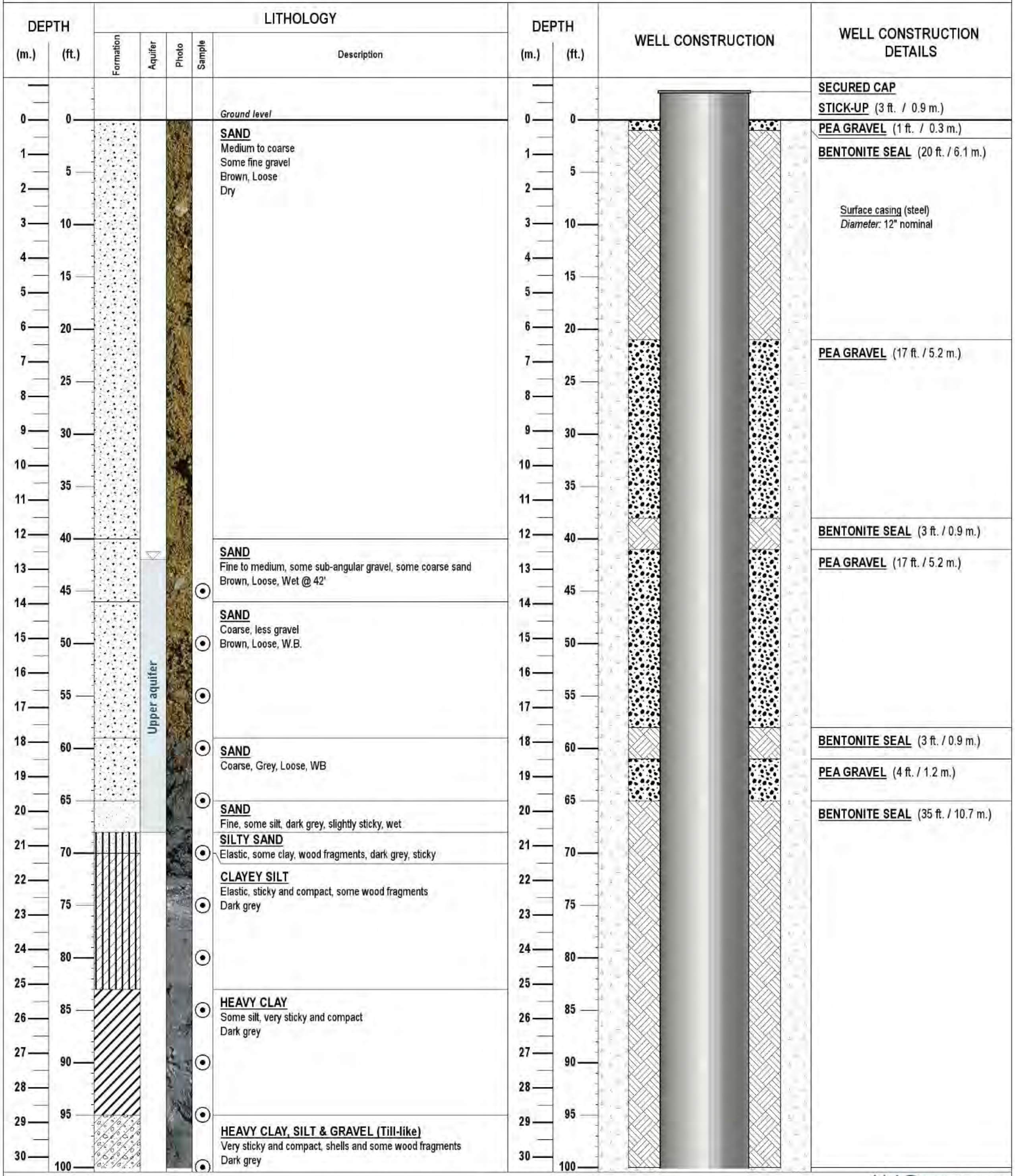
Well Construction and Design

WELL LOG RECORD / PRELIMINARY WELL DESIGN

Well name : Parksville ASR-1
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number: ERWS ASR Project / 1306
Client: Englishman River Water Service
Drilling contractor: Drillwell Entreprises Ltd.

Drilling date : May 2 to 24, 2013
Ground elevation : +/- 141 ft. / 43 m.
Well depth : 165 ft. / 50.3 m.
Method of drilling : Cable tool
Static water level : 102 ft. / 31.1 m. (approx.)

Coordinates : 10 U [408599 ; 5460709]
Logged by : M. Dardare, M.Sc.
Checked by : D. Lowen, P.Geo, P.Eng



Ground level

SAND
Medium to coarse
Some fine gravel
Brown, Loose
Dry

SAND
Fine to medium, some sub-angular gravel, some coarse sand
Brown, Loose, Wet @ 42'

SAND
Coarse, less gravel
Brown, Loose, W.B.

SAND
Coarse, Grey, Loose, WB

SAND
Fine, some silt, dark grey, slightly sticky, wet

SILTY SAND
Elastic, some clay, wood fragments, dark grey, sticky

CLAYEY SILT
Elastic, sticky and compact, some wood fragments
Dark grey

HEAVY CLAY
Some silt, very sticky and compact
Dark grey

HEAVY CLAY, SILT & GRAVEL (Till-like)
Very sticky and compact, shells and some wood fragments
Dark grey

SECURED CAP

STICK-UP (3 ft. / 0.9 m.)

PEA GRAVEL (1 ft. / 0.3 m.)

BENTONITE SEAL (20 ft. / 6.1 m.)

Surface casing (steel)
Diameter: 12" nominal

PEA GRAVEL (17 ft. / 5.2 m.)

BENTONITE SEAL (3 ft. / 0.9 m.)

PEA GRAVEL (17 ft. / 5.2 m.)

BENTONITE SEAL (3 ft. / 0.9 m.)

PEA GRAVEL (4 ft. / 1.2 m.)

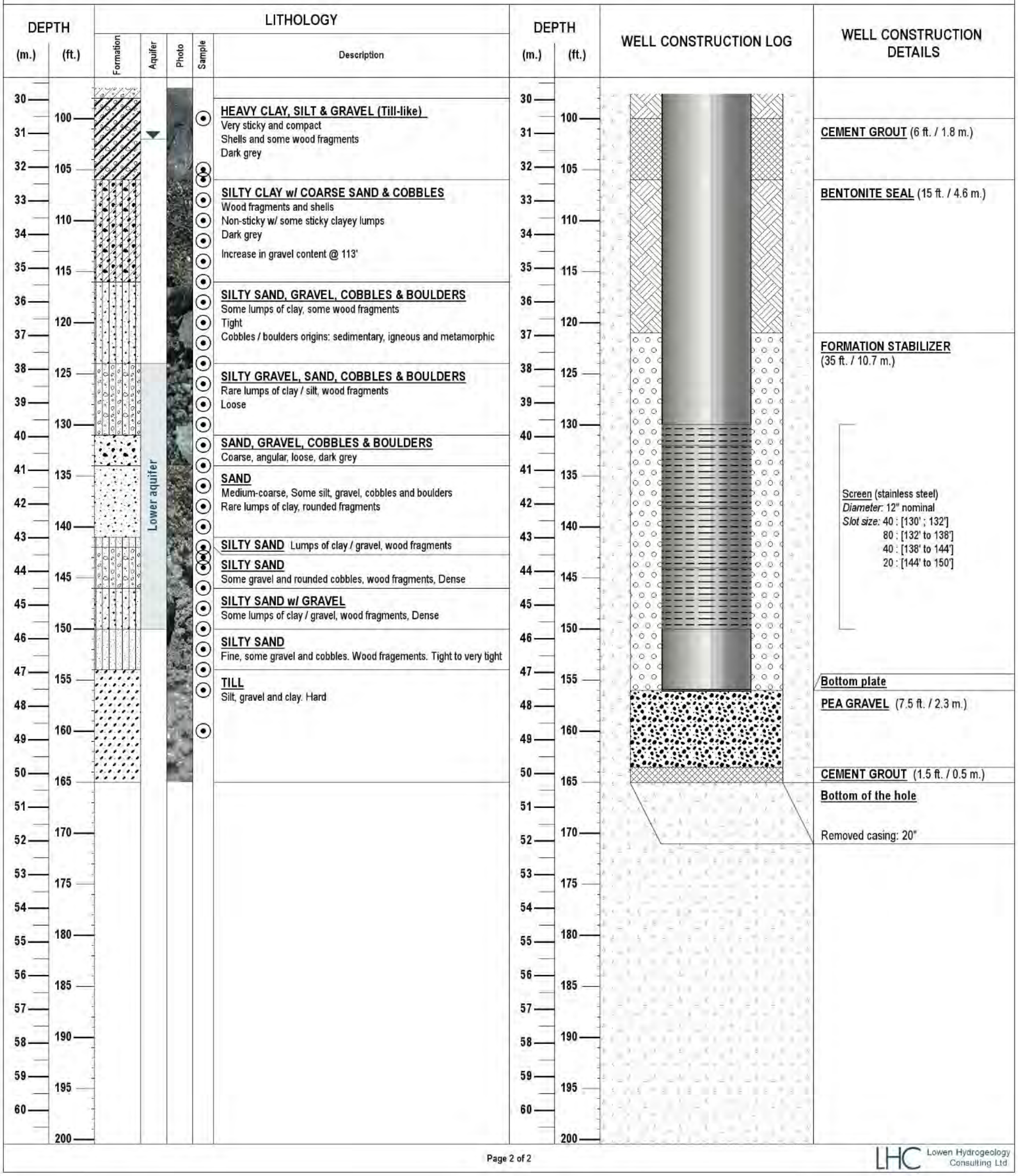
BENTONITE SEAL (35 ft. / 10.7 m.)

WELL LOG RECORD / PRELIMINARY WELL DESIGN - *continued*

Well name : Parksville ASR-1
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number: ERWS ASR Project / 1306
Client: Englishman River Water Service
Drilling contractor: Drillwell Entreprises Ltd.

Drilling date : May 2 to 24, 2013
Ground elevation : +/- 141 ft. / 43 m.
Well depth : 165 ft. / 50.3 m.
Method of drilling : Cable tool
Static water level : 102 ft. / 31.1 m. (approx.)

Logged by : M. Dardare, M.Sc.
Checked by : D. Lowen, P.Geo, P.Eng



HEAVY CLAY, SILT & GRAVEL (Till-like)
Very sticky and compact
Shells and some wood fragments
Dark grey

SILTY CLAY w/ COARSE SAND & COBBLES
Wood fragments and shells
Non-sticky w/ some sticky clayey lumps
Dark grey
Increase in gravel content @ 113'

SILTY SAND, GRAVEL, COBBLES & BOULDERS
Some lumps of clay, some wood fragments
Tight
Cobbles / boulders origins: sedimentary, igneous and metamorphic

SILTY GRAVEL, SAND, COBBLES & BOULDERS
Rare lumps of clay / silt, wood fragments
Loose

SAND, GRAVEL, COBBLES & BOULDERS
Coarse, angular, loose, dark grey

SAND
Medium-coarse, Some silt, gravel, cobbles and boulders
Rare lumps of clay, rounded fragments

SILTY SAND Lumps of clay / gravel, wood fragments

SILTY SAND
Some gravel and rounded cobbles, wood fragments, Dense

SILTY SAND w/ GRAVEL
Some lumps of clay / gravel, wood fragments, Dense

SILTY SAND
Fine, some gravel and cobbles. Wood fragements. Tight to very tight

TILL
Silt, gravel and clay. Hard

CEMENT GROUT (6 ft. / 1.8 m.)

BENTONITE SEAL (15 ft. / 4.6 m.)

FORMATION STABILIZER
(35 ft. / 10.7 m.)

Screen (stainless steel)
Diameter: 12" nominal
Slot size: 40 : [130' ; 132']
80 : [132' to 138']
40 : [138' to 144']
20 : [144' to 150']

Bottom plate

PEA GRAVEL (7.5 ft. / 2.3 m.)

CEMENT GROUT (1.5 ft. / 0.5 m.)

Bottom of the hole

Removed casing: 20"

Page 2 of 2

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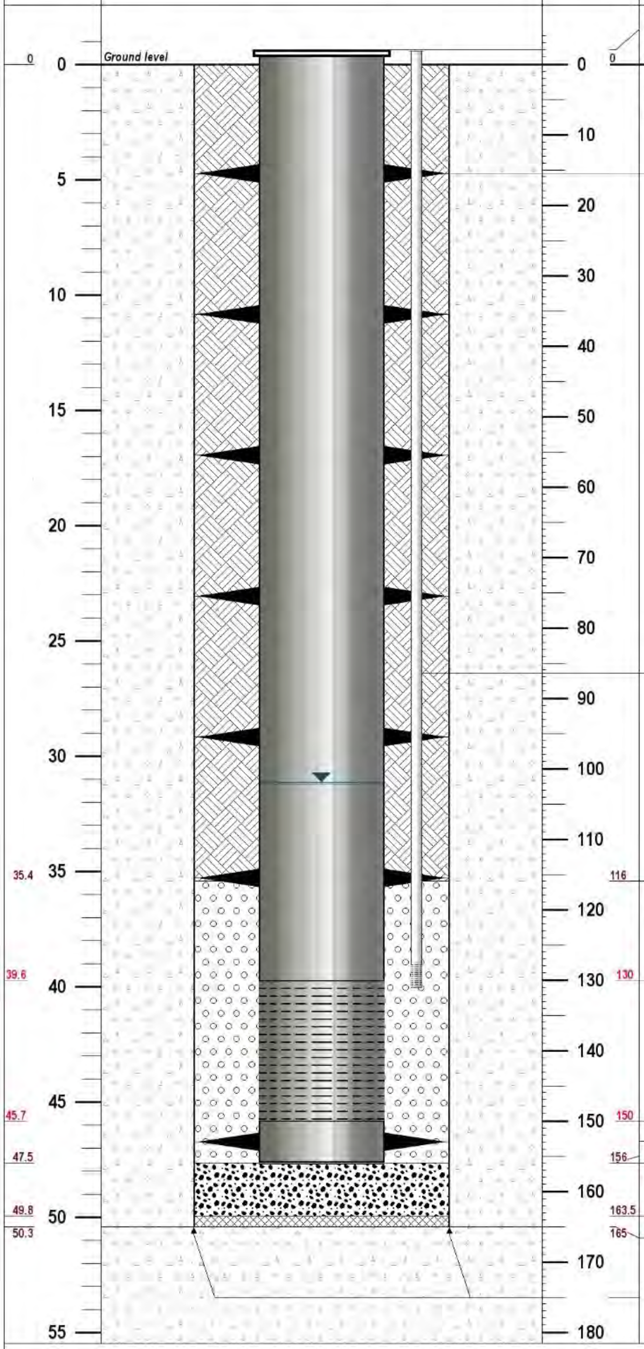
WELL CONSTRUCTION AS-BUILT

Well name : Parksville ASR-1
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number: ERWS ASR Project / 1306
Client: Englishman River Water Service
Drilling contractor: Drillwell Entreprises Ltd.

Drilling date : May 2 to 24, 2013
Ground elevation : +/- 141 ft. / 43 m.
Well depth : 165 ft. / 50.3 m.
Method of drilling : Cable tool
Static water level : 102 ft. / 31.1 m. (approx.)

Coordinates : 10 U [408599 ; 5460709]
Logged by : M. Dardare, M.Sc
Checked by : D. Lowen, P.Geo, P.Eng

DEPTH (meters) | WELL CONSTRUCTION | DEPTH (feet)



WELL CONSTRUCTION DETAILS

SECURED CAP

STICK-UP (2 ft. / 0.6 m.)

BENTONITE + CEMENT GROUT SEAL (116 ft. / 35.4 m.)

Centralizer *(every 20 ft. approx.)*

Casing (stainless steel) : [+2' to 130']
Diameter: 12" I.D.

Piezometer (PVC)
Diameter: 1"
Schedule: 80
Slotted: [128' to 131']

FORMATION STABILIZER (40 ft. / 12.2 m.)
Filter sand: #10-20 : [116' to 120']
: #8-16 : [120' to 156']

Screen (stainless steel)
Diameter: 12" I.D.
Slot size: 40 : [130' to 132']
80 : [132' to 138']
40 : [138' to 144']
20 : [144' to 150']

Blank pipe (stainless steel) : [150' to 156'] - *Diameter:* 12" I.D.

BOTTOM PLATE

PEA GRAVEL (7.5 ft. / 2.3 m.)

CEMENT GROUT (1.5 ft. / 0.5 m.)

CONSTRUCTION CASING (removed) (165 ft. / 50.3 m.)
Diameter: 20" O.D.

LITHOLOGY LOG

SAND
Medium to coarse, some fine gravel
Brown, loose
Dry

Upper aquifer (unconfined)

SAND
Fine to med. Some gravel + coarse sand

SAND
Coarse, less gravel
Brown, loose

SAND Coarse, grey, loose

SAND Fine, some clay, wood fragments, dark grey, slightly sticky

SILTY SAND Elastic, some clay, wood fragments, dark grey, sticky

CLAYEY SILT
Elastic, sticky and compact, wood fragments, dark grey

HEAVY CLAY
Some silt, very sticky and compact
Dark grey

Lower aquifer (confined)

HEAVY CLAY SILT & GRAVEL (Till-like)
Very sticky and compact, shells, wood
Dark grey

SILTY CLAY w/ COARSE SAND & COBBLES
Wood, shells. Non-sticky + clay lumps

SILTY SAND, GRAVEL, COBBLES & BOULDERS
Some lumps of clay. Tight

SILTY GRAVEL, COBBLES & BOULDERS
Rare lumps of clay/silt, wood. Loose

SAND, GRAVEL, COBBLES & BOULDERS
Coarse, angular, loose, dark grey

SAND Med-coarse, some silt

SILTY SAND Lumps of clay/gravel

SILTY SAND w/ GRAVEL
Lumps of clay/gravel, dense

SILTY SAND Fine, some gravel, Tight

TILL
Silt, gravel and clay
Hard

Page 1 of 1

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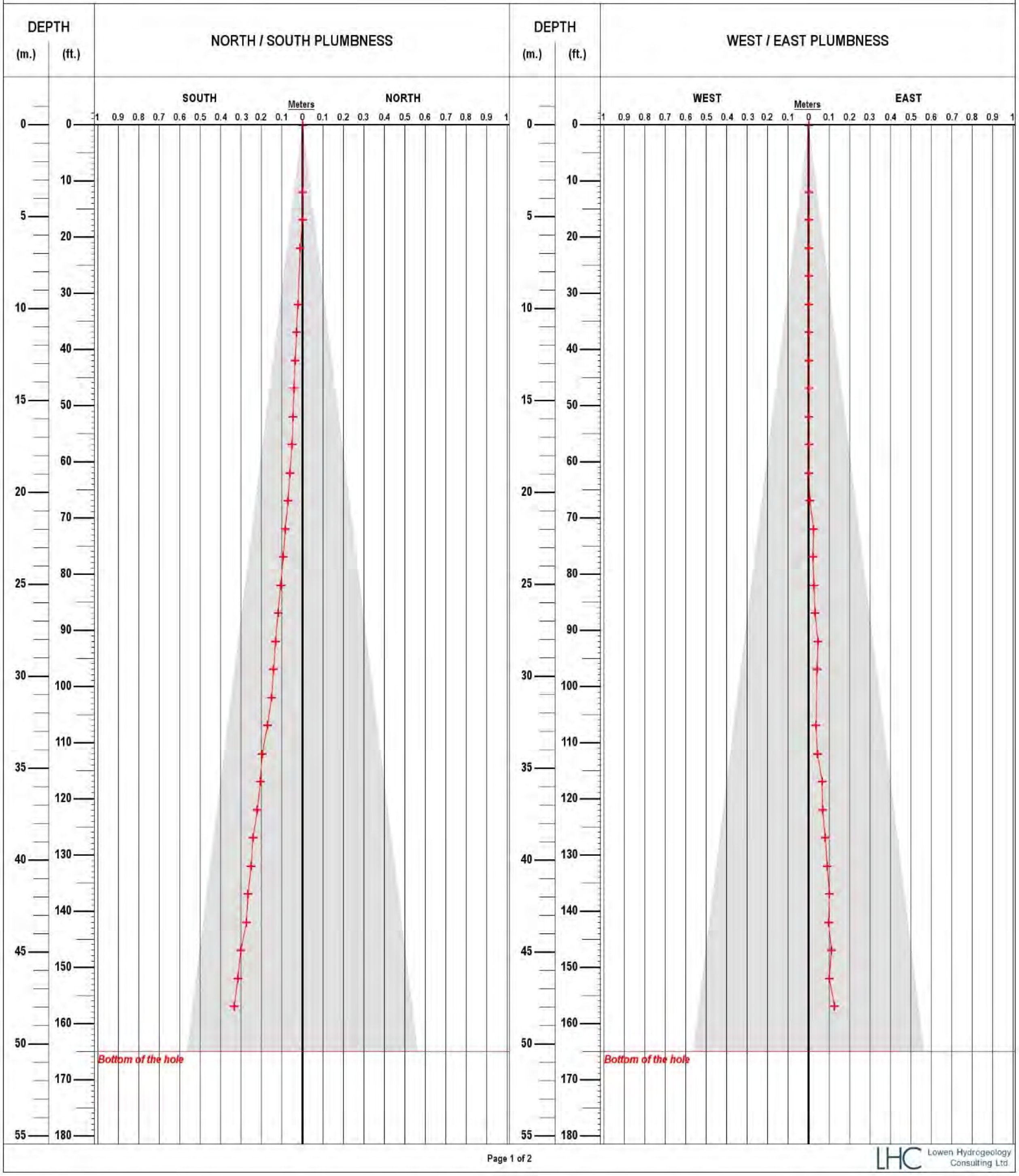
WELL PLUMBNESS AND ALIGNMENT

Well name : ID.- (ASR1 - DS#3)
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number: ERWS ASR Project / 1306
Client: Englishman River Water Service
Drilling contractor: Drillwell Entreprises Ltd.

Measurement date : May 28, 2013
Ground elevation : +/- 141 ft. / 43 m.
Well depth : 165 ft. / 50.3 m.
Casing drifting angle : α (south) = 0.006° / α (east) = 0.002° *(Max: α max = 0.01°)*

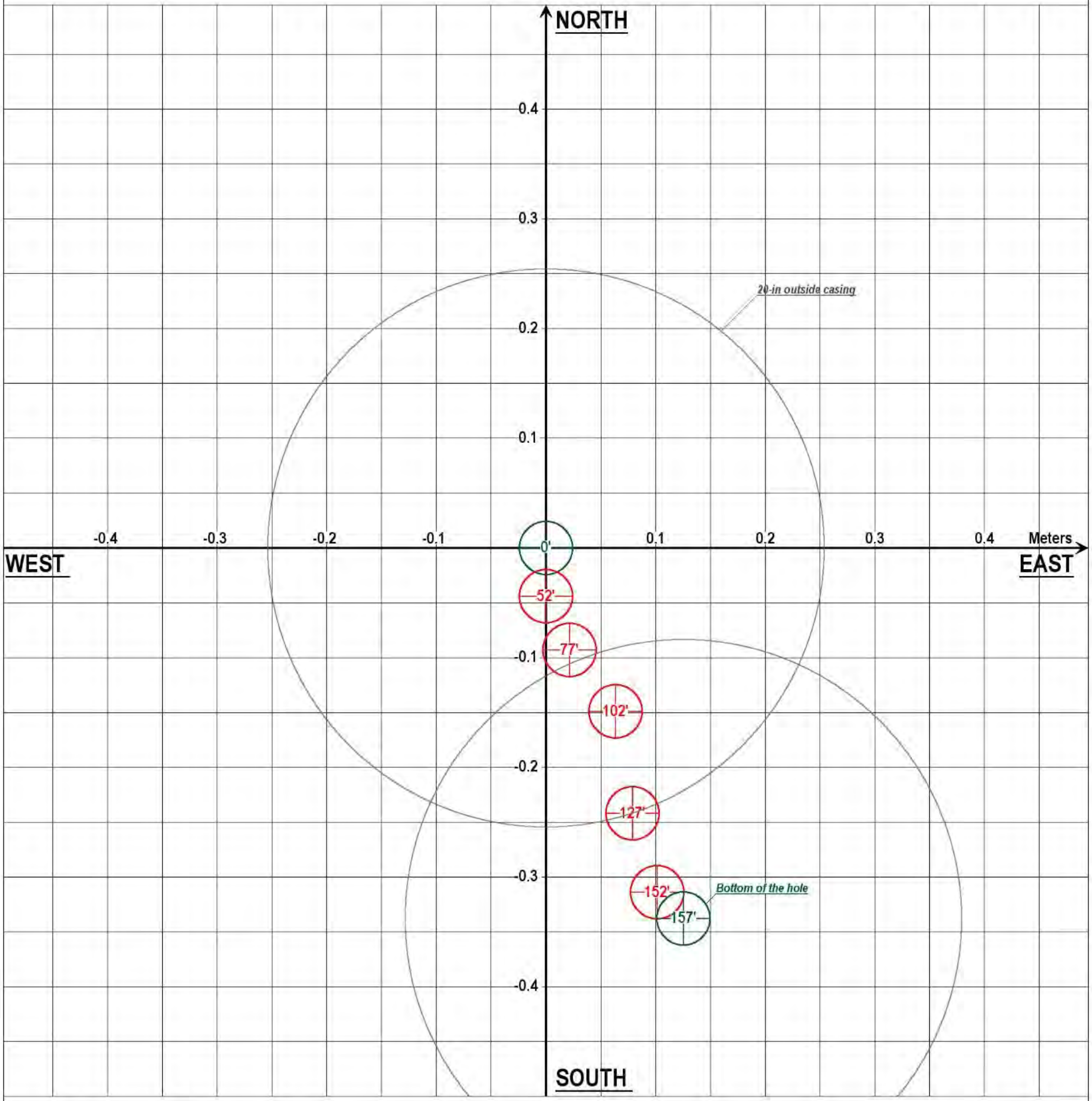


WELL PLUMBNESS AND ALIGNMENT

Well name : ID.- (ASR1 - DS#3)
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number: ERWS ASR Project / 1306
Client: Englishman River Water Service
Drilling contractor: Drillwell Entreprises Ltd.

Measurement date : May 28, 2013
Ground elevation : +/- 141 ft. / 43 m.
Well depth : 165 ft. / 50.3 m.
Casing drifting angle : $\alpha_{(south)}$ = 0.006° / $\alpha_{(east)}$ = 0.002° *(Max: α_{max} = 0.01°)*

PLUMBNESS : VIEW FROM TOP



SIEVE ANALYSIS

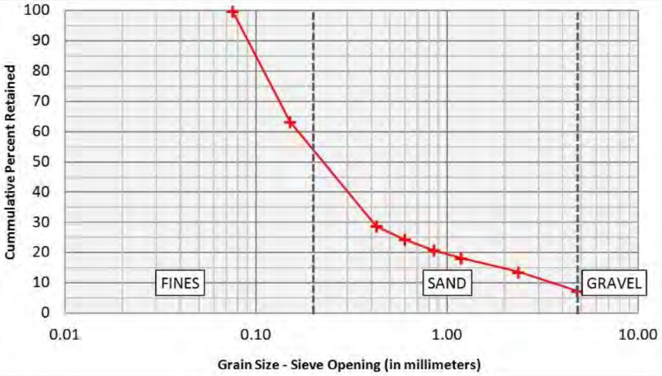
Well name : ID.- (ASR1 - DS#3)
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number : ERWS ASR Project / 1306
Client : Englishman River Water Service
Ground elevation : +/- 141 ft. / 43 m.

Sampling date : May 10 to 13, 2013
Sampled by : M. Dardare, M Sc
Analysed date : May 17, 2013
Sieved by : W. S. Hodge, P. Geo.

SAMPLE DEPTH: 120'

Description: Lot of fine sand and silt.

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*0.00*
4	4.670	7.33
8	2.360	13.61
16	1.180	18.17
20	0.841	20.85
30	0.600	24.33
40	00425	28.76
100	0.150	63.32
200	0.075	99.90
PAN		



SAMPLE DEPTH: 122'

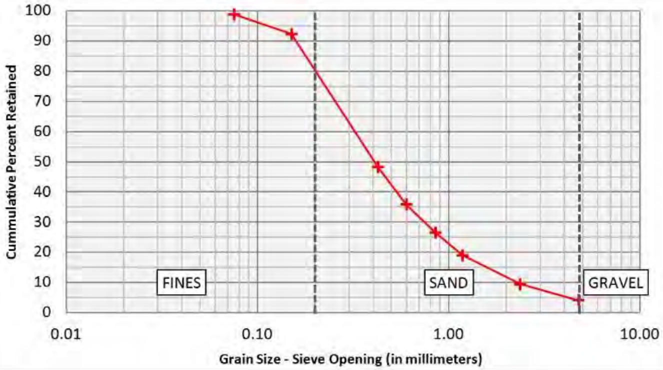
Description: Coarser. Some fine sand and silt

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*0.00*
4	4.670	8.23
8	2.360	14.85
16	1.180	20.19
20	0.841	24.06
30	0.600	30.84
40	00425	42.89
100	0.150	90.41
200	0.075	99.15
PAN		

SAMPLE DEPTH: 124'

Description: Very fine sand w/ some silt

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*0.00*
4	4.670	4.13
8	2.360	9.44
16	1.180	19.15
20	0.841	26.54
30	0.600	35.90
40	00425	48.35
100	0.150	92.47
200	0.075	98.95
PAN		



* The sieve analysis does not include the 1/2" and greater

SIEVE ANALYSIS

Well name : ID.- (ASR1 - DS#3)
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number : ERWS ASR Project / 1306
Client : Englishman River Water Service
Ground elevation : +/- 141 ft. / 43 m.

Sampling date : May 13, 2013
Sampled by : M. Dardare, M Sc
Analysed date : May 17, 2013
Sieved by : W. S. Hodge, P. Geo.

SAMPLE DEPTH: 126'

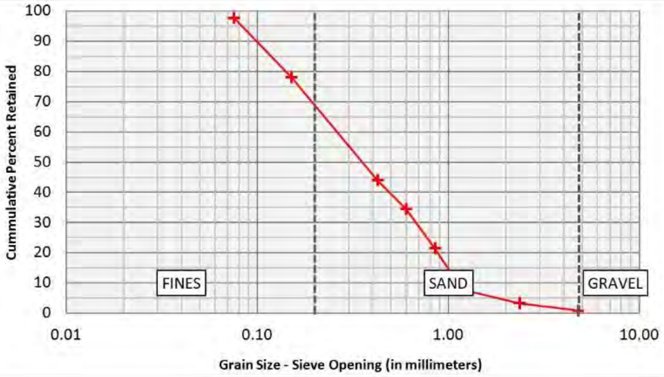
Description: Lot of 1/2 or greater sieved but lots of fine sand + binding material (clay?). Some silt

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*51.38*
4	4.670	17.16
8	2.360	28.67
16	1.180	37.59
20	0.841	42.47
30	0.600	49.15
40	00425	58.02
100	0.150	92.88
200	0.075	99.71
PAN		

SAMPLE DEPTH: 128'

Description: Uniform material, a few rocks. Some fine sand and silt

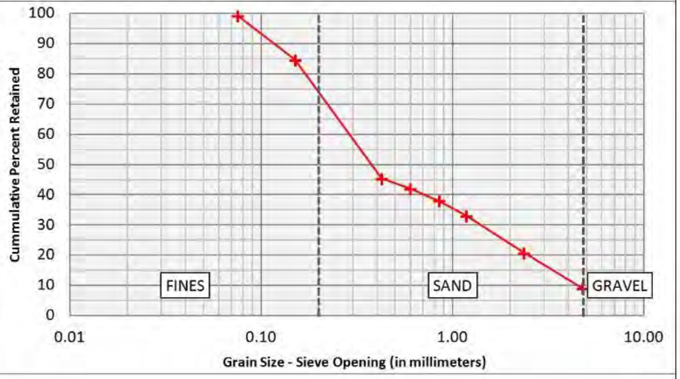
Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*0.00*
4	4.670	0.87
8	2.360	3.29
16	1.180	7.92
20	0.841	21.46
30	0.600	34.54
40	00425	44.04
100	0.150	78.12
200	0.075	97.87
PAN		



SAMPLE DEPTH: 130'

Description: Lots of broken rocks. Uniform material, lots of fine sand and silt

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*54*
4	4.670	9.06
8	2.360	20.68
16	1.180	33.04
20	0.841	37.95
30	0.600	42.078
40	00425	45.32
100	0.150	84.67
200	0.075	99.30
PAN		



* The sieve analysis does not include the 1/2" and greater

SIEVE ANALYSIS

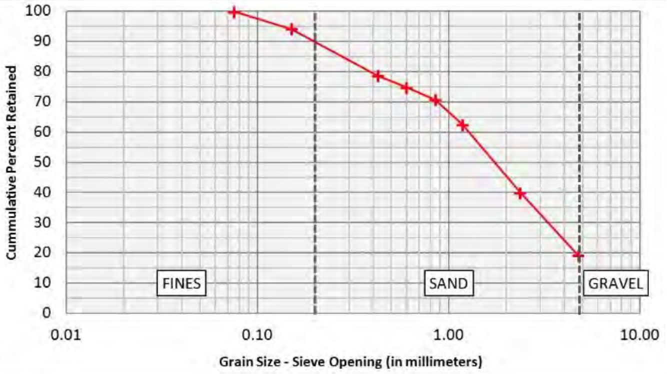
Well name : ID.- (ASR1 - DS#3)
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number : ERWS ASR Project / 1306
Client : Englishman River Water Service
Ground elevation : +/- 141 ft. / 43 m.

Sampling date : May 14, 2013
Sampled by : M. Dardare, M Sc
Analysed date : May 17, 2013
Sieved by : W. S. Hodge, P. Geo.

SAMPLE DEPTH: 132'

Description: Lots of broken rocks + stones > 1/2". Coarse but lots of fine sand + silt

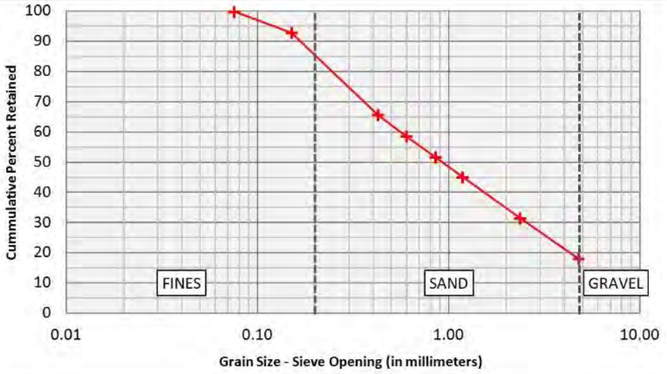
Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*60*
4	4.670	19.15
8	2.360	39.97
16	1.180	62.45
20	0.841	70.69
30	0.600	74.85
40	00425	78.68
100	0.150	94.17
200	0.075	99.92
PAN		



SAMPLE DEPTH: 134'

Description: Lots of very large stones, some fine sand + silt. Coarser material than 132'

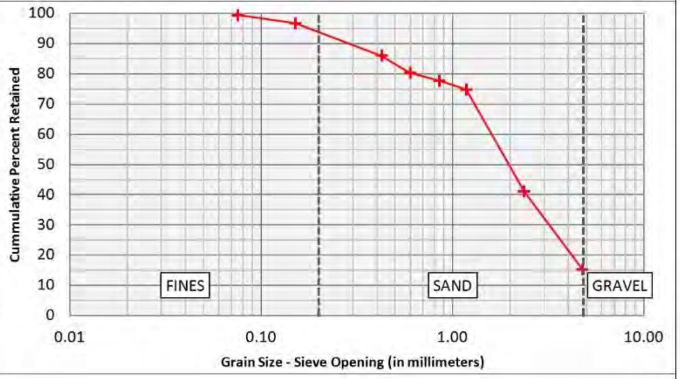
Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*68*
4	4.670	18.13
8	2.360	31.42
16	1.180	45.16
20	0.841	51.68
30	0.600	58.55
40	00425	65.76
100	0.150	92.89
200	0.075	99.90
PAN		



SAMPLE DEPTH: 134.5'

Description: Very similar to 134' but less large stones. Fine sand and silt.

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*30.32*
4	4.670	15.28
8	2.360	41.12
16	1.180	74.92
20	0.841	77.72
30	0.600	80.39
40	00425	86.01
100	0.150	96.77
200	0.075	99.58
PAN		



* The sieve analysis does not include the 1/2" and greater

SIEVE ANALYSIS

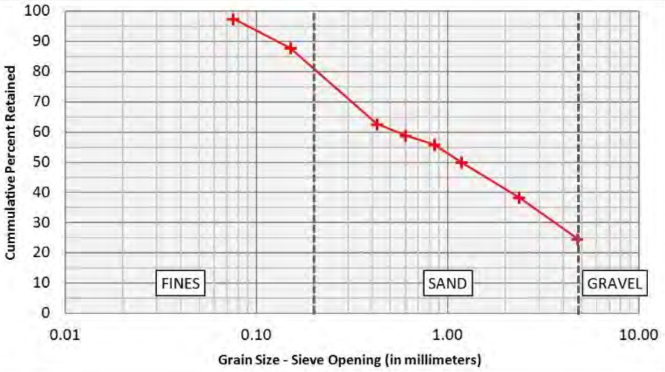
Well name : ID.- (ASR1 - DS#3)
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number : ERWS ASR Project / 1306
Client : Englishman River Water Service
Ground elevation : +/- 141 ft. / 43 m.

Sampling date : May 14, 2013
Sampled by : M. Dardare, M Sc
Analysed date : May 17, 2013
Sieved by : W. S. Hodge, P. Geo.

SAMPLE DEPTH: 136'

Description: Very coarse + lots of large rocks + stones but fine sand

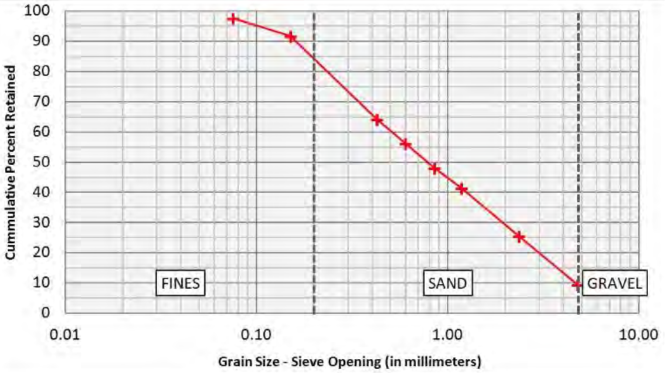
Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*68.62*
4	4.670	24.66
8	2.360	38.36
16	1.180	50.00
20	0.841	55.96
30	0.600	58.90
40	00425	62.67
100	0.150	87.81
200	0.075	97.60
PAN		99.31



SAMPLE DEPTH: 138'

Description: Very coarse + lots of large rocks and stones but fine sand

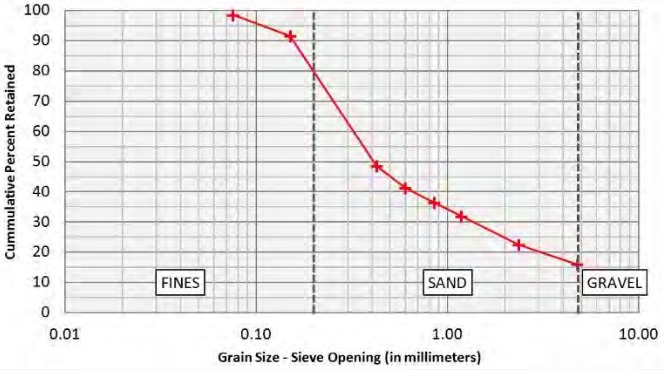
Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*37.41*
4	4.670	9.47
8	2.360	25.44
16	1.180	41.42
20	0.841	49.11
30	0.600	56.21
40	00425	64.12
100	0.150	91.71
200	0.075	97.63
PAN		99.28



SAMPLE DEPTH: 140'

Description:

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*14.37*
4	4.670	16.06
8	2.360	22.44
16	1.180	31.97
20	0.841	36.50
30	0.600	41.35
40	00425	48.54
100	0.150	91.60
200	0.075	98.61
PAN		99.38



* The sieve analysis does not include the 1/2" and greater

SIEVE ANALYSIS

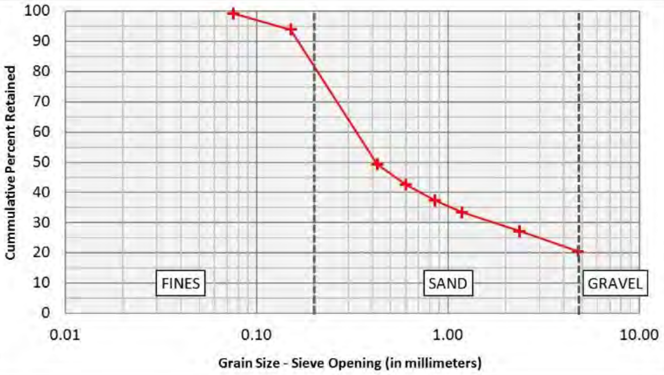
Well name : ID.- (ASR1 - DS#3)
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number : ERWS ASR Project / 1306
Client : Englishman River Water Service
Ground elevation : +/- 141 ft. / 43 m.

Sampling date : May 22, 2013
Sampled by : M. Dardare, M Sc
Analysed date : May 24, 2013
Sieved by : W. S. Hodge, P. Geo.

SAMPLE DEPTH: 142'

Description:

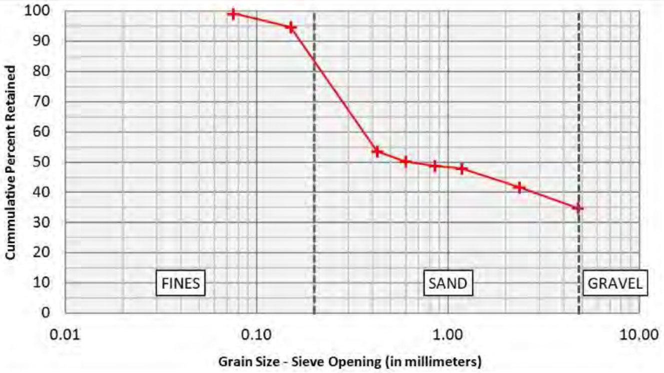
Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*60.80*
4	4.670	20.52
8	2.360	27.27
16	1.180	33.48
20	0.841	37.40
30	0.600	42.66
40	00425	\49.41
100	0.150	93.95
200	0.075	99.35
PAN		99.99



SAMPLE DEPTH: 143'

Description:

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*28.74*
4	4.670	34.78
8	2.360	41.57
16	1.180	47.88
20	0.841	48.78
30	0.600	50.21
40	00425	53.51
100	0.150	94.75
200	0.075	99.21
PAN		99.74



SAMPLE DEPTH: 144'

Description: Some binder and quite silty

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*32.33*
4	4.670	17.40
8	2.360	23.68
16	1.180	27.93
20	0.841	28.95
30	0.600	30.77
40	00425	35.22
100	0.150	89.47
200	0.075	97.78
PAN		99.80

* The sieve analysis does not include the 1/2" and greater

SIEVE ANALYSIS

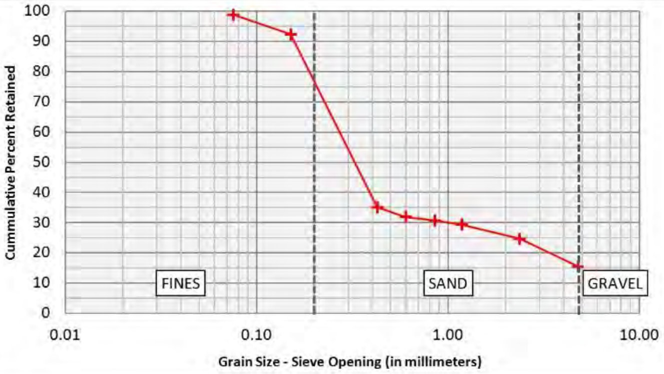
Well name : ID.- (ASR1 - DS#3)
Well location : 1990 Kaye Road - Parksville, B.C.
Project name / number : ERWS ASR Project / 1306
Client : Englishman River Water Service
Ground elevation : +/- 141 ft. / 43 m.

Sampling date : May 23, 2013
Sampled by : M. Dardare, M Sc
Analysed date : May 26, 2013
Sieved by : W. S. Hodge, P. Geo.

SAMPLE DEPTH: 146'

Description: Some binder and quite silty

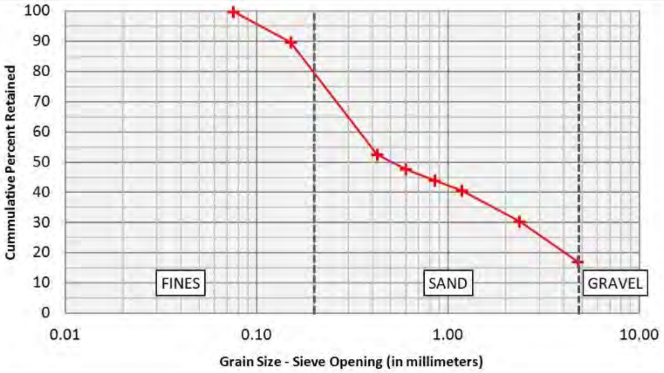
Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*5.4*
4	4.670	15.53
8	2.360	24.78
16	1.180	29.40
20	0.841	30.72
30	0.600	31.94
40	00425	35.21
100	0.150	92.33
200	0.075	98.94
PAN		99.60



SAMPLE DEPTH: 148'

Description: Some binder and quite silty

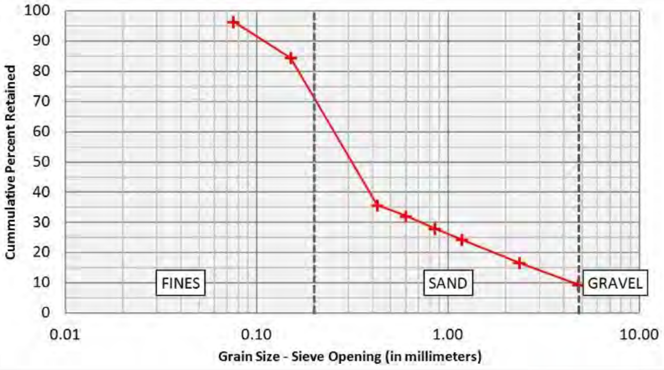
Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*2.2*
4	4.670	17.05
8	2.360	30.34
16	1.180	40.54
20	0.841	43.98
30	0.600	47.73
40	00425	52.57
100	0.150	89.67
200	0.075	97.85
PAN		98.87



SAMPLE DEPTH: 150'

Description: Some binder and quite silty

Sieve No.	Sieve size (mm)	Cumulative percentage retained
*1/2 or greater**	*12.700*	*0.00*
4	4.670	9.40
8	2.360	16.68
16	1.180	24.37
20	0.841	28.03
30	0.600	32.19
40	00425	35.77
100	0.150	84.49
200	0.075	96.56
PAN		98.75



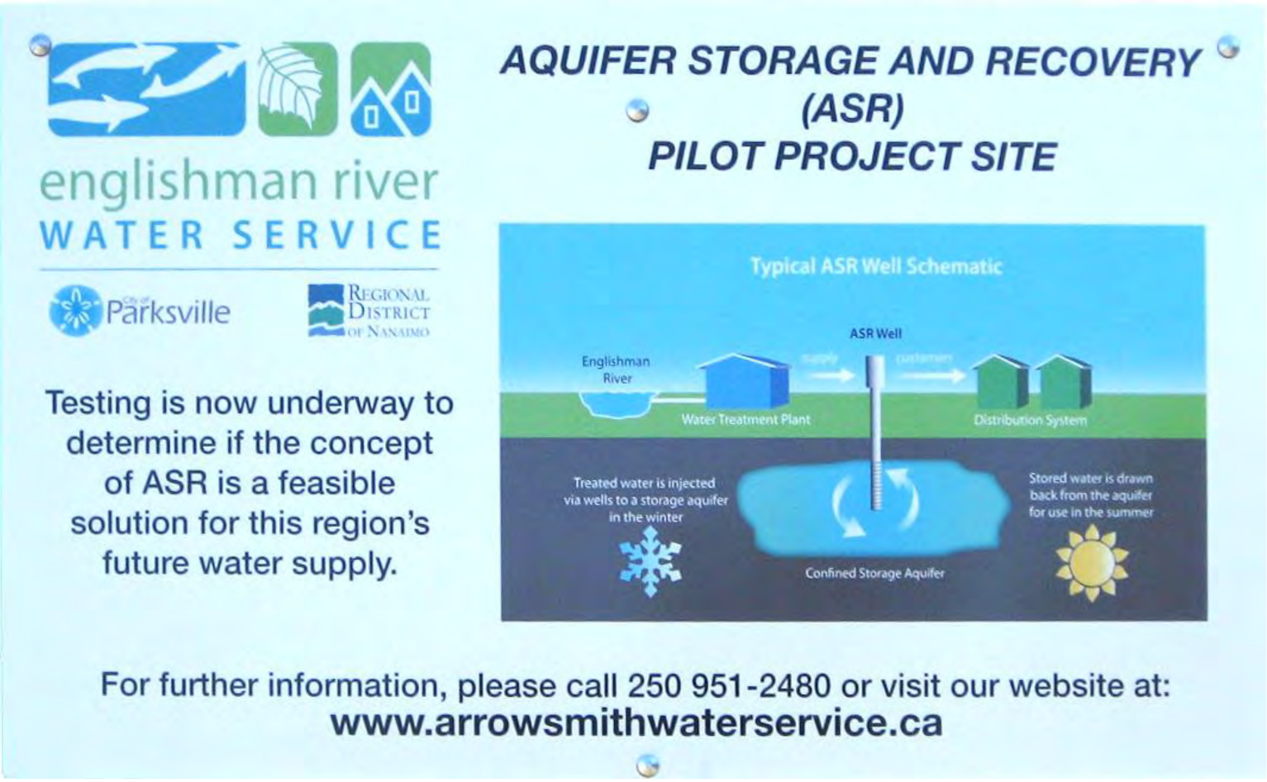
* The sieve analysis does not include the 1/2" and greater

ASR-1 Photos of Drilling and Completion

Cable Tool Drill Rig

Bailer

Informative sign at the ASR well site



englishman river
WATER SERVICE

City of Parksville

Regional District of Nanaimo

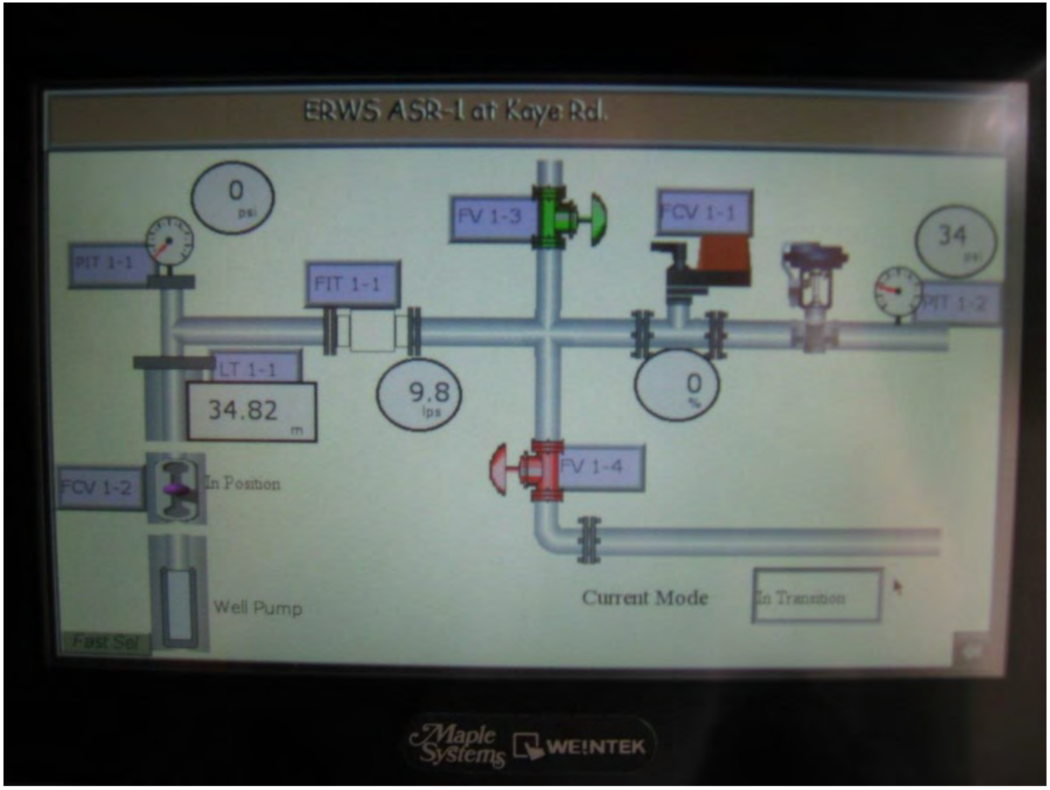
AQUIFER STORAGE AND RECOVERY
(ASR)
PILOT PROJECT SITE

Testing is now underway to determine if the concept of ASR is a feasible solution for this region's future water supply.

For further information, please call 250 951-2480 or visit our website at:
www.arrowsmithwaterservice.ca

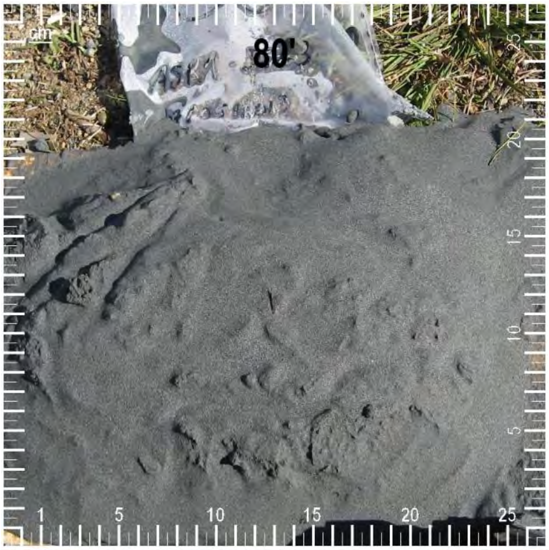
ASR-1 piping system

SCADA System Control Screen



ASR-1 installation and sampling table

Drilling Sample photos at ASR-1


80'
cm


85'
cm


90'
cm


95'
95'
cm


100'
cm


106'
106
cm


cm
Ziploc
108'
1 5 10 15 20 25


cm
110'
1 5 10 15 20 25


cm
114'
1 5 10 15 20 25


cm
116'
1 5 10 15 20 25


cm
120'
1 5 10 15 20 25


cm
122'
1 5 10 15 20 25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124'
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5 10 15 20 25


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126'
1 5 10 15 20 25
5 10 15 20 25


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128'
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5 10 15 20 25


cm
128'
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5 10 15 20 25


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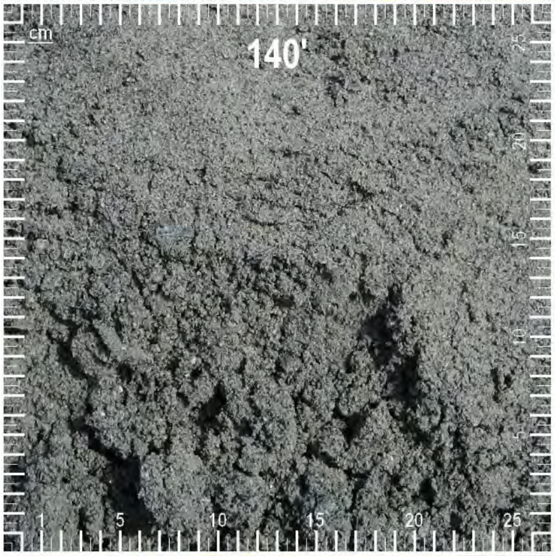
132'
1 5 10 15 20 25
5 10 15 20 25


cm
134'
1 5 10 15 20 25
5 10 15 20 25


136'
cm


138'
cm


140'
cm


142'
cm


143'
cm


144'
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146'
cm
1
5
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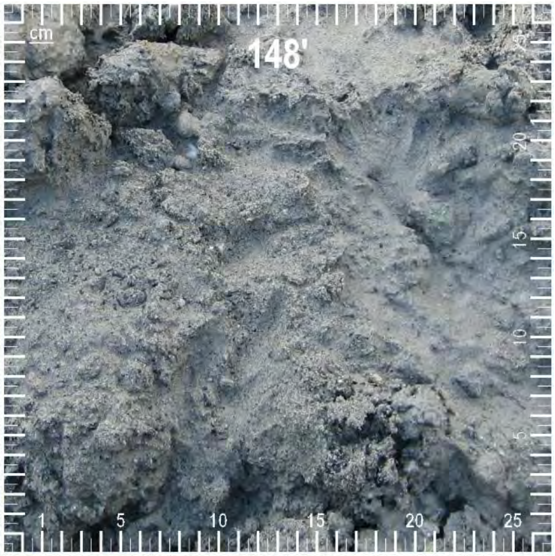
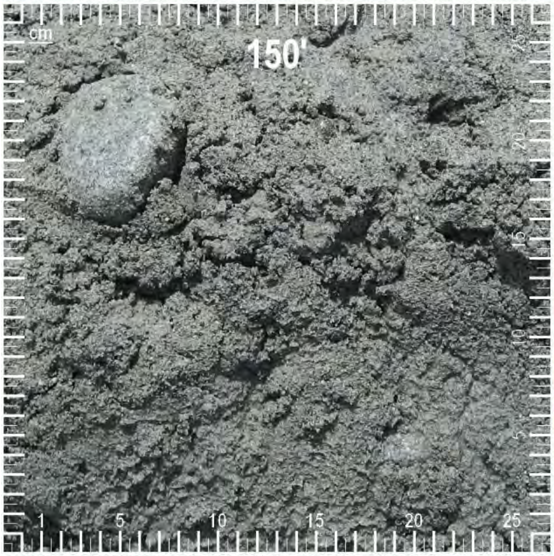
20
25


148'
cm
1
5
10
15
20
25


150'
cm
1
5
10
15
20
25


151'
cm
1
5
10
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20
25


152'
cm
1
5
10
15
20
25


154'
cm
1
5
10
15
20
25

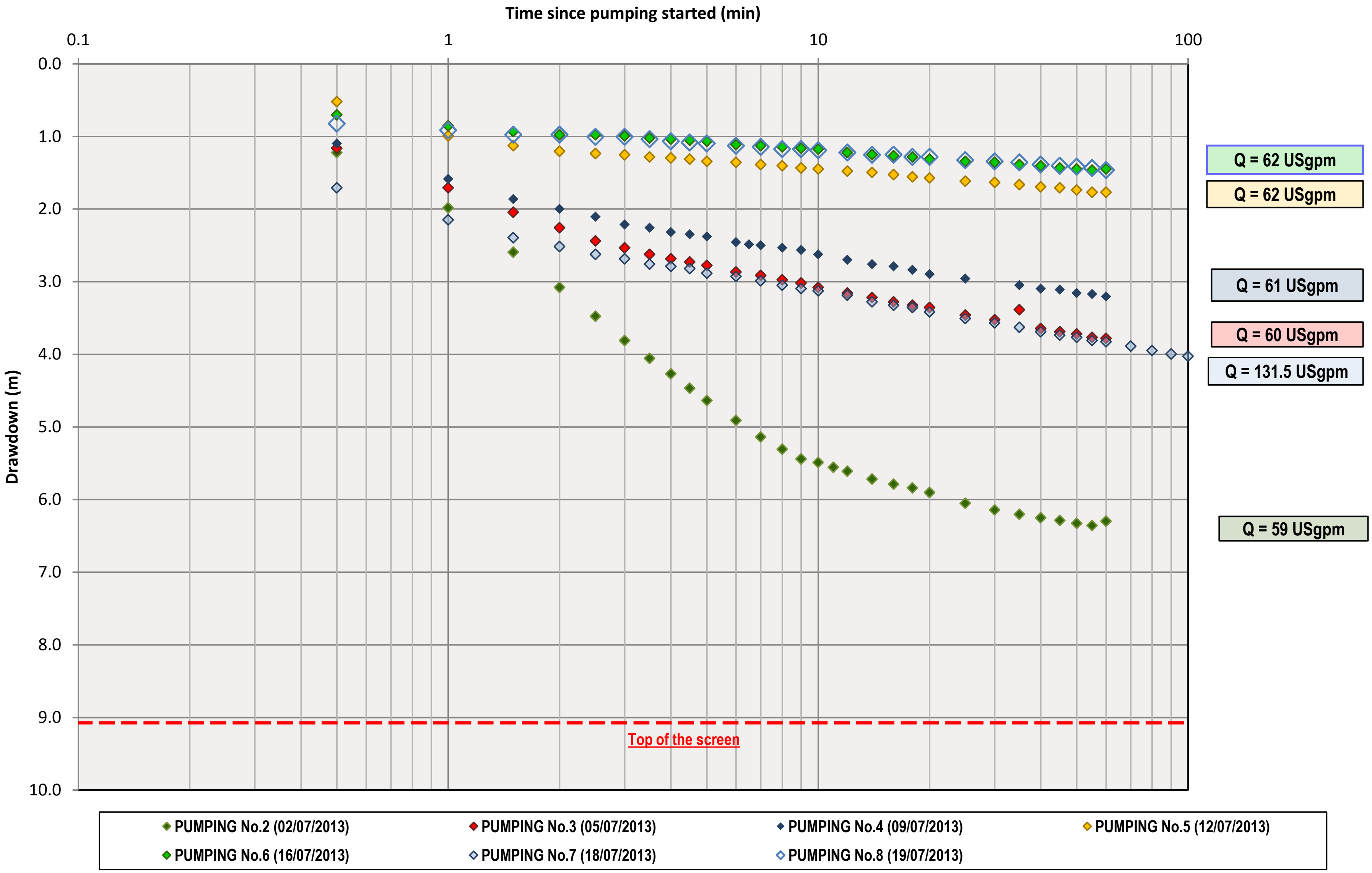

cm
156'
1
5
10
15
20
25


cm
160'
1
5
10
15
20
25

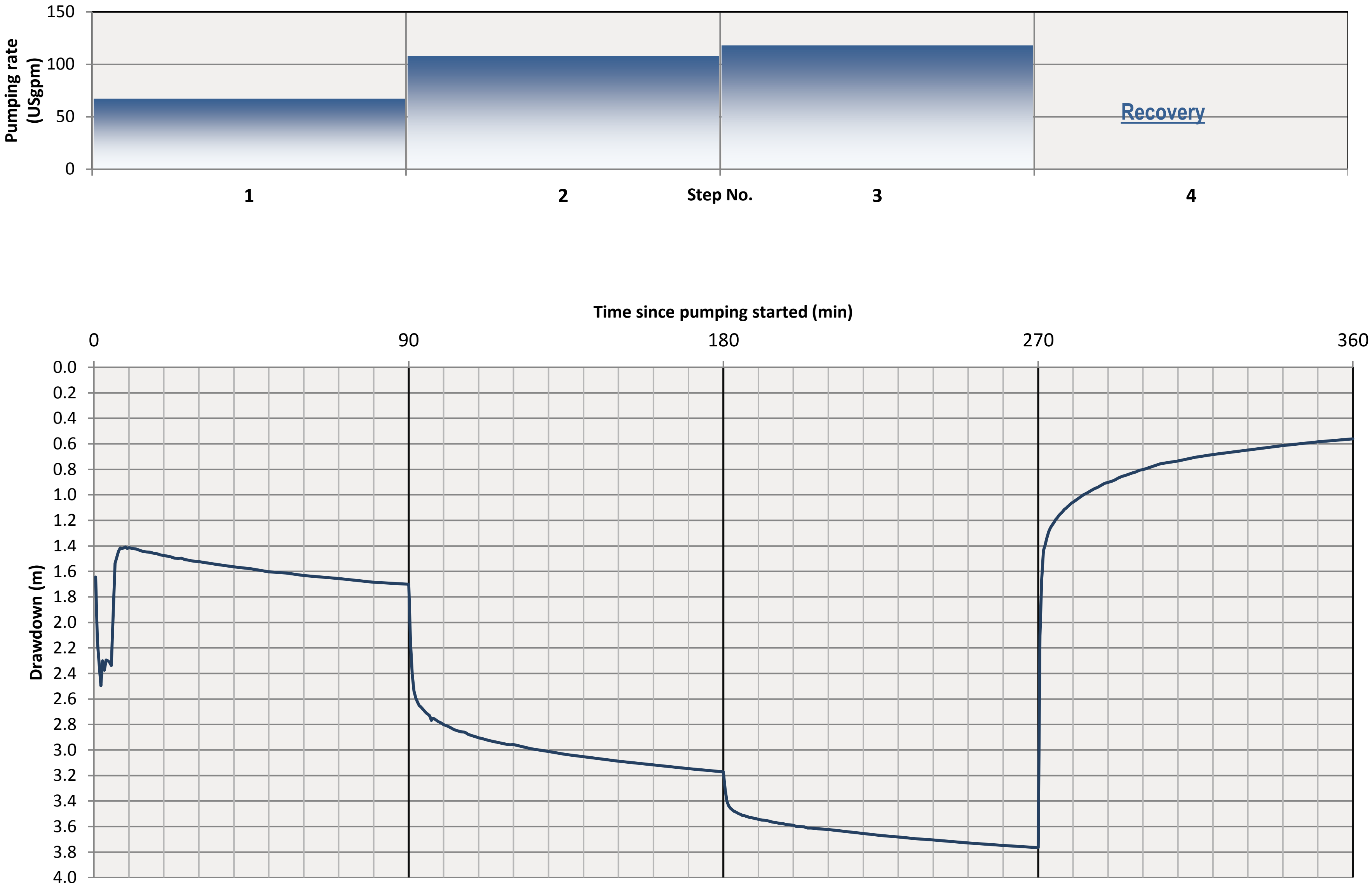
APPENDIX C

Pumping Tests at ASR-1

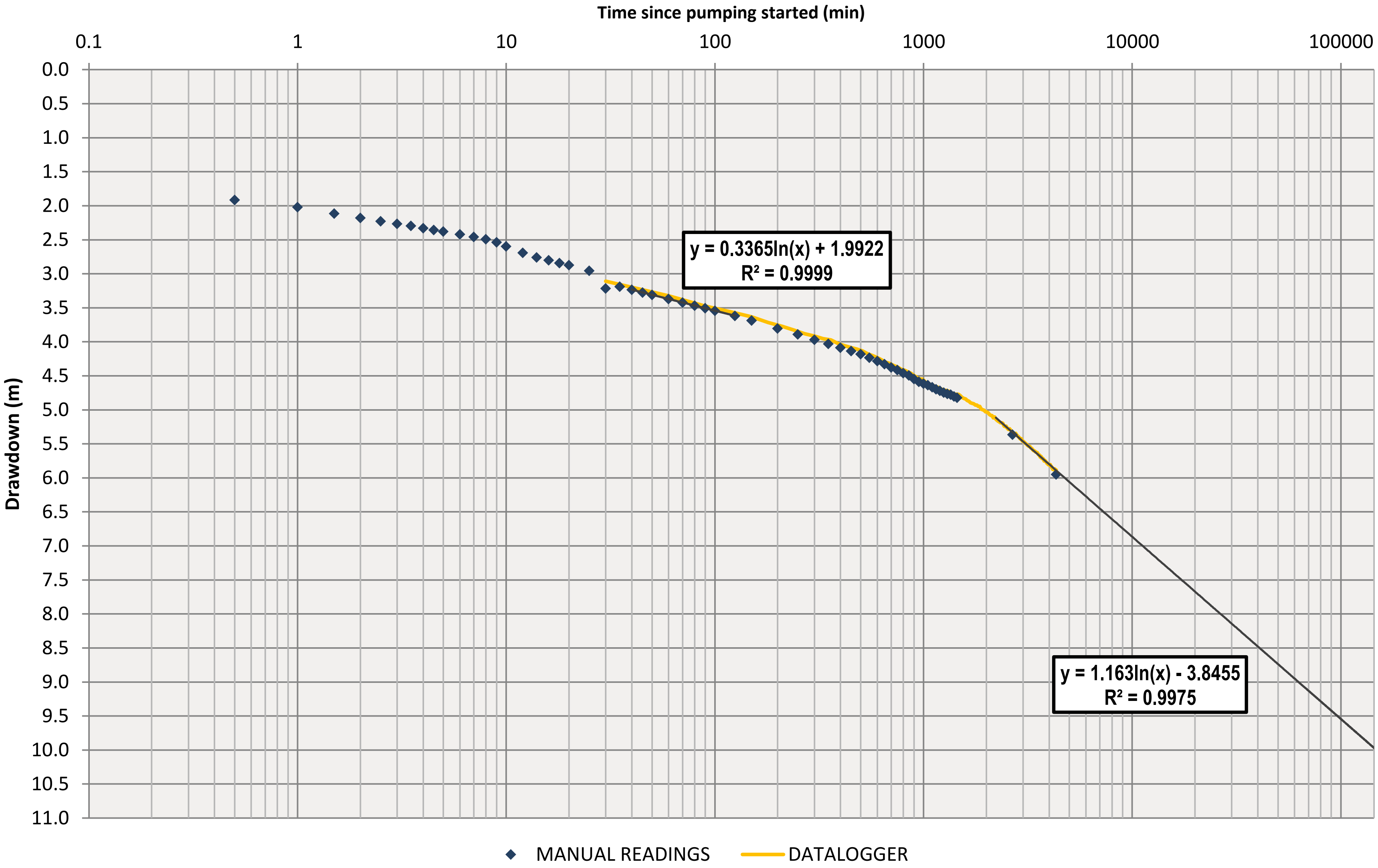
Graph C1 - Pre-Pumping Tests at ASR-1 (during development)



Graph C2 - Step-Test at ASR-1



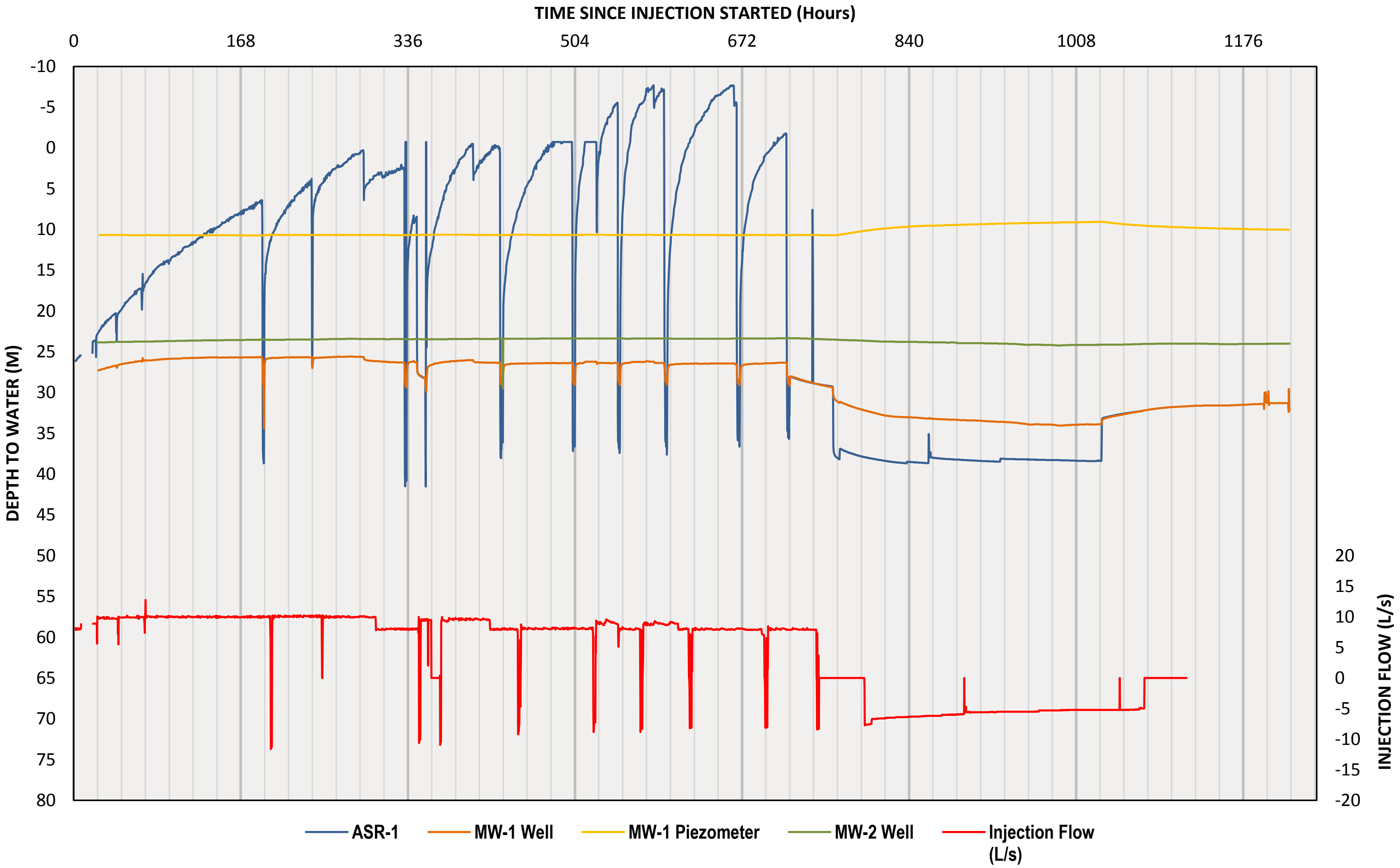
Graph C3 - 3-day Pumping Test at ASR-1



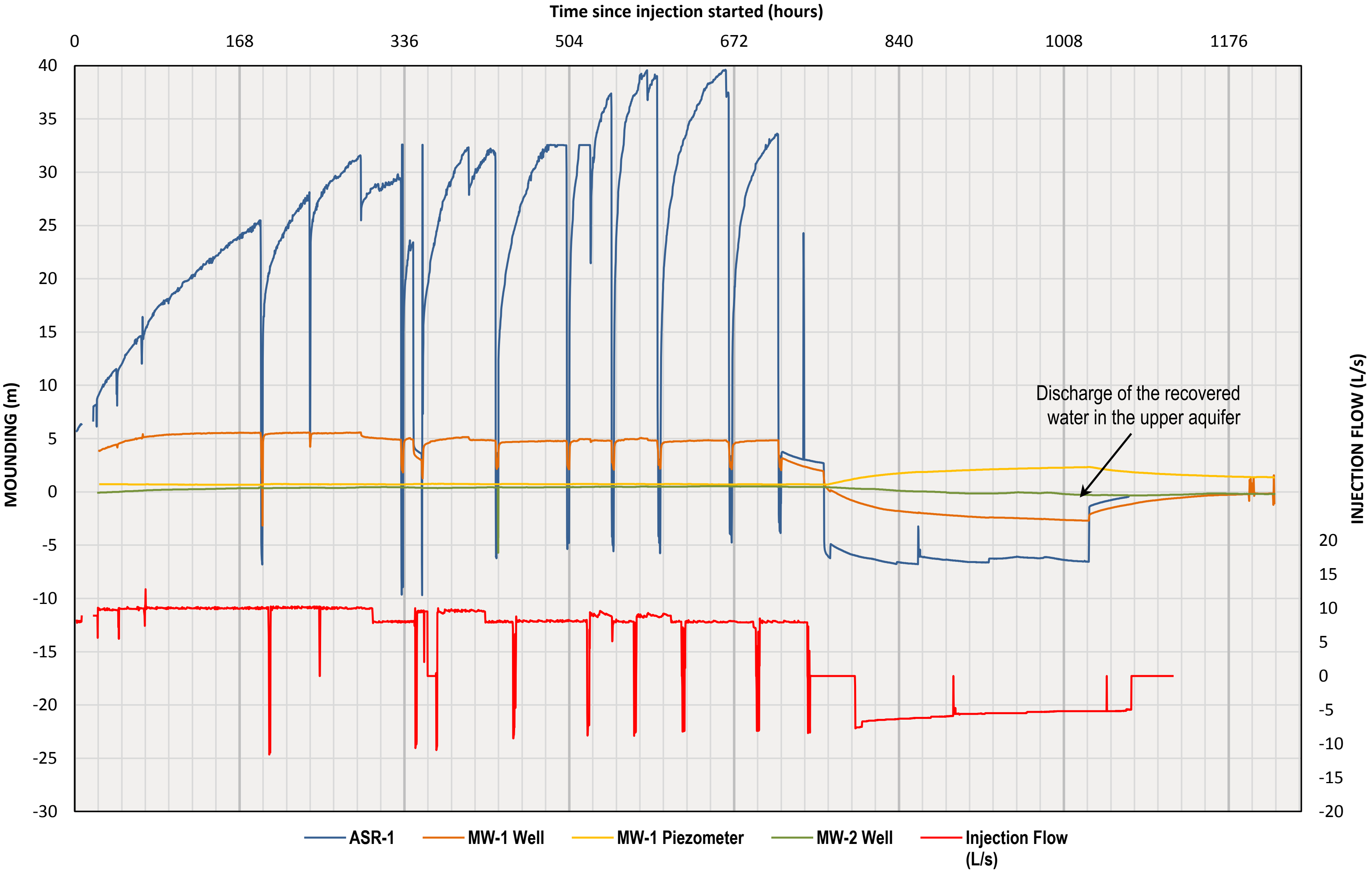
APPENDIX D

Graphs Cycle Test 1

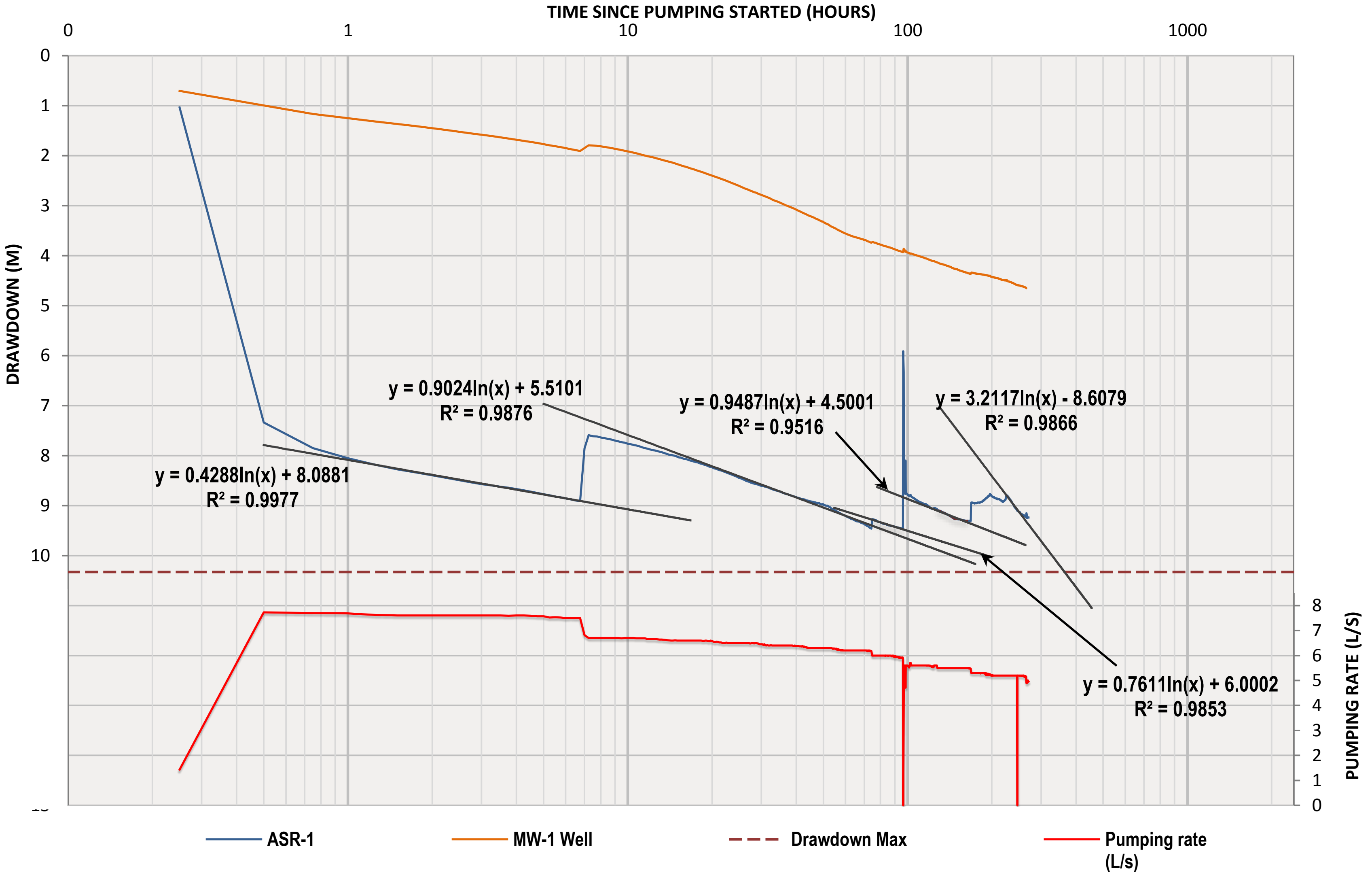
Graph D1 - Evolution of water levels under injection / production



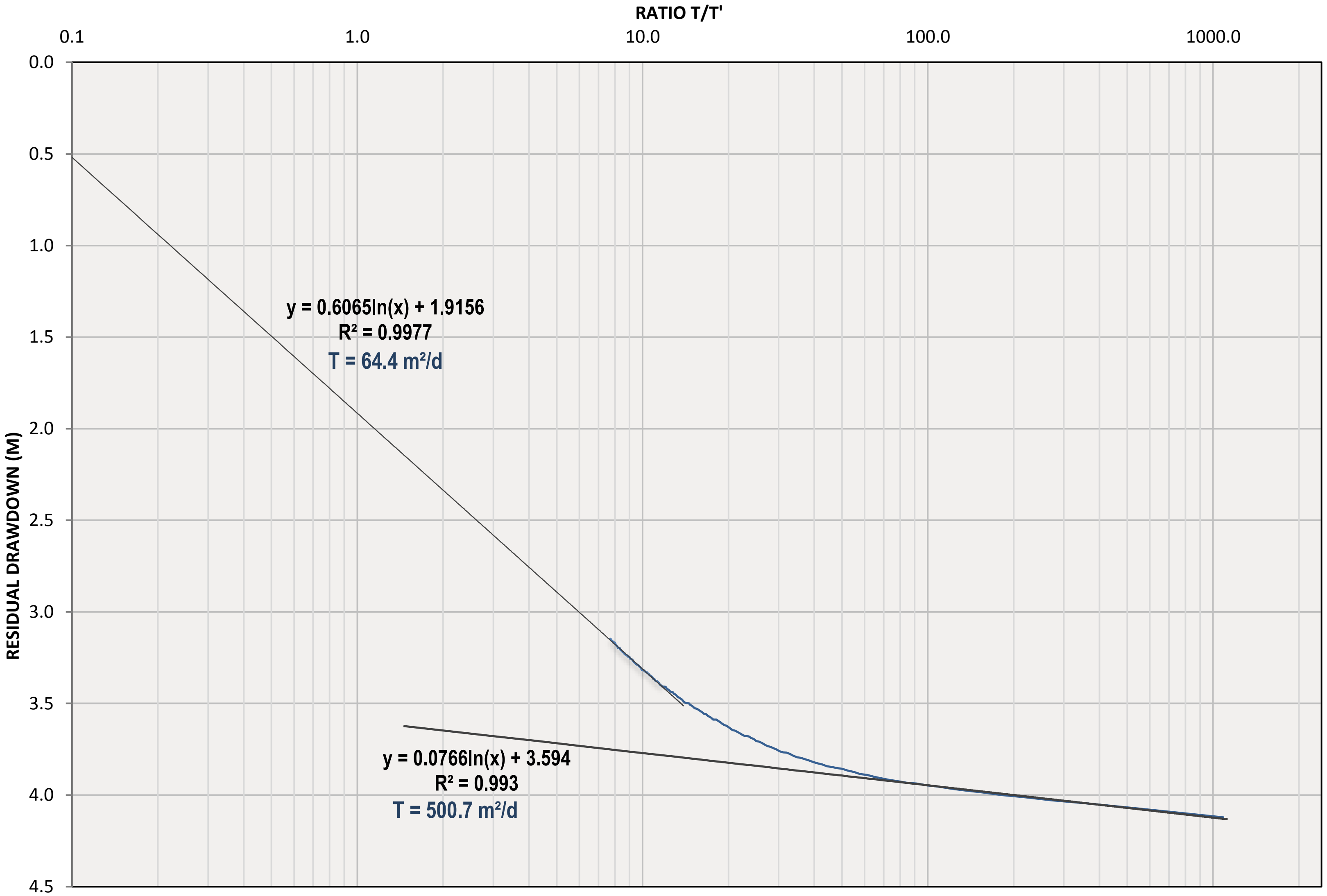
Graph D2 - Evolution of water moundings under injection / production



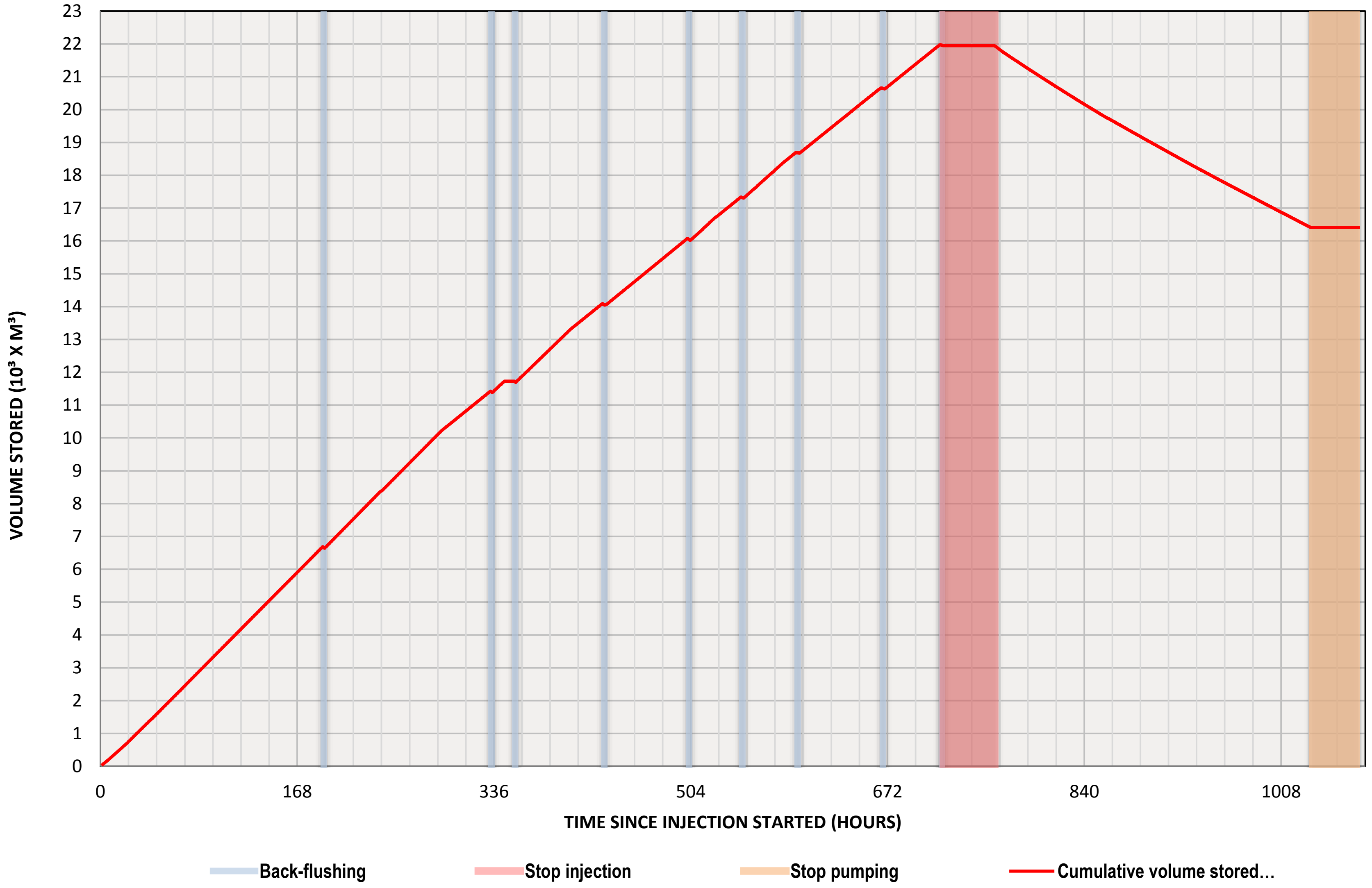
Graph D3 - Evolution of the drawdown during the pumping phase



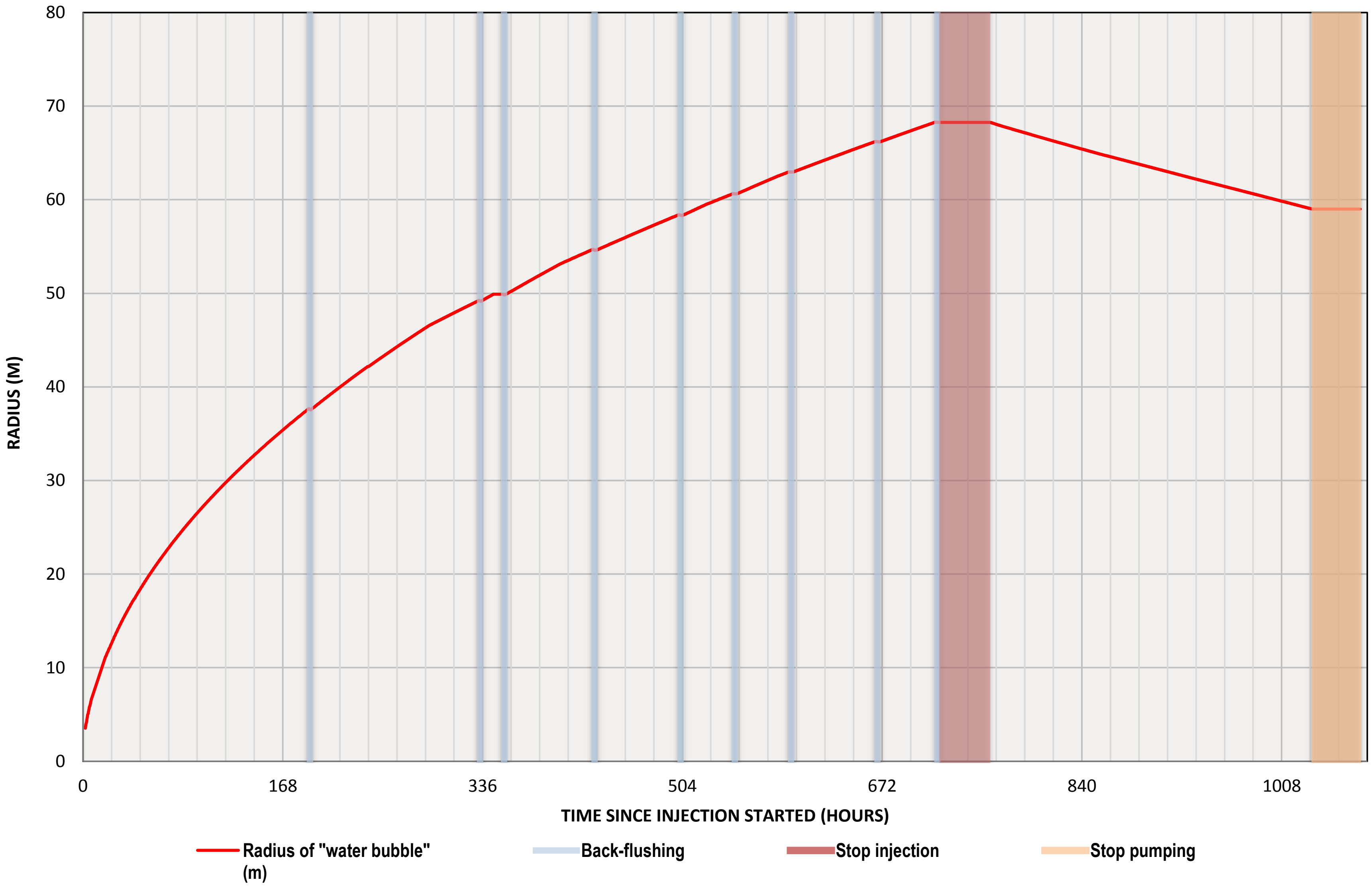
Graph D4 - Recovery at ASR-1 (End of Cycle 1)



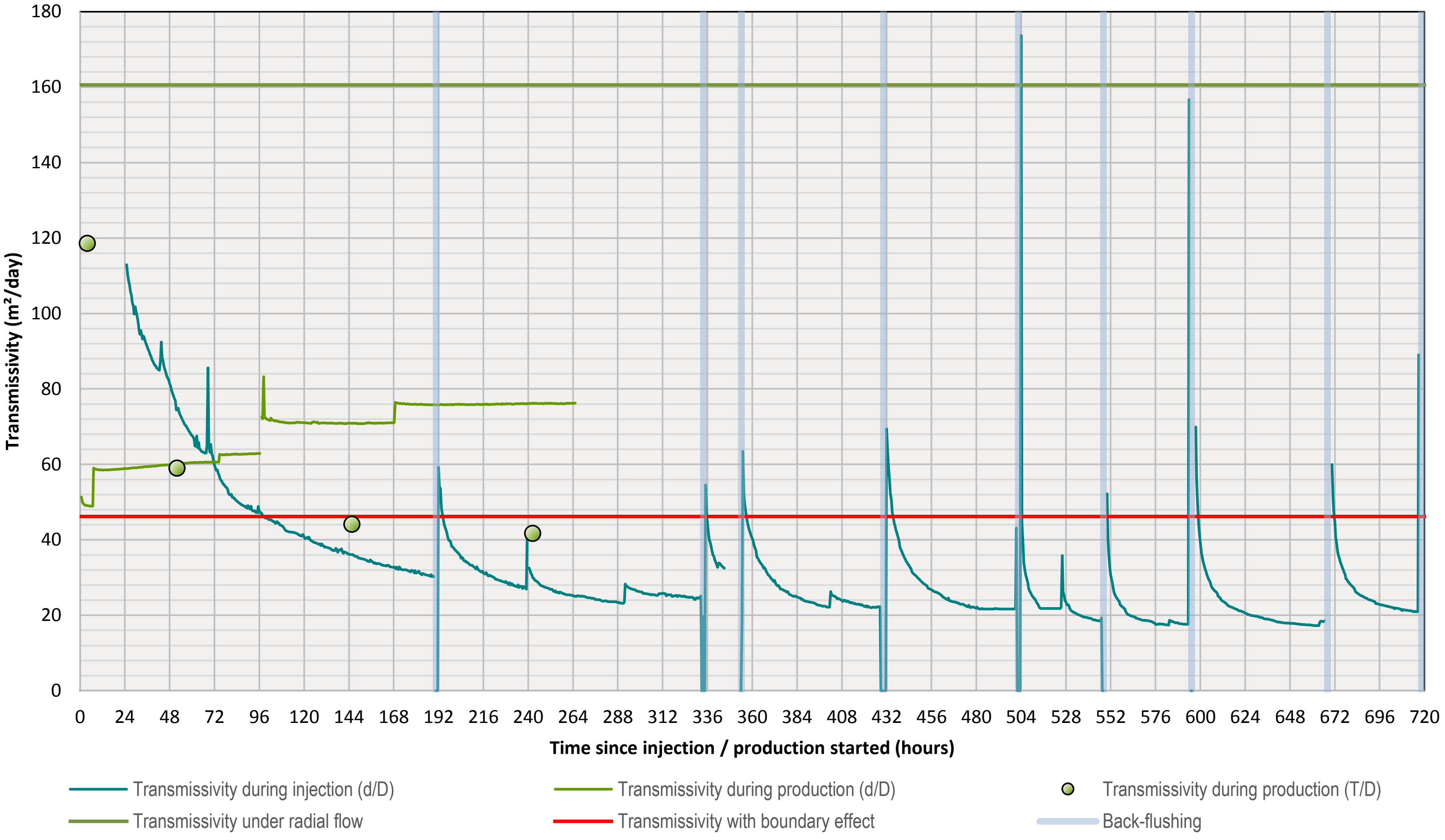
Graph D5 - Cumulative water volume stored



Graph D6 - Theoretical extent of the water bubble



Graph D7 - Evolution of the transmissivity during injection and production



Transmissivity under radial flow = **160.6 m^2/d** ; Transmissivity with boundary effect = **46.2 m^2/d** (see section 5.3)
d/D = Distance / Drawdown Method; **T/D** = Time /Drawdown Method

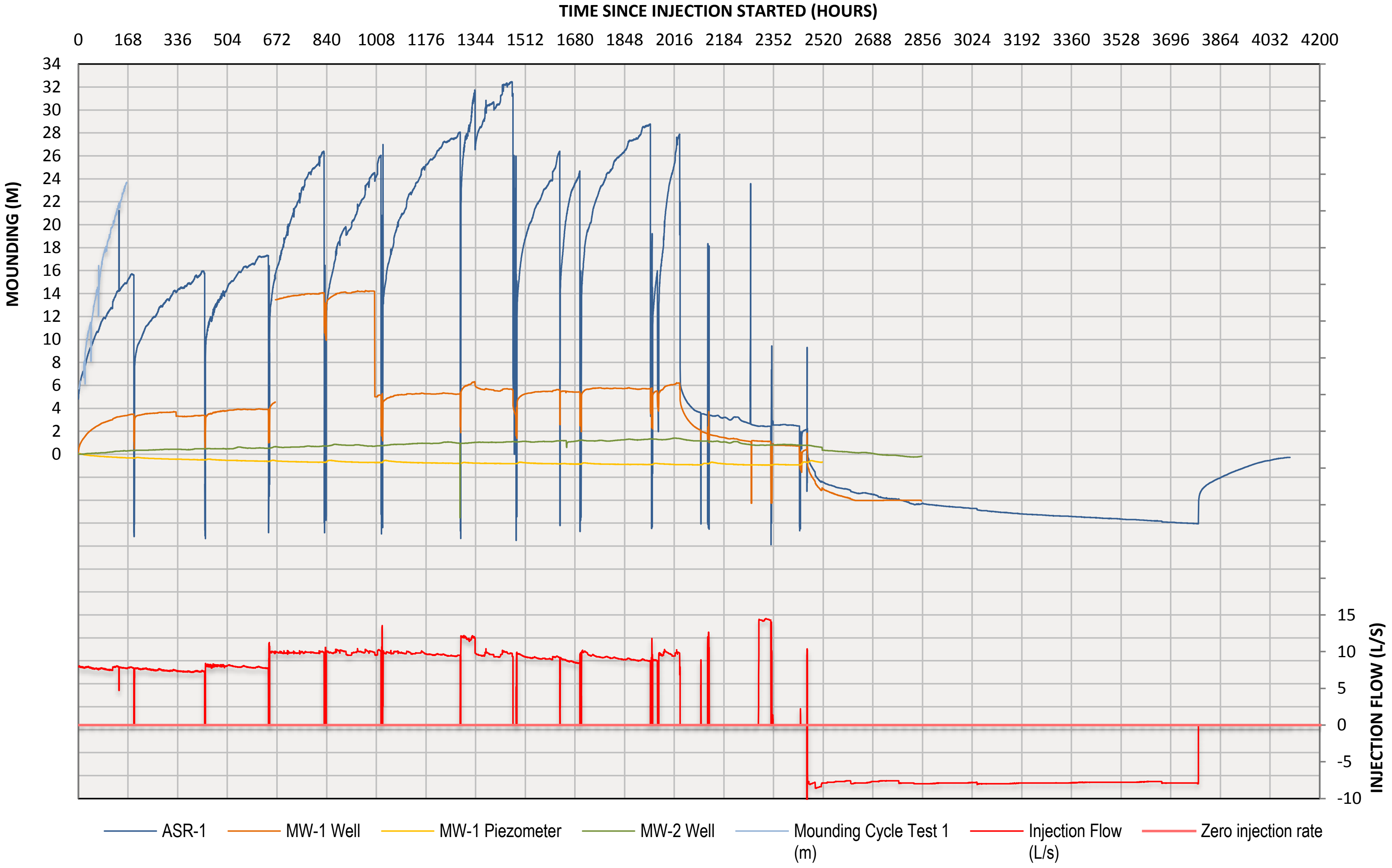
APPENDIX E

Graphs Cycle Test 2

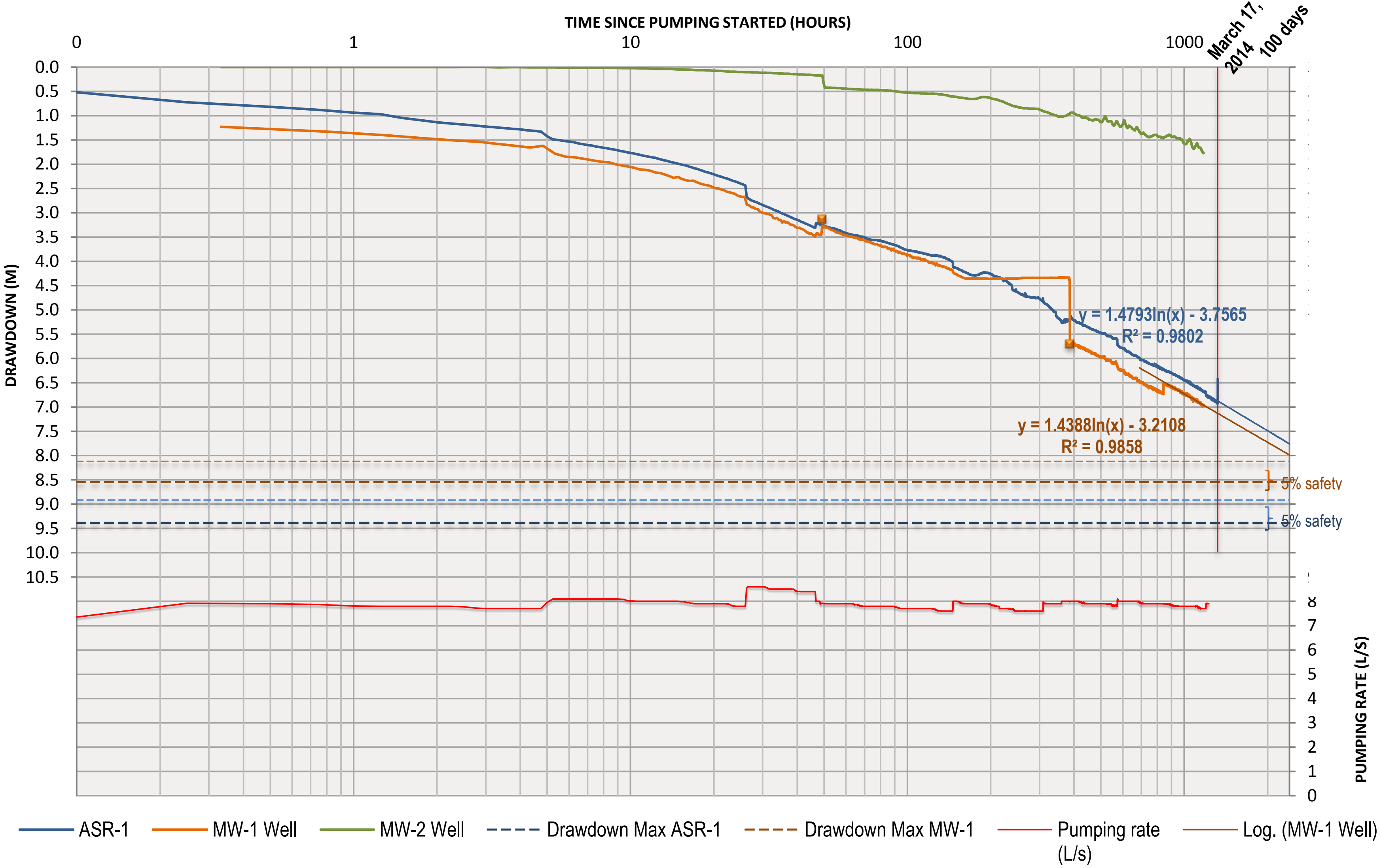
Graph E1 - Evolution of water levels under injection / production

Square points are manual readings. The dashed portion of the MW-1 curve between 2688 and 2856 is due to dewatering of the datalogger.

Graph E2 - Evolution of water moundings under injection / production

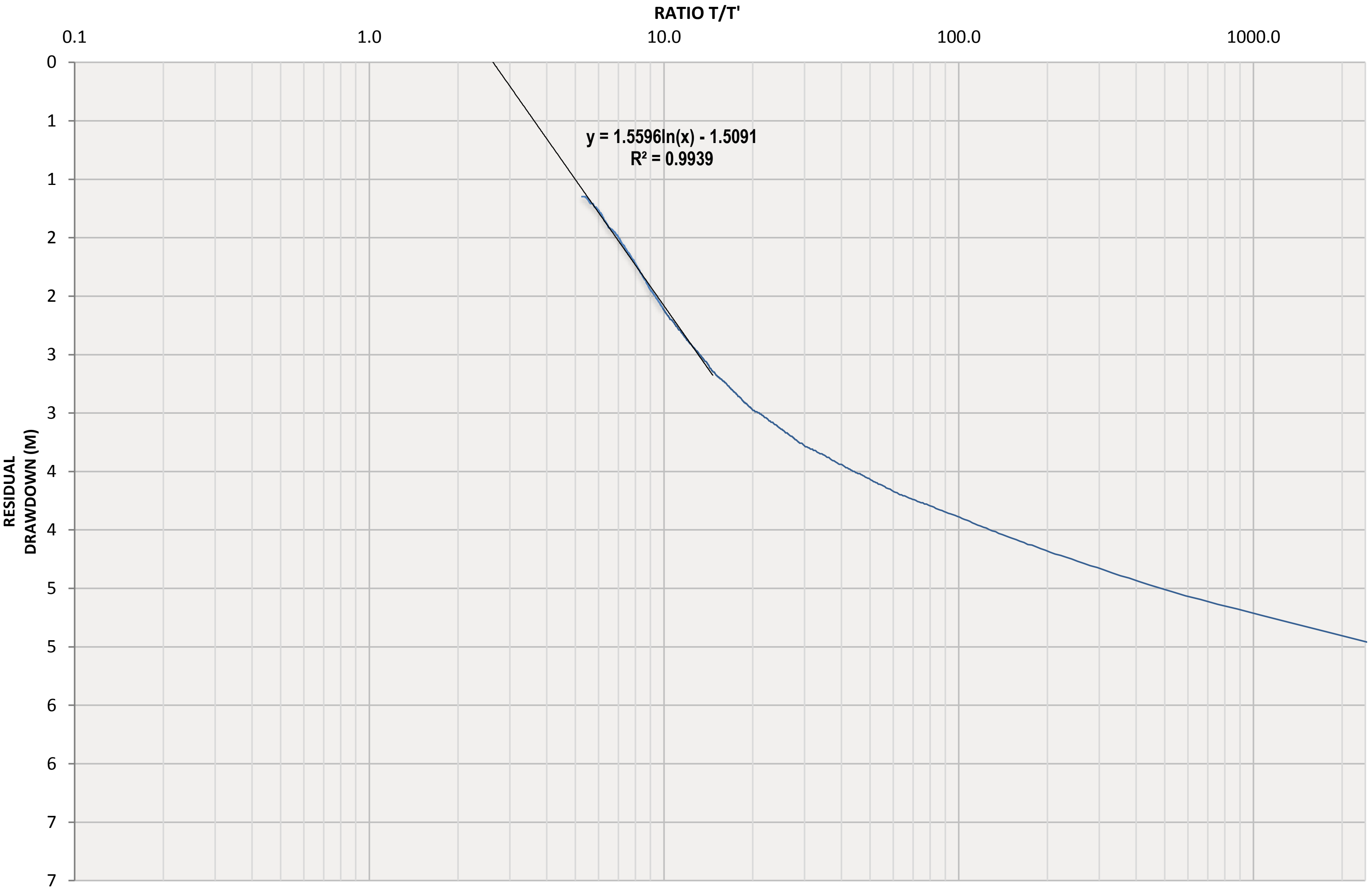


Graph E3 - Evolution of the drawdown during the pumping phase

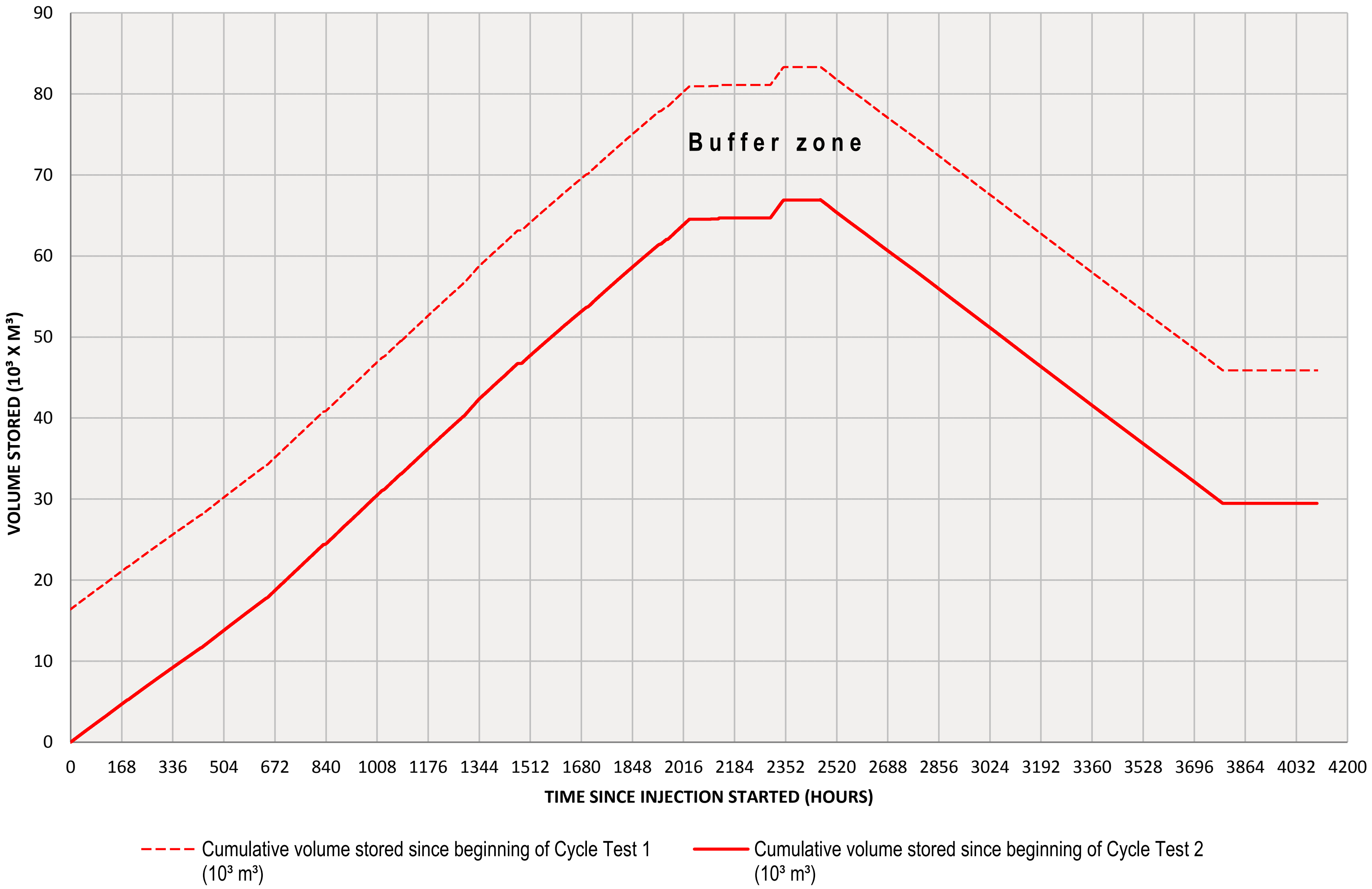


The flat portion of the MW-1 curve is due to dewatering of the datalogger. Data is backed up with manual reading (square dots).

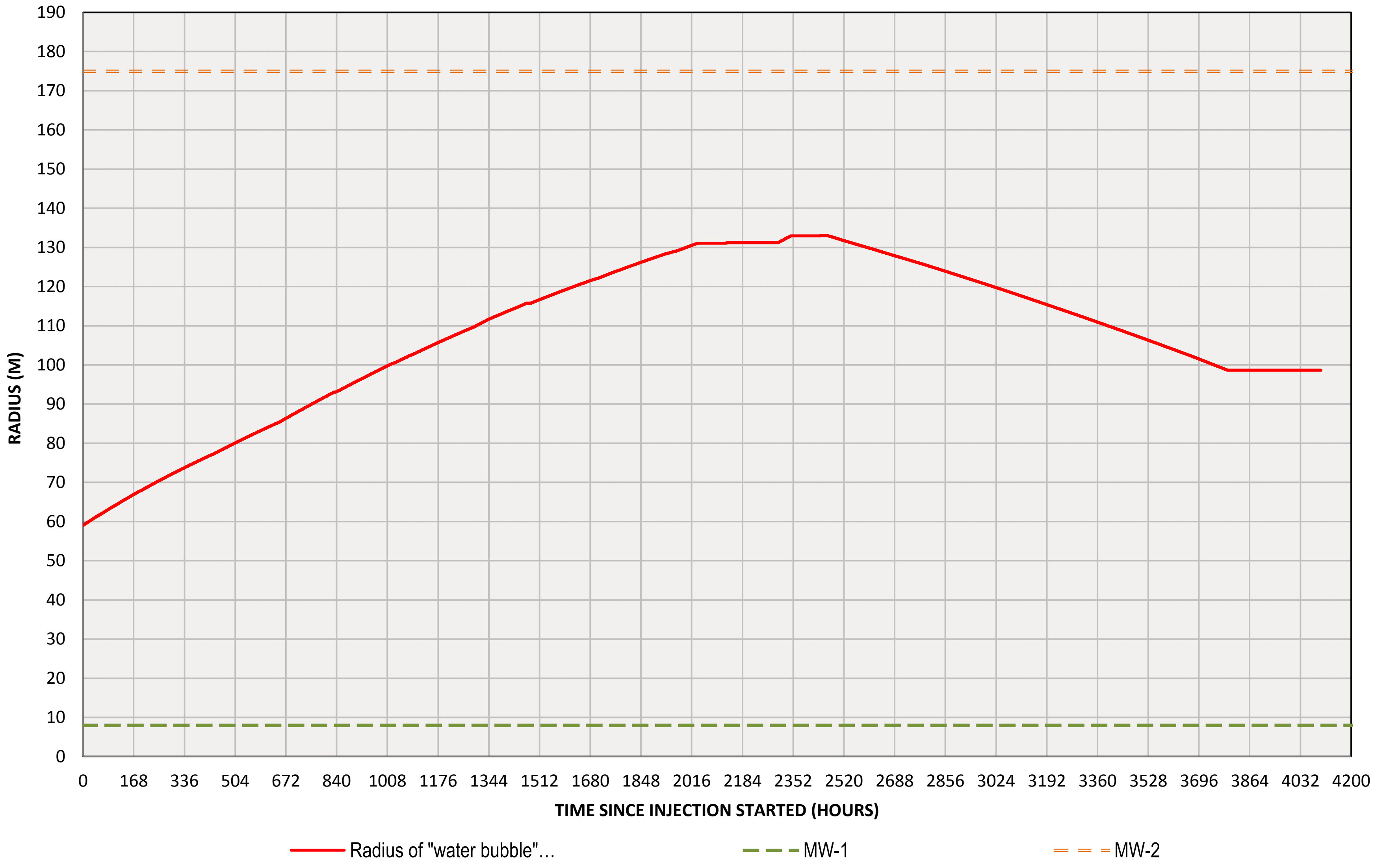
Graph E4 - Recovery at ASR-1 (end of Cycle Test 2)



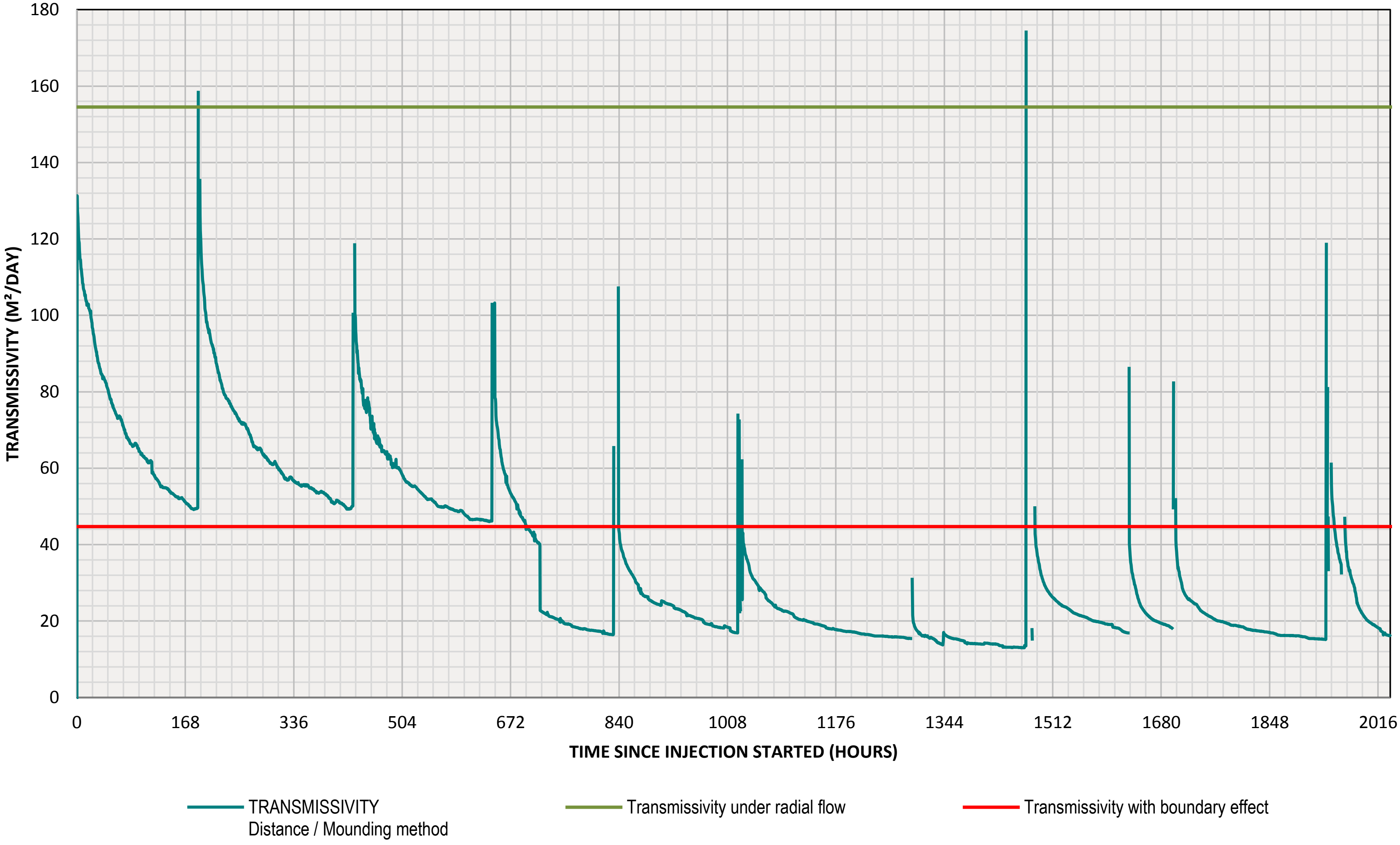
Graph E5 - Cumulative water volume stored



Graph E6 - Theoretical extent of the water bubble



Graph E7 - Evolution of the transmissivity during injection



APPENDIX F

Water Chemistry Monitoring Results

Item 1: Water Sampling Programs

PROGRAM 1: On-site measures

- Temperature
- Conductivity
- pH
- Eh
- Total Dissolved Solids
- Dissolved oxygen
- Turbidity
- Salinity
- Residual chlorine

PROGRAM 2: Partial laboratory analysis

- Alkalinity (speciated)
- Ammonia (N)
- Bicarbonate
- Carbonate
- Color
- Conductivity
- Dissolved chloride (Cl^-)
- Dissolved fluoride (F^-)
- Dissolved nitrate (N)
- Dissolved sulphate (SO_4^{2-})
- pH
- Silica (SiO_2)
- Sulphide (S)
- Total Dissolved Solids
- Total Suspended Solids *(only during injection)*
- Total hardness ($CaCO_3$) – (speciated)
- Total metals

PROGRAM 3: Full laboratory analysis

- Alkalinity (speciated)
- Ammonia (N)
- Bicarbonate
- Carbonate
- Color
- Conductivity
- Dissolved chloride (Cl^-)
- Dissolved fluoride (F^-)
- Dissolved hardness ($CaCO_3$)
- Dissolved nitrate (N)
- Dissolved nitrite (N)
- Dissolved organic carbon (C)
- Dissolved orthophosphate (P)
- Dissolved sulphate (SO_4^{2-})
- E.Coli
- Haloacetic acids (HAAs)
- Heterotrophic plate count
- Hydroxide
- Iron bacteria
- Langelier index (@ 4.4C)
- Langelier index (@ 60C)
- Nitrate plus nitrite
- Non-coliform bacteria
- pH
- Residual chlorine
- Salinity
- Saturation pH (@ 4.4C)
- Saturation pH (@ 60C)
- Silica (SiO_2)
- Sulphide (S)
- Sulphur bacteria
- Total coliform
- Total Dissolved Solids
- Total hardness ($CaCO_3$) (speciated)
- Total metals
- Total nitrogen (N)
- Total phosphorus (P)
- Total Suspended Solids
- Trihalomethanes (THMs)
- Turbidity
- 2,3,4,6-Tetrachlorophenol
- 2,4,6-Trichlorophenol
- 2,4-Dichlorophenol
- N-Nitrous Dimethylamine (NDMA)
- Pentachlorophenol

Item 2: Water Sampling Schedule

Before Cycle Testing

	ASR-1	MW-1	MW-2
Program 1		1 sample	1 sample
Program 2	1 sample		
Program 3	1 sample	2 samples	1 sample
Other	-	-	-

Cycle Test 1 - Injection

	ASR-1	MW-1	MW-2
Program 1	19 samples 6 back-flush sample	20 samples	7 samples
Program 2	1 sample 20.08.13	-	-
Program 3	-	-	-
Other	-	-	-

Cycle Test 1 - Production

	ASR-1	MW-1	MW-2
Program 1	2 samples	2 samples	1 sample
Program 2	2 samples	-	-
Program 3	-	-	-
Other			

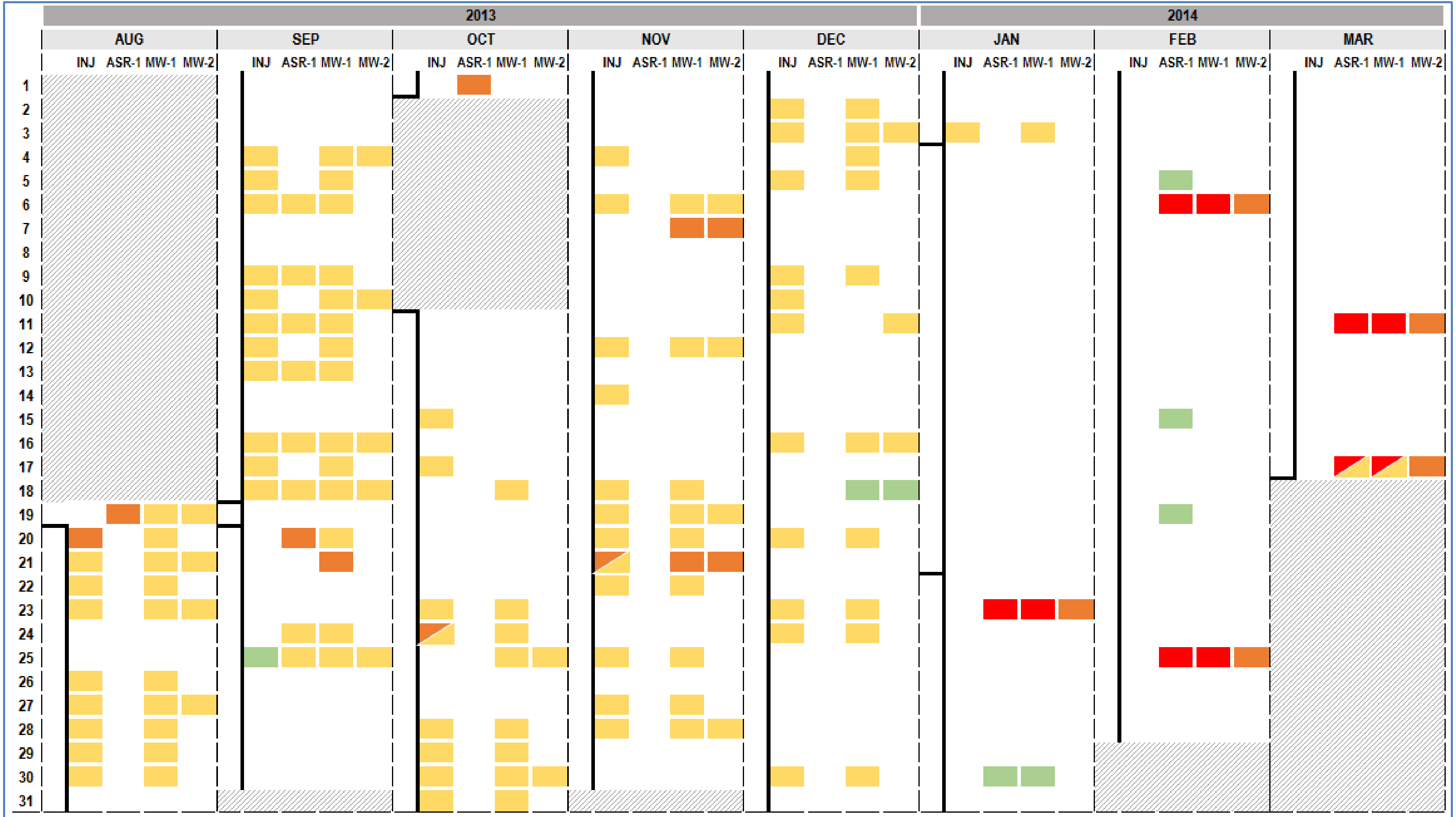
Cycle Test 2 - Injection

	ASR-1	MW-1	MW-2
Program 1	32 samples	28 samples	9 samples
Program 2	2 samples	2 samples	2 samples
Program 3	-	-	-
Other	-	1 sample	1 sample

Cycle Test 2 - Production

	ASR-1	MW-1	MW-2
Program 1	5 samples	2 samples	-
Program 2	-	-	5 samples
Program 3	5 samples	5 samples	-
Other	4 samples	1 sample	-

Record of Sampling Type and Dates



	2013															
	AUG				SEP				OCT				NOV			
	INJ	ASR-1	MW-1	MW-2	INJ	ASR-1	MW-1	MW-2	INJ	ASR-1	MW-1	MW-2	INJ	ASR-1	MW-1	MW-2
1	▨	▨	▨	▨						🟧						
2	▨	▨	▨	▨					▨	▨	▨	▨				
3	▨	▨	▨	▨					▨	▨	▨	▨				
4	▨	▨	▨	▨	🟨		🟨	🟨	▨	▨	▨	▨	🟨			
5	▨	▨	▨	▨	🟨		🟨		▨	▨	▨	▨				
6	▨	▨	▨	▨	🟨	🟨	🟨		▨	▨	▨	▨	🟨		🟨	🟨
7	▨	▨	▨	▨					▨	▨	▨	▨			🟧	🟧
8	▨	▨	▨	▨					▨	▨	▨	▨				
9	▨	▨	▨	▨	🟨	🟨	🟨		▨	▨	▨	▨				
10	▨	▨	▨	▨	🟨		🟨	🟨	▨	▨	▨	▨				
11	▨	▨	▨	▨	🟨	🟨	🟨									
12	▨	▨	▨	▨	🟨		🟨						🟨		🟨	🟨
13	▨	▨	▨	▨	🟨	🟨	🟨									
14	▨	▨	▨	▨									🟨			
15	▨	▨	▨	▨					🟨							
16	▨	▨	▨	▨	🟨	🟨	🟨	🟨								
17	▨	▨	▨	▨	🟨		🟨		🟨							
18	▨	▨	▨	▨	🟨	🟨	🟨	🟨			🟨		🟨		🟨	
19		🟧	🟨	🟨									🟨		🟨	🟨
20	🟧		🟨			🟧	🟨						🟨		🟨	
21	🟨		🟨	🟨			🟧						🟧/🟨		🟧	🟧
22	🟨		🟨										🟨		🟨	
23	🟨		🟨	🟨					🟨		🟨					
24						🟨	🟨		🟧/🟨		🟨					
25					🟩	🟨	🟨	🟨			🟨	🟨	🟨		🟨	
26	🟨		🟨													
27	🟨		🟨	🟨									🟨		🟨	
28	🟨		🟨						🟨		🟨		🟨		🟨	🟨
29	🟨		🟨						🟨		🟨					
30	🟨		🟨						🟨		🟨	🟨				
31					▨	▨	▨	▨	🟨		🟨		▨	▨	▨	▨

	2013				2014											
	DEC				JAN				FEB				MAR			
	INJ	ASR-1	MW-1	MW-2	INJ	ASR-1	MW-1	MW-2	INJ	ASR-1	MW-1	MW-2	INJ	ASR-1	MW-1	MW-2
1																
2	🟨		🟨													
3	🟨		🟨	🟨	🟨		🟨									
4			🟨													
5	🟨		🟨							🟩						
6										🟥	🟥	🟧				
7																
8																
9	🟨		🟨													
10	🟨															
11	🟨			🟨										🟥	🟥	🟧
12																
13																
14																
15										🟩						
16	🟨		🟨	🟨												
17														🟥/🟨	🟥/🟨	🟧
18			🟩	🟩									▨	▨	▨	▨
19										🟩			▨	▨	▨	▨
20	🟨		🟨										▨	▨	▨	▨
21													▨	▨	▨	▨
22													▨	▨	▨	▨
23	🟨		🟨			🟥	🟥	🟧					▨	▨	▨	▨
24	🟨		🟨										▨	▨	▨	▨
25										🟥	🟥	🟧	▨	▨	▨	▨
26													▨	▨	▨	▨
27													▨	▨	▨	▨
28													▨	▨	▨	▨
29									▨	▨	▨	▨	▨	▨	▨	▨
30	🟨		🟨			🟩	🟩		▨	▨	▨	▨	▨	▨	▨	▨
31									▨	▨	▨	▨	▨	▨	▨	▨

🟨 Program 1
🟧 Program 2
🟥 Program 3
🟩 Other program

Item 3: Measure of some water parameters in recovered water from ASR-1 and MW-1 (March 17, 2014)

Method of measuring:

Measurements were taken with a YSI water testing meter complete with a flow-through cell which is critical for obtaining accurate dissolved oxygen readings. The readings were taken after one hour so the parameters could stabilize.

		ASR-1			
	Time:	**1:15**	**1:20**	**1:25**	**1:37**
Temperature	**°C**	9.79	9.83	9.83	10.00
Conductivity	**µS/cm**	295	295	295	285
TDS	**mg/L**	270	270	270	260
Salinity	**ppt**	0.20	0.20	0.20	0.19
Dissolved oxygen	**%**	0.00	0.00	0.00	0.8
Dissolved oxygen	**mg/L**	0.02	0.02	0.00	0.09
pH		8.08	8.08	8.08	8.17
ORP	**mV**	-	-71.7	-72.8	-65.0

		MW-1			
	Time:	**1:43**	**1:47**	**1:52**	
Temperature	**°C**	9.98	9.93	10.0	
Conductivity	**µS/cm**	284	284	285	
TDS	**mg/L**	260	259	260	
Salinity	**ppt**	0.19	0.19	0.19	
Dissolved oxygen	**%**	0.10	0.00	0.20	
Dissolved oxygen	**mg/L**	0.01	0.00	0.02	
pH		8.17	8.17	8.16	
ORP	**mV**	-97.8	-110.8	-117.1	

Item 4 : Laboratory and Field Chemistry Testing

4.1:

Englishman River

or

Parksville Well Water

Injected Water

ENGLISHMAN RIVER or PARKSVILLE WELL WATER : INJECTED WATER

Program No.:			2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Date (dd.mm.yy):			20.08.13	20.08.13	21.08.13	22.08.13	23.08.13	26.08.13	27.08.13	28.08.13	29.08.13	30.08.13	04.09.13	05.09.13	06.09.13	09.09.13	10.09.13	11.09.13	12.09.13	13.09.13	16.09.13	17.09.13
			Beginning of cycle test 1								River station off-line: mix of surface and groundwater											
PHYSICAL PARAMETERS	Unit	Standard																				
Water temperature	°C	15		18.87	18.13	18.86	18.08	19.55	17.71	18.00	17.20	17.4	17.6	16.8	17.2	17.3	16.5	19.8	16.6	18.8	16.6	16.5
Conductivity	µS/cm			80	79	82	79	102	82	92	92	96	145	139	129	150	113	113	110	106	119	203
pH	pH units	6.5 - 8.5		6.51	6.65	7.22	6.65	7.00	6.80	7.24	7.32	7.33	7.18	6.99	7.08	7.02	6.99	6.93	7.01	6.90	6.95	7.05
Eh (Reducing Potential)	mV			666.7	679.2	625.7	656.4	207.8	645.0	530.4	527.3	430.6	528.5	618.8	496.6	528.2	552.6	634.5	521.3	600.5	641.9	607.1
Total dissolved solids	mg/L	500	34	59.0	59.0	60.0	59.0	74.0	62.0	43.0	44.0	45.0	69.0	66.0	61.0	54.3	53.2	53.1	52.1	50.1	56	96.6
Total suspended solids	mg/L		BDL																			
Colour	Col. Unit	15	5.0																			
Corrosiveness																						
Dissolved oxygen	mg/L			7.98	8.14	8.33	8.80	8.44	7.51	9.00	9.03	8.94	8.12	8.12	8.24	9.07	8.46	8.36	8.52	8.32	8.48	9.11
Dissolved oxygen	%			86.1	86.4	91.6	92.8	94.0	96.3	94.8	94.7	93.4	85.6	83.4	85.7	94.7	87.0	94.5	88	89.8	87.7	93.5
Turbidity	NTU		0.4															0.75	0.62	0.65	0.64	0.62
Salinity	ppt	0.5		0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.10
Langelier Index (@ 4.4C)	-																					
Langelier Index (@ 60C)	-																					
Saturation pH (@ 4.4C)	-																					
Saturation pH (@ 60C)	-																					
INORGANICS																						
Alkalinity (total as CaCO3)	mg/L		22.9																			
Alkalinity (PP as CaCO3)	mg/L		BDL																			
Total Hardness (CaCO3)	mg/L		33.6																			
Dissolved Hardness (CaCO3)	mg/L		32.7																			
Bicarbonate (HCO3)	mg/L		27.9																			
Carbonate (CO3)	mg/L		BDL																			
Silica (SiO2)	mg/L		4.56																			
Hydroxide (HO)	mg/L		BDL																			
Chlorine (Cl)	mg/L				0.19	0.10		0.11	0.09	0.06	0.00	0.03	0.08	0.04	0.12	0.08	0.08	0.18	0.30	0.18	0.14	0.09
Dissolved Chloride (Cl-)	mg/L	250	13.6																			
Dissolved Fluoride (F)	mg/L	1.5																				
Dissolved Orthophosphate (P)	mg/L		BDL																			
Dissolved Sulphate (SO4)	mg/L	500	2.14																			
Sulphide (S)	mg/L	0.05																				
NUTRIENTS																						
Ammonia (N)	mg/L		0.024																			
Dissolved Nitrate (N)	mg/L	10	0.054																			
Dissolved Nitrite (N)	mg/L	1																				
Nitrate plus nitrite (N)	mg/L																					
Total Organic Nitrogen (N)	mg/L																					
Total Nitrogen (N)	mg/L																					
Total Phosphorus (P)	mg/L		BDL																			
Dissolved Phosphorus (P)	mg/L																					
Total Organic Carbon (C)	mg/L																					
Dissolved Organic Carbon (C)	mg/L																					
MICROBIOLOGY																						
Total Coliform	MPN100ml	0																				
Non-coliform bacterial	MPN100ml																					
Iron bacteria	CFU/ml																					
Sulphur bacteria	CFU/ml																					
Heterotrophic Plate Count	CFU/ml																					
Escherichia coli	MPN100ml	0																				

ENGLISHMAN RIVER or PARKSVILLE WELL WATER : INJECTED WATER

Beginning of cycle test 1

River station off-line: mix of surface and groundwater

		Program No.:	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Date (dd.mm.yy):	20.08.13	20.08.13	21.08.13	22.08.13	23.08.13	26.08.13	27.08.13	28.08.13	29.08.13	30.08.13	04.09.13	05.09.13	06.09.13	09.09.13	10.09.13	11.09.13	12.09.13	13.09.13	16.09.13	17.09.13
TOTAL METALS	Unit	Standard																				
Aluminum (Al)	ug/L		5.8																			
Antimony (Sb)	ug/L	**6**																				
Arsenic (As)	ug/L	**10**																				
Barium (Ba)	ug/L	**1000**																				
Beryllium (Be)	ug/L																					
Bismuth (Bi)	ug/L																					
Boron (B)	ug/L	**5000**																				
Cadmium (Cd)	ug/L	**5**	BDL																			
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	**50**																				
Cobalt (Co)	ug/L																					
Copper (Cu)	ug/L	**1000**	1.22																			
Iron (Fe)	ug/L	**300**	32.5																			
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	**10**																				
Lithium (Li)	ug/L																					
Manganese (Mn)	ug/L	**50**	BDL																			
Mercury (Hg)	ug/L	**1**																				
Molybdenum (Mo)	ug/L																					
Nickel (Ni)	ug/L																					
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	**10**	BDL																			
Silicon (Si)	ug/L																					
Silver (Ag)	ug/L																					
Strontium (Sr)	ug/L																					
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L																					
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L																					
Titanium (Ti)	ug/L																					
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	**20**																				
Vanadium (V)	ug/L																					
Zinc (Zn)	ug/L	**5000**	BDL																			
Zirconium (Zr)	ug/L																					
Calcium (Ca)	mg/L		11.1																			
Magnesium (Mg)	mg/L		1.45																			
Potassium (K)	mg/L		0.168																			
Sodium (Na)	mg/L	**200**	5.09																			
Sulphur (S)	mg/L		BDL																			

ENGLISHMAN RIVER or PARKSVILLE WELL WATER : INJECTED WATER

Program No.:			2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Date (dd.mm.yy):			20.08.13	20.08.13	21.08.13	22.08.13	23.08.13	26.08.13	27.08.13	28.08.13	29.08.13	30.08.13	04.09.13	05.09.13	06.09.13	09.09.13	10.09.13	11.09.13	12.09.13	13.09.13	16.09.13	17.09.13
			Beginning of cycle test 1								River station off-line: mix of surface and groundwater											
DISSOLVED METALS	Unit	Standard																				
Aluminum (Al)	ug/L		5.8																			
Antimony (Sb)	ug/L	6																				
Arsenic (As)	ug/L	10	0.11																			
Barium (Ba)	ug/L	1000																				
Beryllium (Be)	ug/L																					
Bismuth (Bi)	ug/L																					
Boron (B)	ug/L	5000																				
Cadmium (Cd)	ug/L	5	BDL																			
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	50																				
Cobalt (Co)	ug/L																					
Copper (Cu)	ug/L	1000	1.22																			
Iron (Fe)	ug/L	300	32.5																			
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	10																				
Lithium (Li)	ug/L																					
Manganese (Mn)	ug/L	50	BDL																			
Mercury (Hg)	ug/L	1																				
Molybdenum	ug/L																					
Nickel (Ni)	ug/L																					
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	10	BDL																			
Silicon (Si)	ug/L																					
Silver (Ag)	ug/L																					
Strontium (Sr)	ug/L																					
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L																					
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L																					
Titanium (Ti)	ug/L																					
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	20																				
Vanadium (V)	ug/L																					
Zinc (Zn)	ug/L	5000	BDL																			
Zirconium (Zr)	ug/L																					
Calcium (Ca)	mg/L		10.8																			
Magnesium (Mg)	mg/L		1.41																			
Potassium (K)	mg/L		0.168																			
Sodium (Na)	mg/L	200	5.09																			
Sulphur (S)	mg/L		BDL																			

ENGLISHMAN RIVER or PARKSVILLE WELL WATER : INJECTED WATER

Program No.:			1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Date (dd.mm.yy):			18.09.13	15.10.13	17.10.13	23.10.13	24.10.13	24.10.13	25.10.13	28.10.13	29.10.13	30.10.13	31.10.13	04.11.13	06.11.13	12.11.13	14.11.13	18.11.13	19.11.13	20.11.13	21.11.13	21.11.13
				Beginning of cycle test 2 River station off line: well water																		
PHYSICAL PARAMETERS	Unit	Standard																				
Water temperature	°C	**15**	16.9	14.6	13.8	12.4	12.8			13.6	14.5	13.9	14.0	13.2	11.9	12.2	12.6	11.6	11.6	12.1	10.8	
Conductivity	µS/cm		204	296	294	311	309	315		309	315	305	314	304	298	296	315	320	315	303	309	314
pH	pH units	**6.5 - 8.5**	7.17	7.43	7.44	7.51	7.53	8.00		7.51	7.55	7.52	7.39	7.46	7.46	7.35	7.44	7.50	7.50	7.62	7.69	7.80
Eh (Reducing Potential)	mV		431.9	533.7	575.2	474.8	578.3			554.2	335.8	525.4	550	588.3	562.8	599.1	589.3	380.7	537.9	617	629.4	
Total dissolved solids	mg/L	**500**	96	141.7	140.6	149.1	147	185		148.1	150.7	145.9	150.2	145.5	142.9	141.9	150.7	153.2	151	145	148	205
Total suspended solids	mg/L							BDL														5
Colour	Col. Unit	**15**						5.0														10
Corrosiveness																						
Dissolved oxygen	mg/L		8.64	9.12	8.31	9.6	9.22			8.83	8.48	7.24	7.74	7.49	9.23	7.79	9.08	9.75	10.35	8.47	9.41	
Dissolved oxygen	%		89.5	89.1	80.2	90.2	86.9			84.6	84.1	69.6	74	71.9	78.1	68.7	85.6	95	107	50.5	86	
Turbidity	NTU		0.61	0.85	0.61	0.35	0.58	BDL		1.39	0.94	1.65	0.47	0.48	0.56	0.64	0.55	0.56	0.92	0.66	0.84	0.2
Salinity	ppt	**0.5**	0.1	0.14	0.14	0.15	0.15	0.19		0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.15	0.15	0.15	0.14	0.15	
Langelier Index (@ 4.4C)	-							-0.388														
Langelier Index (@ 60C)	-							0.653														
Saturation pH (@ 4.4C)	-							8.42														
Saturation pH (@ 60C)	-							7.38														
INORGANICS																						
Alkalinity (total as CaCO3)	mg/L							110														122
Alkalinity (PP as CaCO3)	mg/L							BDL														BDL
Total Hardness (CaCO3)	mg/L							139														149
Dissolved Hardness (CaCO3)	mg/L							129														
Bicarbonate (HCO3)	mg/L							134														148
Carbonate (CO3)	mg/L							BDL														BDL
Silica (SiO2)	mg/L							22.5														23.1
Hydroxide (HO)	mg/L							BDL														BDL
Chlorine (Cl)	mg/L		0.08	0.09	0.06	0.16	0.16			0.27	0.01	0.17	0.26	0.18	0.2	0.15	0.14	0.11	0.33	0.32	0.34	
Dissolved Chloride (Cl-)	mg/L	**250**						31.0														29.6
Dissolved Fluoride (F)	mg/L	**1.5**						2.17														0.063
Dissolved Orthophosphate (P)	mg/L							BDL														
Dissolved Sulphate (SO4)	mg/L	**500**						7.12														7.14
Sulphide (S)	mg/L	**0.05**						0.0064														
NUTRIENTS																						
Ammonia (N)	mg/L							0.01														BDL
Dissolved Nitrate (N)	mg/L	**10**																				0.795
Dissolved Nitrite (N)	mg/L	**1**						BDL														
Nitrate plus nitrite (N)	mg/L							0.93														
Total Organic Nitrogen (N)	mg/L							0.119														
Total Nitrogen (N)	mg/L							1.06														
Total Phosphorus (P)	mg/L							0.0098														0.0095
Dissolved Phosphorus (P)	mg/L																					
Total Organic Carbon (C)	mg/L							0.88														
Dissolved Organic Carbon (C)	mg/L							BDL														
MICROBIOLOGY																						
Total Coliform	MPN100ml	**0**																				
Non-coliform bacterial	MPN100ml																					
Iron bacteria	CFU/ml																					
Sulphur bacteria	CFU/ml																					
Heterotrophic Plate Count	CFU/ml																					
Escherichia coli	MPN100ml	**0**																				

ENGLISHMAN RIVER or PARKSVILLE WELL WATER : INJECTED WATER

Beginning of cycle test 2
River station off line: well water

Program No.:			1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Date (dd.mm.yy):			18.09.13	15.10.13	17.10.13	23.10.13	24.10.13	24.10.13	25.10.13	28.10.13	29.10.13	30.10.13	31.10.13	04.11.13	06.11.13	12.11.13	14.11.13	18.11.13	19.11.13	20.11.13	21.11.13	21.11.13
TOTAL METALS	Unit	Standard																				
Aluminum (Al)	ug/L							BDL														3.90
Antimony (Sb)	ug/L	6						BDL														BDL
Arsenic (As)	ug/L	10						0.25														0.25
Barium (Ba)	ug/L	1000						11.10														11.10
Beryllium (Be)	ug/L							BDL														BDL
Bismuth (Bi)	ug/L							BDL														BDL
Boron (B)	ug/L	5000						BDL														BDL
Cadmium (Cd)	ug/L	5						BDL														BDL
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	50						BDL														BDL
Cobalt (Co)	ug/L							BDL														BDL
Copper (Cu)	ug/L	1000						1.83														1.17
Iron (Fe)	ug/L	300						11.10														14.40
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	10						BDL														BDL
Lithium (Li)	ug/L							BDL														BDL
Manganese (Mn)	ug/L	50						1.60														2.1
Mercury (Hg)	ug/L	1						BDL														BDL
Molybdenum (Mo)	ug/L							BDL														BDL
Nickel (Ni)	ug/L							BDL														BDL
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	10						0.13														0.16
Silicon (Si)	ug/L							12,500														11,600
Silver (Ag)	ug/L							BDL														BDL
Strontium (Sr)	ug/L							99.0														97.20
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L							BDL														BDL
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L							BDL														BDL
Titanium (Ti)	ug/L							BDL														BDL
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	20						0.18														0.16
Vanadium (V)	ug/L							BDL														
Zinc (Zn)	ug/L	5000						BDL														BDL
Zirconium (Zr)	ug/L							BDL														BDL
Calcium (Ca)	mg/L							31.90	29.30													33.40
Magnesium (Mg)	mg/L							14.40	13.50													16.00
Potassium (K)	mg/L							0.771														0.796
Sodium (Na)	mg/L	200						8.69														9.40
Sulphur (S)	mg/L							BDL														BDL

ENGLISHMAN RIVER or PARKSVILLE WELL WATER : INJECTED WATER

Beginning of cycle test 2
River station off line: well water

Program No.:			1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Date (dd.mm.yy):			18.09.13	15.10.13	17.10.13	23.10.13	24.10.13	24.10.13	25.10.13	28.10.13	29.10.13	30.10.13	31.10.13	04.11.13	06.11.13	12.11.13	14.11.13	18.11.13	19.11.13	20.11.13	21.11.13	21.11.13
DISSOLVED METALS	Unit	Standard																				
Aluminum (Al)	ug/L																					
Antimony (Sb)	ug/L	6																				
Arsenic (As)	ug/L	10					0.24															
Barium (Ba)	ug/L	1000																				
Beryllium (Be)	ug/L																					
Bismuth (Bi)	ug/L																					
Boron (B)	ug/L	5000																				
Cadmium (Cd)	ug/L	5																				
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	50																				
Cobalt (Co)	ug/L																					
Copper (Cu)	ug/L	1000																				
Iron (Fe)	ug/L	300																				
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	10																				
Lithium (Li)	ug/L																					
Manganese (Mn)	ug/L	50					BDL															
Mercury (Hg)	ug/L	1																				
Molybdenum (Mo)	ug/L																					
Nickel (Ni)	ug/L																					
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	10																				
Silicon (Si)	ug/L																					
Silver (Ag)	ug/L																					
Strontium (Sr)	ug/L																					
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L																					
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L																					
Titanium (Ti)	ug/L																					
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	20																				
Vanadium (V)	ug/L																					
Zinc (Zn)	ug/L	5000																				
Zirconium (Zr)	ug/L																					
Calcium (Ca)	mg/L						29.3															
Magnesium (Mg)	mg/L						13.5															
Potassium (K)	mg/L																					
Sodium (Na)	mg/L	200																				
Sulphur (S)	mg/L																					

ENGLISHMAN RIVER or PARKSVILLE WELL WATER : INJECTED WATER

Program No.:			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
Date (dd.mm.yy):			22.11.13	25.11.13	27.11.13	28.11.13	02.12.13	03.12.13	05.12.13	09.12.13	10.12.13	11.12.13	16.12.13	20.12.13	23.12.13	24.12.13	30.12.13	03.01.14				
PHYSICAL PARAMETERS	Unit	Standard																				
Water temperature	°C	**15**	10.4	10.0	10.6	10.4	10.3	10.0	8.9	9.1	9.1	9.0	8.9	7.9	11.3	10.4	9.5	11.4				
Conductivity	µS/cm		301	311	315	316	302	315	312	305	311	318	313	206	303	293	307	303				
pH	pH units	**6.5 -**	7.69	7.66	7.53	7.47	7.33	7.72	7.69	7.76	7.75	7.84	7.89	7.91	7.88	7.95	8.02	8.11				
Eh (Reducing Potential)	mV		600	588.2	600	590.2	526.8	524.1	587.2	465.3	546.4	405.6	433.3	331	347.9	355.8	348.1	344.9				
Total dissolved solids	mg/L	**500**	144	149.9	150.7	151.3	144.5	151	149.3	146.1	149	152.4	150.2	140.6	144.9	140.1	147.1	144.9				
Total suspended solids	mg/L																					
Colour	Col. Unit	**15**																				
Corrosiveness																						
Dissolved oxygen	mg/L		10.45	9.03	8.81	9.32	8.5	10.27	9.16	8.44	9.28	11.09	8.67	8.06	9.3	9.08	9.03	8.92				
Dissolved oxygen	%		92.3	79.4	79.5	83.7	78.1	85.9	78.5	72.7	80.8	101.3	74	70.3	85.1	79.4	81.9	81.8				
Turbidity	NTU		0.46	1.34	0.93	0.76	0.28	0.8	0.9	2.7	1.3	1.5	0.4	0.9	0.7	0.3	0.8	1.1				
Salinity	ppt	**0.5**	0.14	0.15	0.15	0.15	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.15	0.14				
Langelier Index (@ 4.4C)	-																					
Langelier Index (@ 60C)	-																					
Saturation pH (@ 4.4C)	-																					
Saturation pH (@ 60C)	-																					
INORGANICS																						
Alkalinity (total as CaCO3)	mg/L																					
Alkalinity (PP as CaCO3)	mg/L																					
Total Hardness (CaCO3)	mg/L																					
Dissolved Hardness (CaCO3)	mg/L																					
Bicarbonate (HCO3)	mg/L																					
Carbonate (CO3)	mg/L																					
Silica (SiO2)	mg/L																					
Hydroxide (HO)	mg/L																					
Chlorine (Cl)	mg/L		0.24	0.37	0.4	0.32	0.34	0.23	0.33	0.36	0.26	0.29	0.27	0.22	0.32	0.26	0.28	0.25				
Dissolved Chloride (Cl-)	mg/L	**250**																				
Dissolved Fluoride (F)	mg/L	**1.5**																				
Dissolved Orthophosphate (P)	mg/L																					
Dissolved Sulphate (SO4)	mg/L	**500**																				
Sulphide (S)	mg/L	**0.05**																				
NUTRIENTS																						
Ammonia (N)	mg/L																					
Dissolved Nitrate (N)	mg/L	**10**																				
Dissolved Nitrite (N)	mg/L	**1**																				
Nitrate plus nitrite (N)	mg/L																					
Total Organic Nitrogen (N)	mg/L																					
Total Nitrogen (N)	mg/L																					
Total Phosphorus (P)	mg/L																					
Dissolved Phosphorus (P)	mg/L																					
Total Organic Carbon (C)	mg/L																					
Dissolved Organic Carbon (C)	mg/L																					
MICROBIOLOGY																						
Total Coliform	MPN100ml	**0**																				
Non-coliform bacterial	MPN100ml																					
Iron bacteria	CFU/ml																					
Sulphur bacteria	CFU/ml																					
Heterotrophic Plate Count	CFU/ml																					
Escherichia coli	MPN100ml	**0**																				

End of cycle test 2

4.2:

ASR-1

Produced Water

ASR-1 : PRODUCED WATER

Program No.:			2	1	1	1	1	1	1	1	2	1	1	3	3	-	1	-	1	3	1	-
Date (dd.mm.yy):			19.08.13	19.08.13	06.09.13	09.09.13	11.09.13	13.09.13	16.09.13	18.09.13	20.09.13	24.09.13	25.09.13	01.10.13	23.01.14	30.01.14	30.01.14	05.02.14	05.02.14	06.02.14	14.02.14	15.02.14
				Production cycle test 1								End of production cycle test 1			Production cycle test 2							
PHYSICAL PARAMETERS	Unit	Standard																				
Water temperature	°C	15		9.44	17.6	18.5	17.5	17.4	16.8	16.3		15.7	15.3				10.0		10.0		10.0	
Conductivity	µS/cm		562	388	165	158	158	158	166	238	311	248	261	304	412		391	398	421	406	411	412
pH	pH units	6.5 -	8.3	8.14	7.28	7.31	7.31	7.28	7.22	7.27		8.01	7.98	8.00	8.00	8.16	8.40	8.13	8.75	8.00	8.66	8.15
Eh (Reducing Potential)	mV			-84.4	332	305.2	350	312.1	314.1	330.9		229.9	288.6				347.9		28.9		302.4	
Total dissolved solids	mg/L	500	310	359	78.6	76.3	75	74.9	78.7	113.5	197	118.4	124.7	185	258	234	188.1	226	203	226	198	226
Total suspended solids	mg/L														BDL	BDL				BDL		
Colour	Col. Unit	15	10								10			5	BDL	BDL		BDL		6		BDL
Corrosiveness																						
Dissolved oxygen	mg/L			1.77	5.28	5.27	4.48	5.69	2.4	4.4		0.86	0.5				3.63		3.98		5.84	
Dissolved oxygen	%			15.4	55.4	56.3	47	59.6	24.9	44.8		8.7	5				34.2		36.6		61.8	
Turbidity	NTU		12				7.43	7.44	5.85	7.75	0.3	0.63	0.56	0.3	0.2	0.18	0.7	0.17	0.70	0.5	1.60	BDL
Salinity	ppt	0.5		0.27	0.08	0.08	0.07	0.07	0.08	0.11		0.12	0.12		0.25	0.19	0.19		0.20	0.24	0.20	
Langelier Index (@ 4.4C)	-		-0.086											-0.713	-0.16					-0.269		
Langelier Index (@ 60C)	-		0.955											0.328	0.881					0.772		
Saturation pH (@ 4.4C)	-		8.36											8.68	8.19					8.26		
Saturation pH (@ 60C)	-		7.32											7.64	7.15					7.22		
INORGANICS																						
Alkalinity (total as CaCO3)	mg/L		119								60.1			73.2	132	135		132		126		129
Alkalinity (PP as CaCO3)	mg/L		BDL								BDL			BDL	BDL	BDL		BDL		BDL		BDL
Total Hardness (CaCO3)	mg/L		123								128			83.7	158			156		150		142
Dissolved Hardness (CaCO3)	mg/L														173	155				140		
Bicarbonate (HCO3)	mg/L		145								73.3			89.3	161	164		161		154		157
Carbonate (CO3)	mg/L		BDL								BDL			BDL	BDL	BDL		BDL		BDL		BDL
Silica (SiO2)	mg/L										10.6				19.4					18.4		
Hydroxide (HO)	mg/L		BDL								BDL			BDL	BDL	BDL		BDL		BDL		BDL
Chlorine (Cl)	mg/L				0.03	0.07	0.05	0.02	0.06	0.02		0.04	0.03		BDL				0.03		0.09	
Dissolved Chloride (Cl-)	mg/L	250	101											42.3	32			40		41.9		42
Dissolved Fluoride (F)	mg/L	1.5	BDL											0.045	0.061			0.072		0.063		0.066
Dissolved	mg/L										BDL				0.0306					BDL		
Dissolved Sulphate (SO4)	mg/L	500	10.4								23.6			10.1	20.2			15.3		13.6		12.9
Sulphide (S)	mg/L	0.05	0.0227								0.0057				0.0054	BDL		BDL		0.0059		0.0061
NUTRIENTS																						
Ammonia (N)	mg/L		0.5								0.052			0.2	0.051	0.081		0.11		0.11		0.16
Dissolved Nitrate (N)	mg/L	10	BDL								0.086			0.035	BDL	0.009		BDL		BDL		BDL
Dissolved Nitrite (N)	mg/L	1	BDL											BDL	BDL	BDL		BDL		0.037		BDL
Nitrate plus nitrite (N)	mg/L		BDL											0.04	BDL	BDL		BDL		0.04		BDL
Total Organic Nitrogen (N)	mg/L		0.052											0.02	0.072	0.026				0.067		
Total Nitrogen (N)	mg/L		0.553											0.238	0.124	0.117				0.217		
Total Phosphorus (P)	mg/L										0.0163			0.094	0.0294	0.0484				0.0695		
Dissolved Phosphorus (P)	mg/L													5000+	BDL							
Total Organic Carbon (C)	mg/L		1.23											1.22	1.4	1.18				1.57		
Dissolved Organic Carbon (C)	mg/L													0.91	BDL					1.26		
MICROBIOLOGY																						
Total Coliform	MPN100ml	0	9											BDL	BDL	BDL		BDL		BDL		BDL
Non-coliform bacterial	MPN100ml													340	300					1		
Iron bacteria	CFU/ml		35000											35000	2300		9,000 – 14,000			9,000 – 140,000		
Sulphur bacteria	CFU/ml		10000									5,000 – 18,000		BDL	BDL	BDL				5000		
Heterotrophic Plate Count	CFU/ml		230											12	43	43				9		
Escherichia coli	MPN100ml	0	BDL											BDL	BDL	BDL		BDL		BDL		BDL

ASR-1 : PRODUCED WATER

Program No.:			2	1	1	1	1	1	1	1	2	1	1	3	3	-	1	-	1	3	1	-
Date (dd.mm.yy):			19.08.13	19.08.13	06.09.13	09.09.13	11.09.13	13.09.13	16.09.13	18.09.13	20.09.13	24.09.13	25.09.13	01.10.13	23.01.14	30.01.14	30.01.14	05.02.14	05.02.14	06.02.14	14.02.14	15.02.14
				Production cycle test 1									End of production cycle test 1		Production cycle test 2							
TOTAL METALS	Unit	Standard																				
Aluminum (Al)	ug/L		190								7.6			13.2	5.3	5.2		6.2		14		3.4
Antimony (Sb)	ug/L	6	BDL											BDL	BDL	BDL		BDL		BDL		BDL
Arsenic (As)	ug/L	10	3.23											34.8	23.5	35.8		38.5		38.7		39.0
Barium (Ba)	ug/L	1000	44.5											32.8	25	30.7		33		31.6		32.9
Beryllium (Be)	ug/L		BDL											BDL	BDL	BDL				BDL		
Bismuth (Bi)	ug/L		BDL											BDL	BDL	BDL				BDL		
Boron (B)	ug/L	5000	180											113	BDL	56		77		76		86
Cadmium (Cd)	ug/L	5	0.012								0.01			0.014	0.013	BDL		BDL		BDL		BDL
Cesium (Cs)	ug/L													BDL								
Chromium (Cr)	ug/L	50	BDL											BDL	BDL	BDL		BDL		BDL		BDL
Cobalt (Co)	ug/L		BDL											BDL	BDL	BDL		BDL		BDL		BDL
Copper (Cu)	ug/L	1000	0.53								1.95			1.35	1.68	1.32		0.89		1.3		1.25
Iron (Fe)	ug/L	300	340								9.2			12.3	9.3	5.5		5		7.4		BDL
Lanthanum (La)	ug/L													BDL								
Lead (Pb)	ug/L	10	BDL											BDL	BDL	BDL		BDL		BDL		BDL
Lithium (Li)	ug/L													BDL	BDL	BDL						
Manganese (Mn)	ug/L	50	41.2								103			53.6	137	135		123		120		105
Mercury (Hg)	ug/L	1	0.05												BDL	BDL		BDL		BDL		0.05
Molybdenum (Mo)	ug/L		2.6											2.2	3.9	2.8		2.5		2.4		2.1
Nickel (Ni)	ug/L		BDL											BDL	1.1	BDL		BDL		BDL		BDL
Rubidium (Rb)	ug/L													0.76								
Selenium (Se)	ug/L	10	BDL								0.11			BDL	BDL	BDL		BDL		BDL		BDL
Silicon (Si)	ug/L		9770											6,850	9,510	9,830				9880		
Silver (Ag)	ug/L		BDL											BDL	BDL	BDL		BDL		BDL		BDL
Strontium (Sr)	ug/L		325											169	175	195				198		
Tellurium (Te)	ug/L													BDL								
Thallium (Tl)	ug/L		BDL											BDL	BDL	BDL				0.05		
Thorium (Th)	ug/L													BDL								
Tin (Sn)	ug/L		BDL											BDL	BDL	BDL				BDL		
Titanium (Ti)	ug/L		7.6											BDL	BDL	BDL				BDL		
Tungsten (W)	ug/L													BDL								
Uranium (U)	ug/L	20	BDL											0.99	1.82	1.31		1.32		1.24		1.05
Vanadium (V)	ug/L		BDL											7.2	5.6	6.7		6.7		7		6.7
Zinc (Zn)	ug/L	5000	BDL								5			BDL	BDL	BDL		BDL		BDL		BDL
Zirconium (Zr)	ug/L		BDL											BDL	BDL	BDL				BDL		
Calcium (Ca)	mg/L		32.9								37.2			23.9	39.2	38.8		39.9		37.6		36.1
Magnesium (Mg)	mg/L		9.82								8.54			5.85	14.6	14.2		13.7		13.5		12.5
Potassium (K)	mg/L		2.9								0.864			1.54	1.08	1.47		1.72		1.63		1.68
Sodium (Na)	mg/L	200	64.4								15.1			27.9	14.6	19.1		22.3		22.9		26.9
Sulphur (S)	mg/L		BDL											3.6	3.2	4.8		5.2		4		4.5

ASR-1 : PRODUCED WATER

Program No.:			2	1	1	1	1	1	1	1	2	1	1	3	3	-	1	-	1	3	1	-
Date (dd.mm.yy):			19.08.13	19.08.13	06.09.13	09.09.13	11.09.13	13.09.13	16.09.13	18.09.13	20.09.13	24.09.13	25.09.13	01.10.13	23.01.14	30.01.14	30.01.14	05.02.14	05.02.14	06.02.14	14.02.14	15.02.14
				Production cycle test 1								End of production cycle test 1			Production cycle test 2							
DISSOLVED METALS	Unit	Standard																				
Aluminum (Al)	ug/L														BDL	5.2				1.86		
Antimony (Sb)	ug/L	6													BDL	BDL				0.297		
Arsenic (As)	ug/L	10													BDL	35.8				38.9		
Barium (Ba)	ug/L	1000													28	30.7				31.3		
Beryllium (Be)	ug/L														BDL	BDL				BDL		
Bismuth (Bi)	ug/L														BDL	BDL				BDL		
Boron (B)	ug/L	5000													47	56				70		
Cadmium (Cd)	ug/L	5													BDL	BDL				0.009		
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	50													BDL	BDL				BDL		
Cobalt (Co)	ug/L														BDL	BDL				0.116		
Copper (Cu)	ug/L	1000													BDL	1.32				0.786		
Iron (Fe)	ug/L	300													BDL	5.5				BDL		
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	10													BDL	BDL				0.006		
Lithium (Li)	ug/L														BDL	BDL				1.76		
Manganese (Mn)	ug/L	50													147	135				117		
Mercury (Hg)	ug/L	1																				
Molybdenum (Mo)	ug/L														BDL	2.8				2.5		
Nickel (Ni)	ug/L														BDL	BDL				0.405		
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	10													BDL	BDL				BDL		
Silicon (Si)	ug/L														9,350	9,830				9,220		
Silver (Ag)	ug/L														BDL	BDL				0.008		
Strontium (Sr)	ug/L														177	198				200		
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L															BDL				0.002		
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L														BDL	BDL				BDL		
Titanium (Ti)	ug/L														BDL	BDL				BDL		
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	20														1.31				1.21		
Vanadium (V)	ug/L														BDL	6.7				6.82		
Zinc (Zn)	ug/L	5000													BDL	BDL				0.17		
Zirconium (Zr)	ug/L														BDL	BDL				BDL		
Calcium (Ca)	mg/L														42.6	38.8						
Magnesium (Mg)	mg/L														16.3	14.2						
Potassium (K)	mg/L														1.28	1.47						
Sodium (Na)	mg/L	200													17.1	19.1						
Sulphur (S)	mg/L														6.3	4.8						

ASR-1 : PRODUCED WATER

Program No.:			2	1	1	1	1	1	1	1	2	1	1	3	3	-	1	-	1	3	1	-
Date (dd.mm.yy):			19.08.13	19.08.13	06.09.13	09.09.13	11.09.13	13.09.13	16.09.13	18.09.13	20.09.13	24.09.13	25.09.13	01.10.13	23.01.14	30.01.14	30.01.14	05.02.14	05.02.14	06.02.14	14.02.14	15.02.14
				Production cycle test 1								End of production cycle test 1			Production cycle test 2							
SEMI VOLATILE ORGANICS	Unit	Standard																				
Phenol	ug/L														BDL					BDL		
2-chlorophenol	ug/L														BDL					BDL		
3 & 4-chlorophenol	ug/L														BDL					BDL		
2-methylphenol	ug/L														BDL					BDL		
3 & 4-methylphenol	ug/L														BDL					BDL		
2-nitrophenol	ug/L														BDL					BDL		
2,4-dimethylphenol	ug/L														BDL					BDL		
2,4 + 2,5-dichlorophenol	ug/L														BDL					BDL		
2,3-dichlorophenol	ug/L														BDL					BDL		
2,6-dichlorophenol	ug/L														BDL					BDL		
3,5-dichlorophenol	ug/L														BDL					BDL		
3,4-dichlorophenol	ug/L														BDL					BDL		
2,4,5-trichlorophenol	ug/L														BDL					BDL		
2,4,6-trichlorophenol	ug/L	5													BDL					BDL		
2,3,5-trichlorophenol	ug/L														BDL					BDL		
2,3,6-trichlorophenol	ug/L														BDL					BDL		
2,3,4-trichlorophenol	ug/L														BDL					BDL		
3,4,5-trichlorophenol	ug/L														BDL					BDL		
2,4-dinitrophenol	ug/L														BDL					BDL		
4,6-diitro-2-methylphenol	ug/L														BDL					BDL		
2,3,4,6-tetrachlorophenol	ug/L	100													BDL					BDL		
2,3,4,5-tetrachlorophenol	ug/L														BDL					BDL		
2,3,5,6-tetrachlorophenol	ug/L														BDL					BDL		
4-nitrophenol	ug/L														BDL					BDL		
2,6-dimethylphenol	ug/L														BDL					BDL		
3,4-dimethylphenol	ug/L														BDL					BDL		
Pentachlorophenol	ug/L	60													BDL					BDL		
2,4,6-Tribromophenol	%														93					106		
2-Fluorophenol (sur.)	%														55					23		
VOLATILE ORGANICS																						
Chloroform	ug/L														1.1					1.3		
Chlorodibromomethane	ug/L														BDL					BDL		
Bromodichloromethane	ug/L														BDL					BDL		
Bromoform	ug/L														BDL					BDL		
1,4-Difluorobenzene (sur.)	%														98					93		
4-Bromofluorobenzene	%														83					98		
D4-1,2-Dichloroethane	%														97					99		
OTHER ORGANICS																						
Monochloroacetic Acid (MCAA)	ug/L														BDL					BDL		
Monobromoacetic Acid (MBAA)	ug/L														BDL					BDL		
Dichloroacetic Acid (DCAA)	ug/L														BDL					BDL		
Trichloroacetic Acid (TCAA)	ug/L														BDL					BDL		
Bromochloroacetic Acid (BCAA)	ug/L														BDL					BDL		
Dibromoacetic Acid (DBAA)	ug/L														BDL					BDL		
Total haloacetic Acids	ug/L														BDL					BDL		
2,3-Dibromopropionic Acid	%														96					98		

ASR-1 : PRODUCED WATER

Program No.:			-	1	3	3	1	3	3													
Date (dd.mm.yy):			19.02.14	19.02.14	25.02.14	11.03.14	17.03.14	17.03.14	17.03.14													
								Maxxam	**MB Labs**	**End of cycle test 2**												
PHYSICAL PARAMETERS	Unit	Standard																				
Water temperature	°C	**15**		10.0			12.0															
Conductivity	µS/cm		411	408	419	420	446	421	436													
pH	pH units	**6.5 - 8.5**	8.05	8.61	8.00	8.10	8.90	8.00	8.27													
Eh (Reducing Potential)	mV			303.4			161.7															
Total dissolved solids	mg/L	**500**	240	196.5	239	249	215.2	232	253													
Total suspended solids	mg/L				BDL	BDL		BDL	0.33													
Colour	Col. Unit	**15**	BDL		6	7		BDL	1.8													
Corrosiveness									0.578													
Dissolved oxygen	mg/L			4.52			6.64															
Dissolved oxygen	%			41.5			61.9															
Turbidity	NTU		BDL	0.90	0.10	0.20	1.00	0.20	0.18													
Salinity	ppt	**0.5**		0.20	0.25	0.25	0.21	0.25	0.2													
Langelier Index (@ 4.4C)	-				-0.296	-0.261		-0.319														
Langelier Index (@ 60C)	-				0.745	0.779		0.722														
Saturation pH (@ 4.4C)	-				8.33	8.31		8.34														
Saturation pH (@ 60C)	-				7.29	7.27		7.3														
INORGANICS																						
Alkalinity (total as CaCO3)	mg/L		130		123	125		125	135													
Alkalinity (PP as CaCO3)	mg/L		BDL		BDL	BDL		BDL														
Total Hardness (CaCO3)	mg/L		137		134	131		125	143													
Dissolved Hardness (CaCO3)	mg/L				131	129		122	143													
Bicarbonate (HCO3)	mg/L		158		151	153		153														
Carbonate (CO3)	mg/L		BDL		BDL	BDL		BDL														
Silica (SiO2)	mg/L				0.94	18.3		19.3	13.5													
Hydroxide (HO)	mg/L		BDL		BDL	BDL		BDL														
Chlorine (Cl)	mg/L			0.02	BDL	BDL	0.02	BDL	BDL													
Dissolved Chloride (Cl-)	mg/L	**250**	43		49.1	53		51.9	47.1													
Dissolved Fluoride (F)	mg/L	**1.5**	0.067		0.058	0.073		0.083	0.01													
Dissolved Orthophosphate (P)	mg/L							0.13														
Dissolved Sulphate (SO4)	mg/L	**500**	13.3		12.7	13.1		12.9	11													
Sulphide (S)	mg/L	**0.05**	0.0066		0.107	0.0091		BDL	0.005													
NUTRIENTS																						
Ammonia (N)	mg/L		0.19		0.19	0.21		0.25	0.101													
Dissolved Nitrate (N)	mg/L	**10**	BDL		BDL	BDL		BDL	0.01													
Dissolved Nitrite (N)	mg/L	**1**	BDL			0.062		0.063	0.01													
Nitrate plus nitrite (N)	mg/L		0.02		BDL	0.06		0.06	BDL													
Total Organic Nitrogen (N)	mg/L				0.026	BDL		BDL	0.161													
Total Nitrogen (N)	mg/L				0.212	0.266		0.256	0.262													
Total Phosphorus (P)	mg/L				0.102	0.117		0.119	0.147													
Dissolved Phosphorus (P)	mg/L																					
Total Organic Carbon (C)	mg/L				0.80	0.66		0.84	1.75													
Dissolved Organic Carbon (C)	mg/L				BDL	0.51		BDL	1.88													
MICROBIOLOGY																						
Total Coliform	MPN100ml	**0**	BDL		BDL	BDL		1	1													
Non-coliform bacterial	MPN100ml				BDL	670		9	26													
Iron bacteria	CFU/ml				2,300 – 9,000	35,000		35,000	BDL													
Sulphur bacteria	CFU/ml				BDL	BDL		BDL	BDL													
Heterotrophic Plate Count	CFU/ml				17	34		9	40													
Escherichia coli	MPN100ml	**0**	BDL		BDL	BDL		BDL														

ASR-1 : PRODUCED WATER

		Program No.:	-	1	3	3	1	3	3
		Date (dd.mm.yy):	19.02.14	19.02.14	25.02.14	11.03.14	17.03.14	17.03.14	17.03.14
								Maxxam	MB Labs
TOTAL METALS	Unit	Standard							
Aluminum (Al)	ug/L		3.7		BDL	3.9		4.5	1.21
Antimony (Sb)	ug/L	6	BDL		BDL	BDL		BDL	0.698
Arsenic (As)	ug/L	10	39.1		37.9	36.6		35.5	31.1
Barium (Ba)	ug/L	1000	36.2		34.6	37.9		36.8	40
Beryllium (Be)	ug/L				BDL	BDL		BDL	BDL
Bismuth (Bi)	ug/L				BDL	BDL		BDL	
Boron (B)	ug/L	5000	90		93	113		120	131
Cadmium (Cd)	ug/L	5	BDL		BDL	BDL		BDL	0.01
Cesium (Cs)	ug/L								
Chromium (Cr)	ug/L	50	BDL		BDL	BDL		1	1
Cobalt (Co)	ug/L		BDL		BDL	0.5		BDL	BDL
Copper (Cu)	ug/L	1000	1.12		1.09	1.71		0.9	0.2
Iron (Fe)	ug/L	300	BDL		BDL	BDL		5	205
Lanthanum (La)	ug/L								BDL
Lead (Pb)	ug/L	10	BDL		BDL	BDL		0.2	0.2
Lithium (Li)	ug/L								
Manganese (Mn)	ug/L	50	101		95.4	87.4		81.3	95
Mercury (Hg)	ug/L	1	0.05		BDL	BDL		BDL	0.01
Molybdenum (Mo)	ug/L		2.2		2.1	2.2		2.1	BDL
Nickel (Ni)	ug/L		BDL		BDL	BDL		BDL	BDL
Rubidium (Rb)	ug/L								
Selenium (Se)	ug/L	10	BDL		BDL	BDL		BDL	0.1
Silicon (Si)	ug/L				8720	8930		8,980	7,160
Silver (Ag)	ug/L		BDL		BDL	BDL		BDL	BDL
Strontium (Sr)	ug/L				220	238		228	224
Tellurium (Te)	ug/L								
Thallium (Tl)	ug/L				BDL	BDL		BDL	
Thorium (Th)	ug/L								
Tin (Sn)	ug/L				BDL	BDL		BDL	BDL
Titanium (Ti)	ug/L				BDL	BDL		BDL	BDL
Tungsten (W)	ug/L								BDL
Uranium (U)	ug/L	20	0.86		1	0.9		0.77	
Vanadium (V)	ug/L		6.7		6.7	6.4		5.9	BDL
Zinc (Zn)	ug/L	5000	BDL		BDL	BDL		5	5
Zirconium (Zr)	ug/L				BDL	BDL		BDL	
Calcium (Ca)	mg/L		34.7		33.7	33.2		32.5	36.7
Magnesium (Mg)	mg/L		12.2		12.1	11.7		10.7	12.4
Potassium (K)	mg/L		1.84		1.92	2.31		2.07	2.28
Sodium (Na)	mg/L	200	27.1		31.4	35.7		34.8	34.7
Sulphur (S)	mg/L		3.9		3.4	3.2		3.4	

End of cycle test 2

ASR-1 : PRODUCED WATER

		Program No.:	-	1	3	3	1	3	3	
		Date (dd.mm.yy):	19.02.14	19.02.14	25.02.14	11.03.14	17.03.14	17.03.14	17.03.14	
								Maxxam	MB Labs	End of cycle test 2
DISSOLVED METALS	Unit	Standard								
Aluminum (Al)	ug/L									
Antimony (Sb)	ug/L	6								
Arsenic (As)	ug/L	10			38.2	37.1		33.3		
Barium (Ba)	ug/L	1000								
Beryllium (Be)	ug/L									
Bismuth (Bi)	ug/L									
Boron (B)	ug/L	5000								
Cadmium (Cd)	ug/L	5								
Cesium (Cs)	ug/L									
Chromium (Cr)	ug/L	50								
Cobalt (Co)	ug/L									
Copper (Cu)	ug/L	1000								
Iron (Fe)	ug/L	300								
Lanthanum (La)	ug/L									
Lead (Pb)	ug/L	10								
Lithium (Li)	ug/L									
Manganese (Mn)	ug/L	50			92.1	87.8		82.6		
Mercury (Hg)	ug/L	1								
Molybdenum (Mo)	ug/L									
Nickel (Ni)	ug/L									
Rubidium (Rb)	ug/L									
Selenium (Se)	ug/L	10								
Silicon (Si)	ug/L									
Silver (Ag)	ug/L									
Strontium (Sr)	ug/L									
Tellurium (Te)	ug/L									
Thallium (Tl)	ug/L									
Thorium (Th)	ug/L									
Tin (Sn)	ug/L									
Titanium (Ti)	ug/L									
Tungsten (W)	ug/L									
Uranium (U)	ug/L	20								
Vanadium (V)	ug/L									
Zinc (Zn)	ug/L	5000								
Zirconium (Zr)	ug/L									
Calcium (Ca)	mg/L				33.1	33.8		31.6		
Magnesium (Mg)	mg/L				11.8	10.9		10.5		
Potassium (K)	mg/L									
Sodium (Na)	mg/L	200								
Sulphur (S)	mg/L									

ASR-1 : PRODUCED WATER

End of cycle test 2

		Program No.:	-	1	3	3	1	3	3
		Date (dd.mm.yy):	19.02.14	19.02.14	25.02.14	11.03.14	17.03.14	17.03.14	17.03.14
								Maxxam	**MB Labs**
SEMI VOLATILE ORGANICS	Unit	Standard							
Phenol	ug/L				BDL	BDL		BDL	BDL
2-chlorophenol	ug/L				BDL	BDL		BDL	
3 & 4-chlorophenol	ug/L				BDL	BDL		BDL	
2-methylphenol	ug/L				BDL	BDL		BDL	BDL
3 & 4-methylphenol	ug/L				BDL	BDL		BDL	
2-nitrophenol	ug/L				BDL	BDL		BDL	BDL
2,4-dimethylphenol	ug/L				BDL	BDL		BDL	BDL
2,4 + 2,5-dichlorophenol	ug/L				BDL	BDL		BDL	BDL
2,3-dichlorophenol	ug/L				BDL	BDL		BDL	
2,6-dichlorophenol	ug/L				BDL	BDL		BDL	
3,5-dichlorophenol	ug/L				BDL	BDL		BDL	
3,4-dichlorophenol	ug/L				BDL	BDL		BDL	
2,4,5-trichlorophenol	ug/L				BDL	BDL		BDL	
2,4,6-trichlorophenol	ug/L	**5**			BDL	BDL		BDL	BDL
2,3,5-trichlorophenol	ug/L				BDL	BDL		BDL	
2,3,6-trichlorophenol	ug/L				BDL	BDL		BDL	
2,3,4-trichlorophenol	ug/L				BDL	BDL		BDL	
3,4,5-trichlorophenol	ug/L				BDL	BDL		BDL	
2,4-dinitrophenol	ug/L				BDL	BDL		BDL	
4,6-diitro-2-methylphenol	ug/L				BDL	BDL		BDL	
2,3,4,6-tetrachlorophenol	ug/L	**100**			BDL	BDL		BDL	
2,3,4,5-tetrachlorophenol	ug/L				BDL	BDL		BDL	
2,3,5,6-tetrachlorophenol	ug/L				BDL	BDL		BDL	
4-nitrophenol	ug/L				BDL	BDL		BDL	BDL
2,6-dimethylphenol	ug/L				BDL	BDL		BDL	
3,4-dimethylphenol	ug/L				BDL	BDL		BDL	
Pentachlorophenol	ug/L	**60**			BDL	BDL		BDL	
2,4,6-Tribromophenol (sur.)	%				95	97		90	
2-Fluorophenol (sur.)	%				60	59		61	
VOLATILE ORGANICS									
Chloroform	ug/L				1.1	BDL		BDL	BDL
Chlorodibromomethane	ug/L				BDL	BDL		BDL	
Bromodichloromethane	ug/L				BDL	BDL		BDL	BDL
Bromoform	ug/L				BDL	BDL		BDL	BDL
1,4-Difluorobenzene (sur.)	%				97	112		110	
4-Bromofluorobenzene (sur.)	%				90	96		102	95.7
D4-1,2-Dichloroethane (sur.)	%				99	94		94	
OTHER ORGANICS									
Monochloroacetic Acid (MCAA)	ug/L				BDL			BDL	BDL
Monobromoacetic Acid (MBAA)	ug/L				BDL			BDL	BDL
Dichloroacetic Acid (DCAA)	ug/L				BDL			BDL	BDL
Trichloroacetic Acid (TCAA)	ug/L				BDL			BDL	BDL
Bromochloroacetic Acid (BCAA)	ug/L				BDL			BDL	BDL
Dibromoacetic Acid (DBAA)	ug/L				BDL			BDL	BDL
Total haloacetic Acids	ug/L				BDL			BDL	BDL
2,3-Dibromopropionic Acid	%				78			97	BDL

4.3:

MW-1

MONITORING WELL : MW-1

Program No.:			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Date (dd.mm.yy):			19.08.13	20.08.13	21.08.13	22.08.13	23.08.13	26.08.13	27.08.13	28.08.13	29.08.13	30.08.13	04.09.13	05.09.13	06.09.13	09.09.13	10.09.13	11.09.13	12.09.13	13.09.13	16.09.13	17.09.13
				Injection cycle test 1																		
PHYSICAL PARAMETERS	Unit	Standard																				
Water temperature	°C	**15**	11.44	13.97	14.04	**15.63**	14.72	**17.35**	**17.23**	**16.20**	**16.50**	**16.30**	**17.10**	**16.20**	**16.70**	**16.50**	**16.30**	**18.20**	**17.90**	**15.40**	**16.10**	**15.80**
Conductivity	µS/cm		534	246	205	187	144	134	126	144	138	196	431	191	189.3	172	219	244	158	171	162	221
pH	pH units	**6.5 - 8.5**	8.41	8.16	**8.69**	**8.84**	**8.66**	**8.63**	**8.75**	**8.88**	**8.86**	**8.80**	8.16	8.13	8.22	7.99	8.01	7.94	8.14	8.25	7.98	7.64
Eh (Reducing Potential)	mV		20.2	198.2	277.9	234.1	136	164.8	241.6	217.4	236.3	228.6	277.4	270.5	251.7	277.4	307.4	331.5	328.8	254.4	318.3	352.9
Total dissolved solids	mg/L	**500**	469	203	168	148	116	102	97	68	65	93	209	91	89.9	81.4	104.1	116.2	74.9	80.5	76.5	105.1
Total suspended solids	mg/L																					
Colour	Col. Unit	**15**																				
Corrosiveness																						
Dissolved oxygen	mg/L		3.44	2.73	3.03	2.53	4.81	4.75	6.19	5.53	6.27	5.55	6	5.87	4.73	6.63	6.94	5.23	6.79	6.78	7.04	7.15
Dissolved oxygen	%		31.8	26.5	30	26	47.7	48.5	64.7	56.5	64.7	56.6	63.5	59.7	49.2	68.6	70.9	55.8	72.2	68.3	72	72.4
Turbidity	NTU																	9.49	7.7	12.5	11.7	12
Salinity	ppt	**0.5**	0.35	0.15	0.12	0.11	0.08	0.07	0.07	0.07	0.06	0.09	0.21	0.09	0.09	0.08	0.1	0.12	0.07	0.08	0.08	0.1
Langelier Index (@ 4.4C)	-																					
Langelier Index (@ 60C)	-																					
Saturation pH (@ 4.4C)	-																					
Saturation pH (@ 60C)	-																					
INORGANICS																						
Alkalinity (total as CaCO3)	mg/L																					
Alkalinity (PP as CaCO3)	mg/L																					
Total Hardness (CaCO3)	mg/L																					
Dissolved Hardness (CaCO3)	mg/L																					
Bicarbonate (HCO3)	mg/L																					
Carbonate (CO3)	mg/L																					
Silica (SiO2)	mg/L																					
Hydroxide (HO)	mg/L																					
Chlorine (Cl)	mg/L					0.02		0.03	0.02	BDL	BDL	0.03	0.06	0.02	0.02	0.04	0.03		0.04	0.04	BDL	BDL
Dissolved Chloride (Cl-)	mg/L	**250**																				
Dissolved Fluoride (F)	mg/L	**1.5**																				
Dissolved Orthophosphate (P)	mg/L																					
Dissolved Sulphate (SO4)	mg/L	**500**																				
Sulphide (S)	mg/L	**0.05**																				
NUTRIENTS																						
Ammonia (N)	mg/L																					
Dissolved Nitrate (N)	mg/L	**10**																				
Dissolved Nitrite (N)	mg/L	**1**																				
Nitrate plus nitrite (N)	mg/L																					
Total Organic Nitrogen (N)	mg/L																					
Total Nitrogen (N)	mg/L																					
Total Phosphorus (P)	mg/L																					
Dissolved Phosphorus (P)	mg/L																					
Total Organic Carbon (C)	mg/L																					
Dissolved Organic Carbon (C)	mg/L																					
MICROBIOLOGY																						
Total Coliform	MPN100ml	**0**																				
Non-coliform bacterial	MPN100ml																					
Iron bacteria	CFU/ml																					
Sulphur bacteria	CFU/ml																					
Heterotrophic Plate Count	CFU/ml																					
Escherichia coli	MPN100ml	**0**																				

MONITORING WELL : MW–1

Production cycle test 1 Injection cycle test 2

End of injection cycle test 1

Program No.:			1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1
Date (dd.mm.yy):			18.09.13	24.09.13	25.09.13	18.10.13	23.10.13	24.10.13	25.10.13	28.10.13	29.10.13	30.10.13	31.10.13	06.11.13	07.11.13	12.11.13	18.11.13	19.11.13	20.11.13	21.11.13	22.11.13	25.11.13
PHYSICAL PARAMETERS	Unit	Standard																				
Water temperature	°C	**15**	15.6	15.6	15.7	14.9	13.6	14.4	13.3	15.3	14.3	14.0	13.5	12.4		12.6	12.8	12.7	12.0		11.4	10.8
Conductivity	µS/cm		221	290	95	336	446	359	382	338	223	330	359	369	234	334	673	346	344	339	455	455
pH	pH units	**6.5 - 8.5**	7.97	8.31	8.43	7.68	7.57	7.76	8.10	7.71	8.82	7.97	7.89	8.17	8.70	8.10	7.70	7.96	7.99	7.80	8.04	7.85
Eh (Reducing Potential)	mV		321.1	240.6	245.4	315.4	263	338.4	279.7	254.4	180.9	265.7	368.8	318.9		273.3	278	281.4	315.5		352.8	392.8
Total dissolved solids	mg/L	**500**	105.2	138	95.2								170.9	177.3	156	160.3	328	166.3	165.1	201	219.5	219.5
Total suspended solids	mg/L														17					BDL		
Colour	Col. Unit	**15**													6					9		
Corrosiveness																						
Dissolved oxygen	mg/L		6.64	2.92	3.74	6.62	7.07	6.70	8.79	6.95	4.46	8.11	9.50	11.32		10.34	8.73	9.44	9.68		11.75	10.40
Dissolved oxygen	%		66.7	29.5	37.9	65.6	68.9	66.3	83.4	68.0	43.8	82.8	90.9	97.9		99.5	86.6	91.0	95.1		103.7	92.9
Turbidity	NTU		18.40	0.70	0.56	7.39	17.40	10.30	12.50	19.10	110.0	10.50	17.50	11.20	32.00	12.90	13.90	15.40	9.18	3.00	5.83	11.80
Salinity	ppt	**0.5**	0.10	0.14	0.10	0.16	0.21	0.17	0.18	0.16	0.11	0.16	0.17	0.18		0.16	0.33	0.17	0.16		0.22	0.22
Langelier Index (@ 4.4C)	-																					
Langelier Index (@ 60C)	-																					
Saturation pH (@ 4.4C)	-																					
Saturation pH (@ 60C)	-																					
INORGANICS																						
Alkalinity (total as CaCO3)	mg/L														78.5					132		
Alkalinity (PP as CaCO3)	mg/L														2.6					BDL		
Total Hardness (CaCO3)	mg/L														146					129		
Dissolved Hardness (CaCO3)	mg/L																					
Bicarbonate (HCO3)	mg/L														89.5					161		
Carbonate (CO3)	mg/L														3.1					BDL		
Silica (SiO2)	mg/L														14.7					5.24		
Hydroxide (HO)	mg/L														BDL					BDL		
Chlorine (Cl)	mg/L		BDL	0.03	0.02	0.04	BDL	0.02	0.04	0.04	0.07	0.06	0.07	0.02		0.04	0.06	0.07	0.06		0.04	0.02
Dissolved Chloride (Cl-)	mg/L	**250**													27.5					30.8		
Dissolved Fluoride (F)	mg/L	**1.5**													0.077					BDL		
Dissolved Orthophosphate (P)	mg/L																					
Dissolved Sulphate (SO4)	mg/L	**500**													7.45					7.99		
Sulphide (S)	mg/L	**0.05**																				
NUTRIENTS																						
Ammonia (N)	mg/L														0.21					0.83		
Dissolved Nitrate (N)	mg/L	**10**													0.092					0.735		
Dissolved Nitrite (N)	mg/L	**1**																				
Nitrate plus nitrite (N)	mg/L																					
Total Organic Nitrogen (N)	mg/L																					
Total Nitrogen (N)	mg/L																					
Total Phosphorus (P)	mg/L														0.038					0.052		
Dissolved Phosphorus (P)	mg/L																					
Total Organic Carbon (C)	mg/L																					
Dissolved Organic Carbon (C)	mg/L																					
MICROBIOLOGY																						
Total Coliform	MPN100ml	**0**																				
Non-coliform bacterial	MPN100ml																					
Iron bacteria	CFU/ml																					
Sulphur bacteria	CFU/ml																					
Heterotrophic Plate Count	CFU/ml																					
Escherichia coli	MPN100ml	**0**																				

MONITORING WELL : MW-1

Production cycle test 1

Injection cycle test 2

End of injection cycle test 1

Program No.:			1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1
Date (dd.mm.yy):			18.09.13	24.09.13	25.09.13	18.10.13	23.10.13	24.10.13	25.10.13	28.10.13	29.10.13	30.10.13	31.10.13	06.11.13	07.11.13	12.11.13	18.11.13	19.11.13	20.11.13	21.11.13	22.11.13	25.11.13
TOTAL METALS	Unit	Standard																				
Aluminum (Al)	ug/L														24.2					5.1		
Antimony (Sb)	ug/L	6													BDL					BDL		
Arsenic (As)	ug/L	10													2.1					1.8		
Barium (Ba)	ug/L	1000													81.6					28.6		
Beryllium (Be)	ug/L														BDL					BDL		
Bismuth (Bi)	ug/L														BDL					BDL		
Boron (B)	ug/L	5000													BDL					BDL		
Cadmium (Cd)	ug/L	5													0.035					0.257		
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	50													5.9					BDL		
Cobalt (Co)	ug/L														BDL					BDL		
Copper (Cu)	ug/L	1000													2.88					1.66		
Iron (Fe)	ug/L	300													2480					2780		
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	10													BDL					BDL		
Lithium (Li)	ug/L														BDL					BDL		
Manganese (Mn)	ug/L	50													151					238		
Mercury (Hg)	ug/L	1																				
Molybdenum (Mo)	ug/L														BDL					BDL		
Nickel (Ni)	ug/L														1.7					1.1		
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	10													0.21					BDL		
Silicon (Si)	ug/L														8570					3060		
Silver (Ag)	ug/L														BDL					BDL		
Strontium (Sr)	ug/L														226					200		
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L														BDL					BDL		
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L														BDL					BDL		
Titanium (Ti)	ug/L														BDL					0.05		
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	20													0.11					BDL		
Vanadium (V)	ug/L														BDL					BDL		
Zinc (Zn)	ug/L	5000													BDL					BDL		
Zirconium (Zr)	ug/L														BDL					BDL		
Calcium (Ca)	mg/L														35.2					28.7		
Magnesium (Mg)	mg/L														14					14		
Potassium (K)	mg/L														2.79					5.87		
Sodium (Na)	mg/L	200													18.2					11.4		
Sulphur (S)	mg/L														BDL					BDL		

MONITORING WELL : MW-1

Program No.:			1	1	1	1	1	1	1	1	2	1	1	1	1	1	3	-	1	3	3	3
Date (dd.mm.yy):			27.11.13	28.11.13	02.12.13	03.12.13	04.12.13	05.12.13	09.12.13	16.12.13	18.12.13	20.12.13	23.12.13	24.12.13	30.12.13	03.01.14	23.01.14	30.01.14	30.01.14	06.02.14	25.02.14	11.03.14
																End of injection cycle test 2	Production cycle test 2					
PHYSICAL PARAMETERS	Unit	Standard																				
Water temperature	°C	15	10.7	12	11.2	10.3	9.1	9.5	9	8.3		10.3	10.4	10.9	11.3	11			10.0			
Conductivity	µS/cm		340	326	335	321	369	312	308	434		446	467	330	407	597	431	421	421	422	416	410
pH	pH units	6.5 - 8.5	7.94	7.97	7.89	7.99	8.17	7.87	8.06	8.18		8.42	8.01	8.11	8.44	8.2	8.10	8.09	8.72	8.00	8.10	8.10
Eh (Reducing Potential)	mV		363.8	273	413.9	276.3	414.7	334.8	255.1	328.3		134.6	319	271.5	277.1	325.2			333.4			
Total dissolved solids	mg/L	500	163.2	156.3	160.5	153.3	177.3	149.6	147.7	209		215.8	225	158.5	196.1	290	267	242	203	233	236	248
Total suspended solids	mg/L																BDL	BDL		BDL	BDL	BDL
Colour	Col. Unit	15															BDL	BDL		5	8	5
Corrosiveness																						
Dissolved oxygen	mg/L		9.93	9.51	10.17	12.06	11.18	9.23	10.82	11.49		7.44	8.16	7.89	8.56	10.12			5.08			
Dissolved oxygen	%		91.9	88.3	95.5	103.3	96.9	82.7	92.3	97		69.4	76.3	72.7	77.8	91.1			47.5			
Turbidity	NTU		8.9	16.9	16.2	8.9	6.3	6.8	7.2	9.9	0.3	9.4	8.1	9.6	23	60.4	0.3	BDL	0.5	0.2	BDL	BDL
Salinity	ppt	0.5	0.16	0.16	0.16	0.15	0.18	0.15	0.15	0.21		0.21	0.22	0.16	0.2	0.29	0.26	0.2	0.2	0.25	0.25	0.25
Langelier Index (@ 4.4C)	-																-0.114			-0.238	-0.244	-0.261
Langelier Index (@ 60C)	-																0.927			0.803	0.797	0.78
Saturation pH (@ 4.4C)	-																8.18			8.27	8.35	8.35
Saturation pH (@ 60C)	-																7.14			7.23	7.31	7.31
INORGANICS																						
Alkalinity (total as CaCO3)	mg/L																134	133		124	120	120
Alkalinity (PP as CaCO3)	mg/L																BDL	BDL		BDL	BDL	BDL
Total Hardness (CaCO3)	mg/L										155						161			147	121	119
Dissolved Hardness	mg/L										153						172	154		141	123	119
Bicarbonate (HCO3)	mg/L																164	162		152	147	146
Carbonate (CO3)	mg/L																BDL	BDL		BDL	BDL	BDL
Silica (SiO2)	mg/L																18.9			17.7	0.91	18.1
Hydroxide (HO)	mg/L																BDL	BDL		BDL	BDL	BDL
Chlorine (Cl)	mg/L		0.04	0.02	0.14	0.11	0.04	0.05	0.09	0.02		0.02	0	0.04	0.04	0.15	BDL		0.02		BDL	BDL
Dissolved Chloride (Cl-)	mg/L	250															42.0			48.2	50.0	53.1
Dissolved Fluoride (F)	mg/L	1.5															0.063			0.071	0.104	0.094
Dissolved Orthophosphate	mg/L																0.032			BDL		
Dissolved Sulphate (SO4)	mg/L	500															18.5			12.7	12.5	12.8
Sulphide (S)	mg/L	0.05															0.0052	0.0062		BDL	0.0084	0.0068
NUTRIENTS																						
Ammonia (N)	mg/L																0.071	0.08		0.098	0.16	0.18
Dissolved Nitrate (N)	mg/L	10															BDL	0.0056		BDL	BDL	BDL
Dissolved Nitrite (N)	mg/L	1															BDL	BDL		0.033	BDL	0.047
Nitrate plus nitrite (N)	mg/L																BDL	0.0056		0.03	BDL	0.05
Total Organic Nitrogen (N)	mg/L																0.055	BDL		0.032	BDL	BDL
Total Nitrogen (N)	mg/L																0.125	0.101		0.163	0.177	0.197
Total Phosphorus (P)	mg/L																0.032	0.0418		0.0565	0.0794	0.101
Dissolved Phosphorus (P)	mg/L																BDL	0.0418				
Total Organic Carbon (C)	mg/L																1.00	1.02		0.87	0.67	0.91
Dissolved Organic Carbon	mg/L																0.85			0.66	BDL	0.83
MICROBIOLOGY																						
Total Coliform	MPN100ml	0															BDL	BDL		BDL	BDL	2
Non-coliform bacterial	MPN100ml																590			BDL	11	BDL
Iron bacteria	CFU/ml																2300			2300	500	500
Sulphur bacteria	CFU/ml																BDL	BDL		BDL	BDL	BDL
Heterotrophic Plate Count	CFU/ml																45	4		15	6	1
Escherichia coli	MPN100ml	0															BDL	BDL		BDL	BDL	BDL

MONITORING WELL : MW–1

		Program No.:	1	1	1	1	1	1	1	1	2	1	1	1	1	1	3	-	1	3	3	3
		Date (dd.mm.yy):	27.11.13	28.11.13	02.12.13	03.12.13	04.12.13	05.12.13	09.12.13	16.12.13	18.12.13	20.12.13	23.12.13	24.12.13	30.12.13	03.01.14	23.01.14	30.01.14	30.01.14	06.02.14	25.02.14	11.03.14
																End of injection cycle test 2	Production cycle test 2					
TOTAL METALS	Unit	Standard																				
Aluminum (Al)	ug/L										7.0						15.9			14.2	BDL	BDL
Antimony (Sb)	ug/L	6									BDL						BDL			BDL	BDL	BDL
Arsenic (As)	ug/L	10									0.61						10.2			13.6	14.5	15.3
Barium (Ba)	ug/L	1000									89.4						60.6			58.8	57.7	57.0
Beryllium (Be)	ug/L										BDL						BDL			BDL	BDL	BDL
Bismuth (Bi)	ug/L										BDL						BDL			BDL	BDL	BDL
Boron (B)	ug/L	5000									BDL						64			92	109	125
Cadmium (Cd)	ug/L	5									BDL						0.011			BDL	BDL	BDL
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	50									BDL						BDL			BDL	BDL	BDL
Cobalt (Co)	ug/L										BDL						BDL			BDL	BDL	BDL
Copper (Cu)	ug/L	1000									3.92						3.56			3.52	3.96	2.54
Iron (Fe)	ug/L	300									116						27.3			12.6	8.8	11.0
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	10									BDL						0.32			0.36	0.42	0.25
Lithium (Li)	ug/L										BDL						BDL					
Manganese (Mn)	ug/L	50									11.9						63.5			61.2	53.6	51.7
Mercury (Hg)	ug/L	1															BDL			BDL	BDL	BDL
Molybdenum (Mo)	ug/L										BDL						2.1			1.6	1.6	1.7
Nickel (Ni)	ug/L										BDL						BDL			BDL	BDL	BDL
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	10									0.23						0.16			BDL	BDL	BDL
Silicon (Si)	ug/L										11,500						9,670			9,400	7,930	8,840
Silver (Ag)	ug/L										BDL						BDL			BDL	BDL	BDL
Strontium (Sr)	ug/L										168						201			220	232	260
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L										BDL						BDL			BDL	BDL	BDL
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L										BDL						BDL			BDL	BDL	BDL
Titanium (Ti)	ug/L										BDL						BDL			BDL	BDL	BDL
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	20									0.19						1.75			1.02	0.72	0.66
Vanadium (V)	ug/L										BDL						6.9			10.3	11.1	10.7
Zinc (Zn)	ug/L	5000									BDL						11.4			6.3	BDL	BDL
Zirconium (Zr)	ug/L										BDL						BDL			BDL	BDL	BDL
Calcium (Ca)	mg/L										37.0						40.4			37.4	30.3	31.0
Magnesium (Mg)	mg/L										15.2						14.6			13.0	11.0	10.2
Potassium (K)	mg/L										1.05						1.26			1.60	1.76	2.10
Sodium (Na)	mg/L	200									13.4						20.9			27.9	34.4	37.4
Sulphur (S)	mg/L										BDL						BDL			3.7	3.1	3.3

MONITORING WELL : MW-1

Program No.:			1	1	1	1	1	1	1	1	2	1	1	1	1	1	3	-	1	3	3	3
Date (dd.mm.yy):			27.11.13	28.11.13	02.12.13	03.12.13	04.12.13	05.12.13	09.12.13	16.12.13	18.12.13	20.12.13	23.12.13	24.12.13	30.12.13	03.01.14	23.01.14	30.01.14	30.01.14	06.02.14	25.02.14	11.03.14
																End of injection cycle test 2	Production cycle test 2					
DISSOLVED METAL	Unit	Standard																				
Aluminum (Al)	ug/L										BDL						BDL	33.9		1.56		
Antimony (Sb)	ug/L	6									BDL						BDL	BDL		0.372		
Arsenic (As)	ug/L	10									0.61						BDL	12.1		13.6	15.2	15.3
Barium (Ba)	ug/L	1000									89.7						0.0635	59.2		56.7		
Beryllium (Be)	ug/L										BDL						BDL	BDL		BDL		
Bismuth (Bi)	ug/L										BDL						BDL	BDL		BDL		
Boron (B)	ug/L	5000									BDL						0.062	71		86		
Cadmium (Cd)	ug/L	5									BDL						BDL	0.011		0.007		
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	50									BDL						BDL	BDL		BDL		
Cobalt (Co)	ug/L										2.44						BDL	BDL		0.043		
Copper (Cu)	ug/L	1000									2.44						BDL	0.97		2.74		
Iron (Fe)	ug/L	300									BDL						0.017	18.4		6.7		
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	10									BDL						BDL	BDL		0.2		
Lithium (Li)	ug/L										BDL						BDL	BDL		2.35		
Manganese (Mn)	ug/L	50									BDL						0.0647	63.6		60.7	51.2	50.0
Mercury (Hg)	ug/L	1																BDL				
Molybdenum (Mo)	ug/L										BDL						BDL	1.7		1.63		
Nickel (Ni)	ug/L										BDL						BDL	BDL		0.358		
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	10									0.22						BDL	BDL		0.077		
Silicon (Si)	ug/L										11,50						9.08	9,100		8990		
Silver (Ag)	ug/L										BDL						BDL	BDL		BDL		
Strontium (Sr)	ug/L										170						0.199	215		219		
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L										BDL							BDL		0.002		
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L										BDL						BDL	BDL		BDL		
Titanium (Ti)	ug/L										BDL						BDL	BDL		BDL		
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	20									0.20							1.16		0.99		
Vanadium (V)	ug/L										BDL						BDL	9.3		10.4		
Zinc (Zn)	ug/L	5000									BDL						0.008	BDL		5.08		
Zirconium (Zr)	ug/L										BDL						BDL	BDL		BDL		
Calcium (Ca)	mg/L										35.9						42.6	38.8			31.8	32.3
Magnesium (Mg)	mg/L										15.3						15.8	13.8			10.6	9.2
Potassium (K)	mg/L										1.06						1.47	1.49				
Sodium (Na)	mg/L	200									13.8						23.5	24.1				
Sulphur (S)	mg/L										BDL						5.82	4.8				

MONITORING WELL : MW-1

Program No.:			1	1	1	1	1	1	1	1	2	1	1	1	1	1	3	-	1	3	3	3
Date (dd.mm.yy):			27.11.13	28.11.13	02.12.13	03.12.13	04.12.13	05.12.13	09.12.13	16.12.13	18.12.13	20.12.13	23.12.13	24.12.13	30.12.13	03.01.14	23.01.14	30.01.14	30.01.14	06.02.14	25.02.14	11.03.14
														End of injection cycle test 2			Production cycle test 2					
SEMI VOLATILE ORGANICS	Unit	Standard																				
Phenol	ug/L																BDL			BDL	BDL	BDL
2-chlorophenol	ug/L																BDL			BDL	BDL	BDL
3 & 4-chlorophenol	ug/L																BDL			BDL	BDL	BDL
2-methylphenol	ug/L																BDL			BDL	BDL	BDL
3 & 4-methylphenol	ug/L																BDL			BDL	BDL	BDL
2-nitrophenol	ug/L																BDL			BDL	BDL	BDL
2,4-dimethylphenol	ug/L																BDL			BDL	BDL	BDL
2,4 + 2,5-dichlorophenol	ug/L																BDL			BDL	BDL	BDL
2,3-dichlorophenol	ug/L																BDL			BDL	BDL	BDL
2,6-dichlorophenol	ug/L																BDL			BDL	BDL	BDL
3,5-dichlorophenol	ug/L																BDL			BDL	BDL	BDL
3,4-dichlorophenol	ug/L																BDL			BDL	BDL	BDL
2,4,5-trichlorophenol	ug/L																BDL			BDL	BDL	BDL
2,4,6-trichlorophenol	ug/L	5															BDL			BDL	BDL	BDL
2,3,5-trichlorophenol	ug/L																BDL			BDL	BDL	BDL
2,3,6-trichlorophenol	ug/L																BDL			BDL	BDL	BDL
2,3,4-trichlorophenol	ug/L																BDL			BDL	BDL	BDL
3,4,5-trichlorophenol	ug/L																BDL			BDL	BDL	BDL
2,4-dinitrophenol	ug/L																BDL			BDL	BDL	BDL
4,6-diitro-2-methylphenol	ug/L																BDL			BDL	BDL	BDL
2,3,4,6-tetrachlorophenol	ug/L	100															BDL			BDL	BDL	BDL
2,3,4,5-tetrachlorophenol	ug/L																BDL			BDL	BDL	BDL
2,3,5,6-tetrachlorophenol	ug/L																BDL			BDL	BDL	BDL
4-nitrophenol	ug/L																BDL			BDL	BDL	BDL
2,6-dimethylphenol	ug/L																BDL			BDL	BDL	BDL
3,4-dimethylphenol	ug/L																BDL			BDL	BDL	BDL
Pentachlorophenol	ug/L	60															BDL			BDL	BDL	BDL
2,4,6-Tribromophenol (sur.)	%																98			105	90	92
2-Fluorophenol (sur.)	%																47			48	56	69
VOLATILE ORGANICS																						
Chloroform	ug/L																1.1			1.2	1.2	BDL
Chlorodibromomethane	ug/L																BDL			BDL	BDL	BDL
Bromodichloromethane	ug/L																BDL			BDL	BDL	BDL
Bromoform	ug/L																BDL			BDL	BDL	BDL
1,4-Difluorobenzene (sur.)	%																99			111	100	108
4-Bromofluorobenzene (sur.)	%																86			99	101	93
D4-1,2-Dichloroethane (sur.)	%																98			94	102	98
OTHER ORGANICS																						
Monochloroacetic Acid (MCAA)	ug/L																BDL			BDL	BDL	
Monobromoacetic Acid (MBAA)	ug/L																BDL			BDL	BDL	
Dichloroacetic Acid (DCAA)	ug/L																BDL			BDL	BDL	
Trichloroacetic Acid (TCAA)	ug/L																BDL			BDL	BDL	
Bromochloroacetic Acid (BCAA)	ug/L																BDL			BDL	BDL	
Dibromoacetic Acid (DBAA)	ug/L																BDL			BDL	BDL	
Total haloacetic Acids	ug/L																BDL			BDL	BDL	
2,3-Dibromopropionic Acid	%																108			102	78	

MONITORING WELL : MW–1

Program No.:			1	3	3	
Date (dd.mm.yy):			17.03.14	17.03.14	17.03.14	
				Maxxam	MB Labs	End of cycle test 2
PHYSICAL PARAMETERS	Unit	Standard				
Water temperature	°C	**15**	11.3			
Conductivity	µS/cm		298	408	418	
pH	pH units	**6.5 - 8.5**	9.17	8.10	8.37	
Eh (Reducing Potential)	mV		64.9			
Total dissolved solids	mg/L	**500**	195.8	231	242	
Total suspended solids	mg/L			BDL	BDL	
Colour	Col. Unit	**15**		BDL	1.62	
Corrosiveness					0.582	
Dissolved oxygen	mg/L		5.38			
Dissolved oxygen	%		49.0			
Turbidity	NTU		2.1	0.1	0.14	
Salinity	ppt	**0.5**	0.20	0.25	0.2	
Langelier Index (@ 4.4C)	-			-0.31		
Langelier Index (@ 60C)	-			0.73		
Saturation pH (@ 4.4C)	-			8.4		
Saturation pH (@ 60C)	-			7.36		
INORGANICS						
Alkalinity (total as CaCO3)	mg/L			120	130	
Alkalinity (PP as CaCO3)	mg/L			BDL		
Total Hardness (CaCO3)	mg/L			110	117	
Dissolved Hardness (CaCO3)	mg/L			108	116	
Bicarbonate (HCO3)	mg/L			147		
Carbonate (CO3)	mg/L			BDL		
Silica (SiO2)	mg/L			19.3	12.5	
Hydroxide (HO)	mg/L			BDL		
Chlorine (Cl)	mg/L		0.10	BDL	BDL	
Dissolved Chloride (Cl-)	mg/L	**250**		49.9	43.5	
Dissolved Fluoride (F)	mg/L	**1.5**		0.079	0.01	
Dissolved Orthophosphate (P)	mg/L			0.13		
Dissolved Sulphate (SO4)	mg/L	**500**		13.1	10.5	
Sulphide (S)	mg/L	**0.05**		BDL	BDL	
NUTRIENTS						
Ammonia (N)	mg/L			0.2	0.056	
Dissolved Nitrate (N)	mg/L	**10**		BDL	0.02	
Dissolved Nitrite (N)	mg/L	**1**		0.057	0.005	
Nitrate plus nitrite (N)	mg/L			0.06	BDL	
Total Organic Nitrogen (N)	mg/L			BDL	0.118	
Total Nitrogen (N)	mg/L			0.198	0.174	
Total Phosphorus (P)	mg/L			0.102	0.119	
Dissolved Phosphorus (P)	mg/L					
Total Organic Carbon (C)	mg/L			0.92	2.00	
Dissolved Organic Carbon (C)	mg/L			0.60	1.88	
MICROBIOLOGY						
Total Coliform	MPN100ml	**0**		BDL	BDL	
Non-coliform bacterial	MPN100ml			BDL	0.02	
Iron bacteria	CFU/ml			500 – 2,300	BDL	
Sulphur bacteria	CFU/ml			BDL	BDL	
Heterotrophic Plate Count	CFU/ml			3	0.3	
Escherichia coli	MPN100ml	**0**		BDL		

MONITORING WELL : MW–1

Program No.:			1	3	3	
Date (dd.mm.yy):			17.03.14	17.03.14	17.03.14	
				Maxxam	MB Labs	End of cycle test 2
TOTAL METALS	Unit	Standard				
Aluminum (Al)	ug/L			BDL	16	
Antimony (Sb)	ug/L	**6**		BDL	BDL	
Arsenic (As)	ug/L	**10**		15.2	16.2	
Barium (Ba)	ug/L	**1000**		55.9	53	
Beryllium (Be)	ug/L			BDL	BDL	
Bismuth (Bi)	ug/L			BDL		
Boron (B)	ug/L	**5000**		135	95	
Cadmium (Cd)	ug/L	**5**		BDL	BDL	
Cesium (Cs)	ug/L					
Chromium (Cr)	ug/L	**50**		BDL	BDL	
Cobalt (Co)	ug/L			0.5	BDL	
Copper (Cu)	ug/L	**1000**		2.92	0.20	
Iron (Fe)	ug/L	**300**		8.4	5.0	
Lanthanum (La)	ug/L				BDL	
Lead (Pb)	ug/L	**10**		0.27	BDL	
Lithium (Li)	ug/L					
Manganese (Mn)	ug/L	**50**		46.9	49.0	
Mercury (Hg)	ug/L	**1**		BDL	BDL	
Molybdenum (Mo)	ug/L			1.6	BDL	
Nickel (Ni)	ug/L			BDL	BDL	
Rubidium (Rb)	ug/L					
Selenium (Se)	ug/L	**10**		BDL	BDL	
Silicon (Si)	ug/L			8370	6630	
Silver (Ag)	ug/L			BDL	BDL	
Strontium (Sr)	ug/L			237	222	
Tellurium (Te)	ug/L					
Thallium (Tl)	ug/L			BDL		
Thorium (Th)	ug/L					
Tin (Sn)	ug/L			BDL	BDL	
Titanium (Ti)	ug/L			BDL	BDL	
Tungsten (W)	ug/L				BDL	
Uranium (U)	ug/L	**20**		0.53		
Vanadium (V)	ug/L			9.7	BDL	
Zinc (Zn)	ug/L	**5000**		BDL	BDL	
Zirconium (Zr)	ug/L			BDL		
Calcium (Ca)	mg/L			29.0	30.6	
Magnesium (Mg)	mg/L			9.25	9.97	
Potassium (K)	mg/L			1.82	1.93	
Sodium (Na)	mg/L	**200**		37.5	30.3	
Sulphur (S)	mg/L			3.2		

MONITORING WELL : MW-1

Program No.:			1	3	3																	
Date (dd.mm.yy):			17.03.14	17.03.14	17.03.14																	
				Maxxam	MB Labs	End of cycle test 2																
DISSOLVED METALS	Unit	Standard																				
Aluminum (Al)	ug/L																					
Antimony (Sb)	ug/L	6																				
Arsenic (As)	ug/L	10		13.8																		
Barium (Ba)	ug/L	1000																				
Beryllium (Be)	ug/L																					
Bismuth (Bi)	ug/L																					
Boron (B)	ug/L	5000																				
Cadmium (Cd)	ug/L	5																				
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	50																				
Cobalt (Co)	ug/L																					
Copper (Cu)	ug/L	1000																				
Iron (Fe)	ug/L	300																				
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	10																				
Lithium (Li)	ug/L																					
Manganese (Mn)	ug/L	50		49.6																		
Mercury (Hg)	ug/L	1																				
Molybdenum (Mo)	ug/L																					
Nickel (Ni)	ug/L																					
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	10																				
Silicon (Si)	ug/L																					
Silver (Ag)	ug/L																					
Strontium (Sr)	ug/L																					
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L																					
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L																					
Titanium (Ti)	ug/L																					
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	20																				
Vanadium (V)	ug/L																					
Zinc (Zn)	ug/L	5000																				
Zirconium (Zr)	ug/L																					
Calcium (Ca)	mg/L			28.5																		
Magnesium (Mg)	mg/L			8.88																		
Potassium (K)	mg/L																					
Sodium (Na)	mg/L	200																				
Sulphur (S)	mg/L																					

MONITORING WELL : MW-1

		Program No.:	1	3	3	
		Date (dd.mm.yy):	17.03.14	17.03.14	17.03.14	
				Maxxam	MB Labs	End of cycle test 2
SEMI VOLATILE ORGANICS	Unit	Standard				
Phenol	ug/L			BDL	BDL	
2-chlorophenol	ug/L			BDL		
3 & 4-chlorophenol	ug/L			BDL		
2-methylphenol	ug/L			BDL	BDL	
3 & 4-methylphenol	ug/L			BDL		
2-nitrophenol	ug/L			BDL	BDL	
2,4-dimethylphenol	ug/L			BDL	BDL	
2,4 + 2,5-dichlorophenol	ug/L			BDL	BDL	
2,3-dichlorophenol	ug/L			BDL		
2,6-dichlorophenol	ug/L			BDL		
3,5-dichlorophenol	ug/L			BDL		
3,4-dichlorophenol	ug/L			BDL		
2,4,5-trichlorophenol	ug/L			BDL		
2,4,6-trichlorophenol	ug/L	**5**		BDL	BDL	
2,3,5-trichlorophenol	ug/L			BDL		
2,3,6-trichlorophenol	ug/L			BDL		
2,3,4-trichlorophenol	ug/L			BDL		
3,4,5-trichlorophenol	ug/L			BDL		
2,4-dinitrophenol	ug/L			BDL		
4,6-diitro-2-methylphenol	ug/L			BDL		
2,3,4,6-tetrachlorophenol	ug/L	**100**		BDL		
2,3,4,5-tetrachlorophenol	ug/L			BDL		
2,3,5,6-tetrachlorophenol	ug/L			BDL		
4-nitrophenol	ug/L			BDL	BDL	
2,6-dimethylphenol	ug/L			BDL		
3,4-dimethylphenol	ug/L			BDL		
Pentachlorophenol	ug/L	**60**		BDL		
2,4,6-Tribromophenol (sur.)	%			96		
2-Fluorophenol (sur.)	%			59		
VOLATILE ORGANICS						
Chloroform	ug/L			BDL	BDL	
Chlorodibromomethane	ug/L			BDL		
Bromodichloromethane	ug/L			BDL	BDL	
Bromoform	ug/L			BDL	BDL	
1,4-Difluorobenzene (sur.)	%			91		
4-Bromofluorobenzene (sur.)	%			99	95.7	
D4-1,2-Dichloroethane (sur.)	%			101		
OTHER ORGANICS						
Monochloroacetic Acid (MCAA)	ug/L			BDL	BDL	
Monobromoacetic Acid (MBAA)	ug/L			BDL	BDL	
Dichloroacetic Acid (DCAA)	ug/L			BDL	BDL	
Trichloroacetic Acid (TCAA)	ug/L			BDL	BDL	
Bromochloroacetic Acid (BCAA)	ug/L			BDL	BDL	
Dibromoacetic Acid (DBAA)	ug/L			BDL	BDL	
Total haloacetic Acids	ug/L			BDL	BDL	
2,3-Dibromopropionic Acid	%			99	BDL	

4.4:

MW-2

MONITORING WELL : MW-2

Program No.:			1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1
Date (dd.mm.yy):			19.08.13	21.08.13	23.08.13	27.08.13	04.09.13	10.09.13	16.09.13	18.09.13	25.09.13	25.10.13	30.10.13	06.11.13	07.11.13	12.11.13	19.11.13	21.11.13	28.11.13	03.12.13	11.12.13	16.12.13
				Injection cycle test 1				End of injection cycle test 1		Production cycle test 1		Injection cycle test 2										
PHYSICAL PARAMETERS	Unit	Standard																				
Water temperature	°C	**15**	10.41	10.56	9.89	12.04	13.7	13.5	12.3	12.4	11.5	12.1	12.5	10.3		10.7	11.5		10.6	8.4	8.7	10.1
Conductivity	µS/cm		330	363	332	379	461	489	493	472	489	491	493	484	475	494	485	438	499	518	507	496
pH	pH units	**6.5 -**	9.07	8.41	7.98	8.57	9.09	8.69	8.58	8.64	8.56	8.57	8.75	8.51	8.7	8.8	8.91	9	8.85	8.63	9.17	8.9
Eh (Reducing Potential)	mV		-48.9	84.5	129.9	96.4	146.1	198.6	200.6	201	193.2	178.5	157	317.2		193.9	201.4		183.3	230.2	160.7	287.2
Total dissolved solids	mg/L	**500**	298	325	304	327	225	236	238	228	237	238	239	235	246	239	234	235	241	251	245	240
Total suspended solids	mg/L														47			27				
Colour	Col. Unit	**15**													10			10				
Corrosiveness																						
Dissolved oxygen	mg/L		1.06	2.88	2.58	2.42	2.91	3.61	3.22	3.61	4.52	4.97	3.52	8.51		6.15	4.77		5.23	5.93	6.41	8.72
Dissolved oxygen	%		9.5	26	22.9	22.8	29.9	35	29.6	34.3	42	46.4	33.4	74		57.1	43.5		47	53.8	54.7	79.3
Turbidity	NTU														50			22				
Salinity	ppt	**0.5**	0.22	0.24	0.23	0.24	0.22	0.24	0.24	0.23	0.24	0.24	0.24	0.23		0.23	0.24		0.25			0.24
Langelier Index (@ 4.4C)	-																					
Langelier Index (@ 60C)	-																					
Saturation pH (@ 4.4C)	-																					
Saturation pH (@ 60C)	-																					
INORGANICS																						
Alkalinity (total as CaCO3)	mg/L														120			101				
Alkalinity (PP as CaCO3)	mg/L														4.5			6.9				
Total Hardness (CaCO3)	mg/L														90.2			101				
Dissolved Hardness (CaCO3)	mg/L																					
Bicarbonate (HCO3)	mg/L														135			107				
Carbonate (CO3)	mg/L														5.4			8.3				
Silica (SiO2)	mg/L														9.38			9.88				
Hydroxide (HO)	mg/L														BDL			BDL				
Chlorine (Cl)	mg/L																					
Dissolved Chloride (Cl-)	mg/L	**250**													82.3			84.8				
Dissolved Fluoride (F)	mg/L	**1.5**													0.09			0.07				
Dissolved Orthophosphate (P)	mg/L																					
Dissolved Sulphate (SO4)	mg/L	**500**													0.85			BDL				
Sulphide (S)	mg/L	**0.05**																				
NUTRIENTS																						
Ammonia (N)	mg/L														0.32			0.34				
Dissolved Nitrate (N)	mg/L	**10**													0.02			BDL				
Dissolved Nitrite (N)	mg/L	**1**																				
Nitrate plus nitrite (N)	mg/L																					
Total Organic Nitrogen (N)	mg/L																					
Total Nitrogen (N)	mg/L																					
Total Phosphorus (P)	mg/L														0.199			0.148				
Dissolved Phosphorus (P)	mg/L																					
Total Organic Carbon (C)	mg/L																					
Dissolved Organic Carbon (C)	mg/L																					
MICROBIOLOGY																						
Total Coliform	MPN100ml	**0**																				
Non-coliform bacterial	MPN100ml																					
Iron bacteria	CFU/ml																					
Sulphur bacteria	CFU/ml																					
Heterotrophic Plate Count	CFU/ml																					
Escherichia coli	MPN100ml	**0**																				

MONITORING WELL : MW–2

Program No.:			1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1
Date (dd.mm.yy):			19.08.13	21.08.13	23.08.13	27.08.13	04.09.13	10.09.13	16.09.13	18.09.13	25.09.13	25.10.13	30.10.13	06.11.13	07.11.13	12.11.13	19.11.13	21.11.13	28.11.13	03.12.13	11.12.13	16.12.13
				Injection cycle test 1				End of injection cycle test 1		Production cycle test 1		Injection cycle test 2										
TOTAL METALS	Unit	Standard																				
Aluminum (Al)	ug/L														469			788				
Antimony (Sb)	ug/L	**6**													0.5			0.5				
Arsenic (As)	ug/L	**10**													4.06			4.57				
Barium (Ba)	ug/L	**1000**													24.2			26.4				
Beryllium (Be)	ug/L														0.1			0.1				
Bismuth (Bi)	ug/L														1			1				
Boron (B)	ug/L	**5000**													36			376				
Cadmium (Cd)	ug/L	**5**													0.122			0.228				
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	**50**													1			2				
Cobalt (Co)	ug/L														0.5			0.5				
Copper (Cu)	ug/L	**1000**													2.35			3.49				
Iron (Fe)	ug/L	**300**													7720			5690				
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	**10**													0.2			0.2				
Lithium (Li)	ug/L														5			5				
Manganese (Mn)	ug/L	**50**													79.4			77.4				
Mercury (Hg)	ug/L	**1**													BDL			BDL				
Molybdenum (Mo)	ug/L														3.7			3.6				
Nickel (Ni)	ug/L														1.4			1.8				
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	**10**													0.1			0.1				
Silicon (Si)	ug/L														6050			7440				
Silver (Ag)	ug/L														0.02			0.02				
Strontium (Sr)	ug/L														290			312				
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L														0.05			0.05				
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L														5			5				
Titanium (Ti)	ug/L														42.3			87.7				
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	**20**													0.11			0.11				
Vanadium (V)	ug/L														5			5				
Zinc (Zn)	ug/L	**5000**													5			5				
Zirconium (Zr)	ug/L														0.5			0.5				
Calcium (Ca)	mg/L														25.1			28.1				
Magnesium (Mg)	mg/L														6.69			7.44				
Potassium (K)	mg/L														2.8			3				
Sodium (Na)	mg/L	**200**													80			83.8				
Sulphur (S)	mg/L														3			3				

MONITORING WELL : MW-2

		Program No.:	-	2	2	2	2	2
		Date (dd.mm.yy):	18.12.13	23.01.14	06.02.14	25.02.14	11.03.14	17.03.14
PHYSICAL PARAMETERS	Unit	Standard						
Water temperature	°C	15						
Conductivity	µS/cm			437	437	433	427	432
pH	pH units	6.5 - 8.5		9.2	9.1	9.5	9.3	9.3
Eh (Reducing Potential)	mV							
Total dissolved solids	mg/L	500		236	208	227	235	217
Total suspended solids	mg/L							
Colour	Col. Unit	15		BDL	5	7	7	BDL
Corrosiveness								
Dissolved oxygen	mg/L							
Dissolved oxygen	%							
Turbidity	NTU		0.2	7.5	15	16	28	12
Salinity	ppt	0.5						
Langelier Index (@ 4.4C)	-							
Langelier Index (@ 60C)	-							
Saturation pH (@ 4.4C)	-							
Saturation pH (@ 60C)	-							
INORGANICS								
Alkalinity (total as CaCO3)	mg/L			91.8	93.7	91.2	92.6	91.3
Alkalinity (PP as CaCO3)	mg/L			8.8	8.2	BDL	10.3	10.1
Total Hardness (CaCO3)	mg/L		97.3	30.3	32.1	30.2	29.8	27.4
Dissolved Hardness (CaCO3)	mg/L		93.2					
Bicarbonate (HCO3)	mg/L			90.5	94.2	111	87.9	86.8
Carbonate (CO3)	mg/L			10.6	9.9	BDL	12.4	12.1
Silica (SiO2)	mg/L			BDL	BDL	1.58	BDL	BDL
Hydroxide (HO)	mg/L			BDL	BDL	BDL	BDL	BDL
Chlorine (Cl)	mg/L							
Dissolved Chloride (Cl-)	mg/L	250		77	77.7	84.4	84.5	82.3
Dissolved Fluoride (F)	mg/L	1.5		0.180	0.121	0.192	0.112	0.159
Dissolved Orthophosphate (P)	mg/L							
Dissolved Sulphate (SO4)	mg/L	500		BDL	BDL	BDL	BDL	BDL
Sulphide (S)	mg/L	0.05		0.0191	0.0163	0.0169	0.0159	0.0138
NUTRIENTS								
Ammonia (N)	mg/L			0.34	0.41	0.32	0.30	0.31
Dissolved Nitrate (N)	mg/L	10		BDL	0.029	0.016	0.028	BDL
Dissolved Nitrite (N)	mg/L	1		BDL				
Nitrate plus nitrite (N)	mg/L			BDL				
Total Organic Nitrogen (N)	mg/L							
Total Nitrogen (N)	mg/L							
Total Phosphorus (P)	mg/L			0.0108	0.0082	0.0065	0.0074	BDL
Dissolved Phosphorus (P)	mg/L							
Total Organic Carbon (C)	mg/L							
Dissolved Organic Carbon (C)	mg/L							
MICROBIOLOGY								
Total Coliform	MPN100ml	0						
Non-coliform bacterial	MPN100ml							
Iron bacteria	CFU/ml							
Sulphur bacteria	CFU/ml							
Heterotrophic Plate Count	CFU/ml							
Escherichia coli	MPN100ml	0						

End of cycle test 2

MONITORING WELL : MW–2

End of cycle test 2

		Program No.:	-	2	2	2	2	2
		Date (dd.mm.yy):	18.12.13	23.01.14	06.02.14	25.02.14	11.03.14	17.03.14
TOTAL METALS	Unit	Standard						
Aluminum (Al)	ug/L		4.4	26.2	15.1	14.4	10.6	5.8
Antimony (Sb)	ug/L	**6**	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic (As)	ug/L	**10**	4.05	0.22	0.12	0.15	0.18	0.15
Barium (Ba)	ug/L	**1000**	24.3	6.5	6.4	4.7	5.3	6.1
Beryllium (Be)	ug/L		BDL	BDL	BDL	BDL	BDL	BDL
Bismuth (Bi)	ug/L		BDL	BDL	BDL	BDL	BDL	BDL
Boron (B)	ug/L	**5000**	386	313	354	302	280	285
Cadmium (Cd)	ug/L	**5**	BDL	0.234	0.027	0.01	0.282	0.018
Cesium (Cs)	ug/L							
Chromium (Cr)	ug/L	**50**	BDL	BDL	BDL	BDL	BDL	BDL
Cobalt (Co)	ug/L		BDL	BDL	BDL	BDL	BDL	BDL
Copper (Cu)	ug/L	**1000**	0.6	3.98	0.78	0.33	2.09	0.86
Iron (Fe)	ug/L	**300**	72.4	**2,230**	**1,540**	**1,170**	**1,630**	**1,070**
Lanthanum (La)	ug/L							
Lead (Pb)	ug/L	**10**	BDL	0.26	BDL	BDL	BDL	BDL
Lithium (Li)	ug/L		BDL	BDL				
Manganese (Mn)	ug/L	**50**	25.6	49	39	31	43.6	29.5
Mercury (Hg)	ug/L	**1**		BDL	BDL	BDL	BDL	BDL
Molybdenum (Mo)	ug/L		3.6	3.5	2.2	2.9	1.6	3.0
Nickel (Ni)	ug/L		BDL	1.1	BDL	BDL	BDL	BDL
Rubidium (Rb)	ug/L							
Selenium (Se)	ug/L	**10**	BDL	BDL	BDL	BDL	BDL	BDL
Silicon (Si)	ug/L		5870	144	149	109	153	126
Silver (Ag)	ug/L		BDL	BDL	BDL	BDL	BDL	BDL
Strontium (Sr)	ug/L		321	114	112	99.1	109	98.4
Tellurium (Te)	ug/L							
Thallium (Tl)	ug/L		BDL	BDL	BDL	BDL	BDL	BDL
Thorium (Th)	ug/L							
Tin (Sn)	ug/L		BDL	BDL	BDL	BDL	BDL	BDL
Titanium (Ti)	ug/L		BDL	BDL	BDL	BDL	BDL	BDL
Tungsten (W)	ug/L							
Uranium (U)	ug/L	**20**	0.12	BDL	BDL	BDL	BDL	BDL
Vanadium (V)	ug/L		BDL	BDL	BDL	BDL	BDL	BDL
Zinc (Zn)	ug/L	**5000**	BDL	5.5	BDL	5.9	BDL	BDL
Zirconium (Zr)	ug/L		BDL	BDL	BDL	BDL	BDL	BDL
Calcium (Ca)	mg/L		27.9	5.36	5.77	5.03	5.7	4.86
Magnesium (Mg)	mg/L		6.73	4.11	4.3	4.27	4.1	3.70
Potassium (K)	mg/L		2.98	2.69	2.75	2.74	3.03	2.71
Sodium (Na)	mg/L	**200**	75.6	71.6	75.8	78.7	78.8	72.8
Sulphur (S)	mg/L		BDL	BDL	BDL	BDL	BDL	BDL

MONITORING WELL : MW-2

		Program No.:	-	2	2	2	2	2														
		Date (dd.mm.yy):	18.12.13	23.01.14	06.02.14	25.02.14	11.03.14	17.03.14														
DISSOLVED METALS	Unit	Standard																				
Aluminum (Al)	ug/L		BDL																			
Antimony (Sb)	ug/L	**6**	BDL																			
Arsenic (As)	ug/L	**10**	4.25																			
Barium (Ba)	ug/L	**1000**	23.0																			
Beryllium (Be)	ug/L		BDL																			
Bismuth (Bi)	ug/L		BDL																			
Boron (B)	ug/L	**5000**	363																			
Cadmium (Cd)	ug/L	**5**	BDL																			
Cesium (Cs)	ug/L																					
Chromium (Cr)	ug/L	**50**	BDL																			
Cobalt (Co)	ug/L		BDL																			
Copper (Cu)	ug/L	**1000**	0.39																			
Iron (Fe)	ug/L	**300**	13.9																			
Lanthanum (La)	ug/L																					
Lead (Pb)	ug/L	**10**	BDL																			
Lithium (Li)	ug/L		BDL																			
Manganese (Mn)	ug/L	**50**	23.7																			
Mercury (Hg)	ug/L	**1**																				
Molybdenum (Mo)	ug/L		4.0																			
Nickel (Ni)	ug/L		BDL																			
Rubidium (Rb)	ug/L																					
Selenium (Se)	ug/L	**10**	BDL																			
Silicon (Si)	ug/L		5,650																			
Silver (Ag)	ug/L		BDL																			
Strontium (Sr)	ug/L		327																			
Tellurium (Te)	ug/L																					
Thallium (Tl)	ug/L		BDL																			
Thorium (Th)	ug/L																					
Tin (Sn)	ug/L		BDL																			
Titanium (Ti)	ug/L		BDL																			
Tungsten (W)	ug/L																					
Uranium (U)	ug/L	**20**	0.13																			
Vanadium (V)	ug/L		BDL																			
Zinc (Zn)	ug/L	**5000**	BDL																			
Zirconium (Zr)	ug/L		BDL																			
Calcium (Ca)	mg/L		26.3																			
Magnesium (Mg)	mg/L		6.67																			
Potassium (K)	mg/L		2.91																			
Sodium (Na)	mg/L	**200**	75.6																			
Sulphur (S)	mg/L		BDL																			

End of cycle test 2

4.5:

ID.50036 (WEIGHT SCALE)

Program No.: -
Date (dd.mm.yy): 25-02-14

INORGANICS	Unit	Standard	
Total Hardness (CaCO3)	mg/L		112
TOTAL METALS			
Aluminum (Al)	ug/L		BDL
Antimony (Sb)	ug/L	**6**	BDL
Arsenic (As)	ug/L	**10**	0.66
Barium (Ba)	ug/L	**1000**	6.0
Beryllium (Be)	ug/L		BDL
Bismuth (Bi)	ug/L		BDL
Boron (B)	ug/L	**5000**	BDL
Cadmium (Cd)	ug/L	**5**	0.011
Cesium (Cs)	ug/L		
Chromium (Cr)	ug/L	**50**	BDL
Cobalt (Co)	ug/L		BDL
Copper (Cu)	ug/L	**1000**	17.0
Iron (Fe)	ug/L	**300**	BDL
Lanthanum (La)	ug/L		
Lead (Pb)	ug/L	**10**	1.51
Lithium (Li)	ug/L		
Manganese (Mn)	ug/L	**50**	1.0
Mercury (Hg)	ug/L	**1**	BDL
Molybdenum (Mo)	ug/L		BDL
Nickel (Ni)	ug/L		1.0
Rubidium (Rb)	ug/L		
Selenium (Se)	ug/L	**10**	BDL
Silicon (Si)	ug/L		6,980
Silver (Ag)	ug/L		BDL
Strontium (Sr)	ug/L		134
Tellurium (Te)	ug/L		
Thallium (Tl)	ug/L		BDL
Thorium (Th)	ug/L		
Tin (Sn)	ug/L		BDL
Titanium (Ti)	ug/L		BDL
Tungsten (W)	ug/L		
Uranium (U)	ug/L	**20**	BDL
Vanadium (V)	ug/L		BDL
Zinc (Zn)	ug/L	**5000**	80.5
Zirconium (Zr)	ug/L		BDL
Calcium (Ca)	mg/L		30.2
Magnesium (Mg)	mg/L		8.86
Potassium (K)	mg/L		0.855
Sodium (Na)	mg/L	**200**	11.7
Sulphur (S)	mg/L		BDL

APPENDIX G

Well ID.14506 on Claudet Road

WELL LOG RECORD
ID Plate No. 14506

PROJECT:	**RDN**	GROUND ELEVATION:	**193 ft**
PROJECT No.:	**N/A**	WELL DEPTH:	**199 ft**
DATE:	**22/10/2008**	STATIC WATER LEVEL:	**151 ft**
WELL ID. PLATE No.:	**145106**	METHOD OF DRILLING:	**Air Rotary**
LOCATION:	**Claudet Rd, Nanoose Bay**	METHOD OF DEVELOPMENT:	**Air lifting**
DRILLING CONTRACTOR:	**Fyfe's**	ESTIMATED YIELD:	**100+ USgpm**
CLIENT:	**RDN**	LOGGED BY:	**Fyfe/Hodge**

Depth (feet bgl.)		**Geologic Formation**		
From	**To**	**Description**	**Colour**	**Relative hardness**
0	5	Fine silty sand	Brown	Compact
5	20	Sandy till	Grey	Medium hard
20	80	↗ clay; ↘ sand		
80	130	Wet silty sand	Grey	Compact
130	150	Wet sandy clay	Grey	Compact
150	170	Cemented sand and gravel dry	Grey	
170	183	Fine sand and gravel, clay wash *Air lift: 50+ gpm*		
183	184	Sand and gravel; ↗ gravel *Air lift: 100 gpm*		
184	186	Coarse sand and gravel; ↘ clay *Air lift: 100+ gpm*		
186	197	Coarse sand and gravel, slight ↗ fine sand and clay wash *Air lift: 100 gpm*		
197	200	Fine to coarse sand w/ some gravel; high clay wash *Air lift: 50+ gpm*		
200	210	Fine sand w/ some gravel; clay wash *Air lift: 30 gpm*		
		Completed depth = 199 ft.		

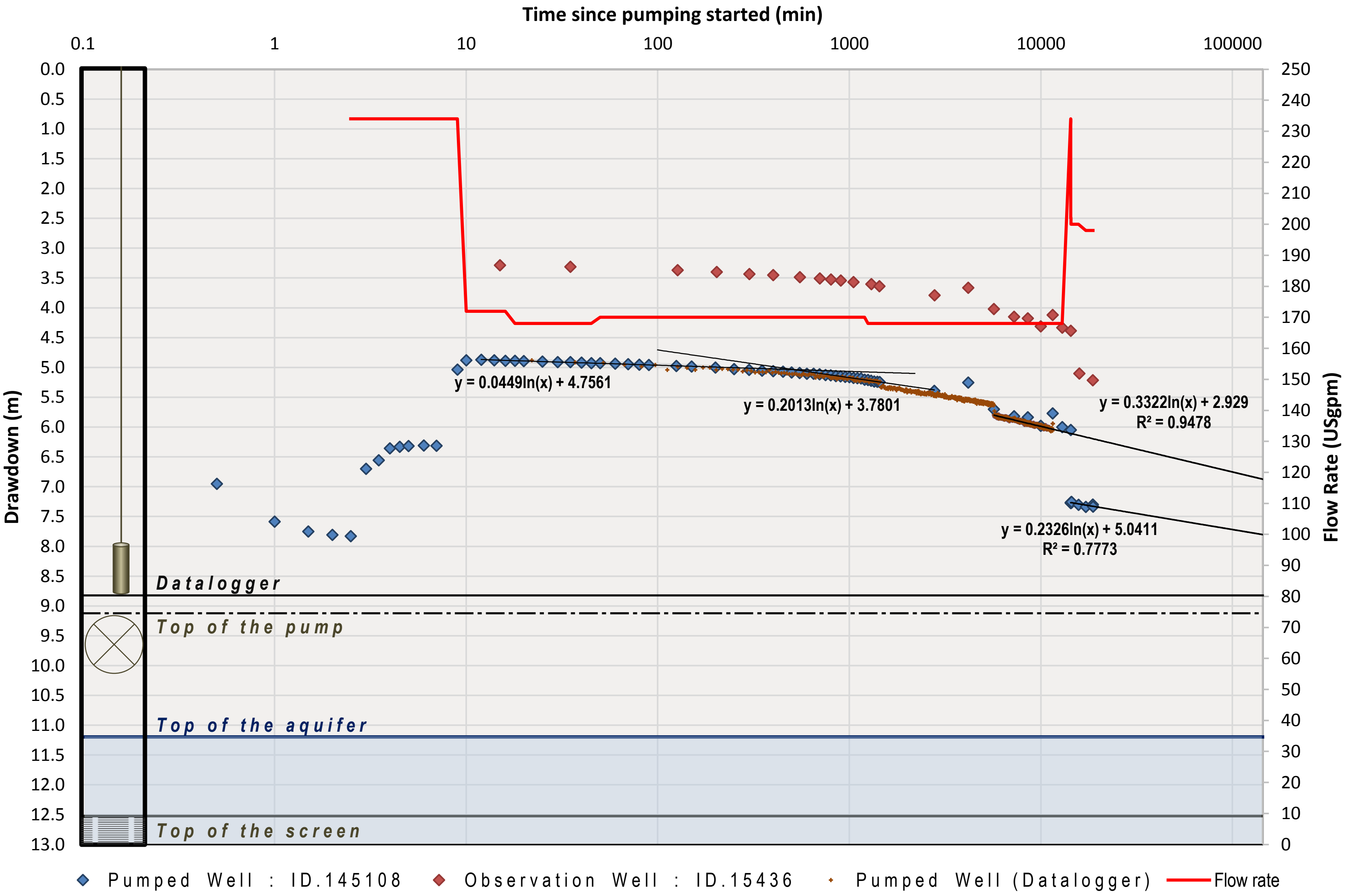
bgl. = below ground level

Depth (feet bgl.)		**Well Construction**
From	**To**	
2	0	Stick-up
0	191	Casing : 8-inch diameter
0	*17.5*	Bentonite seal (2-inch continuous seal)
191	199	Screen : 8-inch diameter; stainless steel; 250 slot
199	210	Back fill

Notes:

Water: Fresh, clear

Graph G1 - Drawdown plot at wells ID.14506 and ID.15436



WATER QUALITY RESULTS

PARAMETER	UNIT	ID.14506 (Claudet Road)	Health Canada*
Physical Properties			
pH	*pH unit*	8.17	*6.5 – 8.5*
Alkalinity (total as $CaCO_3$)	*mg/L*	149	*No limit set*
Alkalinity (PP as $CaCO_3$)	*mg/L*	<0.5	*No limit set*
Conductivity	*uS/cm*	340	*No limit set*
Total dissolved solids	*mg/L*	214	*500*
Total suspended solids	*mg/L*	<4	*No limit set*
Hardness (total as $CaCO_3$)	*mg/L*	137	*No limit set*
Dissolved hardness ($CaCO_3$)	*Mg/L*	136	*No limit set*
Nutrients			
Ammonia (N)	*mg/L*	1.21	*No limit set*
Dissolved nitrate (N)	*mg/L*	<0.02	*10*
Dissolved nitrite (N)	*mg/L*	<0.005	*1*
Nitrate + Nitrite (N)	*mg/L*	<0.02	*No limit set*
Total nitrogen (N)	*mg/L*		*No limit set*
Inorganics			
Bicarbonate (HCO3)	*mg/L*	182	*No limit set*
Carbonate (CO3)	*mg/L*	<0.5	*No limit set*
Hydroxide (OH)	*mg/L*	<0.5	*No limit set*
Dissolved chloride (Cl)	*mg/L*	8.6	*250*
Dissolved fluoride (F)	*mg/L*	0.140	*1.5*
Dissolved sulphate (SO4)	*mg/L*	13.0	*500*
Microbiology			
E. Coli	*CFU/100mL*	<1	*0*
Total Coliform	*CFU/100mL*	<1	*0*
Fecal coliform	*CFU/100mL*	<1	*0*

Follows on next page

PARAMETER	UNIT	ID.14506 (Claudet Road)	Health Canada*
Total Metals			
Aluminum (Al)	*ug/L*	<3.0	*100*
Antimony (Sb)	*ug/L*	<0.5	*6*
Arsenic (As)	*ug/L*	0.25	*10*
Barium (Ba)	*ug/L*	13.0	*1000*
Beryllium (Be)	*ug/L*	<0.1	*No limit set*
Bismuth (Bi)	*ug/L*	<1.0	*No limit set*
Boron (B)	*ug/L*	<50	*5000*
Cadmium (Cd)	*ug/L*	<0.01	*5*
Chromium (Cr)	*ug/L*	<1.0	*50*
Cobalt (Co)	*ug/L*	<0.5	*No limit set*
Copper (Cu)	*ug/L*	<0.2	*1000*
Iron (Fe)	*ug/L*	334	*300*
Lead (Pb)	*ug/L*	<0.2	*10*
Lithium (Li)	*ug/L*	<5.0	
Manganese (Mn)	*ug/L*	**164**	*50*
Mercury (Hg)	*ug/L*	<0.05	*1*
Molybdenum (Mo)	*ug/L*	<1.0	*No limit set*
Nickel (Ni)	*ug/L*	<1.0	*No limit set*
Selenium (Se)	*ug/L*	<0.1	*10*
Silicon (Si)	*ug/L*	11,800	*No limit set*
Silver (Ag)	*ug/L*	<0.02	*No limit set*
Strontium (Sr)	*ug/L*	126	*No limit set*
Thallium (Tl)	*ug/L*	<0.05	*No limit set*
Tin (Sn)	*ug/L*	<5.0	*No limit set*
Titanium (Ti)	*ug/L*	<5.0	*No limit set*
Uranium (U)	*ug/L*	<0.1	*20*
Vanadium (V)	*ug/L*	<5.0	*No limit set*
Zinc (Zn)	*ug/L*	<5.0	*5000*
Zirconium (Zr)	*ug/L*	<0.5	*No limit set*
Calcium (Ca)	*mg/L*	36.0	*No limit set*
Magnesium (Mg)	*mg/L*	11.5	*No limit set*
Potassium (K)	*mg/L*	2.79	*No limit set*
Sodium (Na)	*mg/L*	14.8	*200*
Sulphur (S)	*mg/L*	4.3	*No limit set*

Follows on next page

PARAMETER	UNIT	ID.14506 (Claudet Road)	Health Canada*
Dissolved Metals			
Aluminum (Al)	*ug/L*	<3	*100*
Antimony (Sb)	*ug/L*	<0.5	*6*
Arsenic (As)	*ug/L*	0.25	*10*
Barium (Ba)	*ug/L*	12.2	*1000*
Beryllium (Be)	*ug/L*	<0.1	*No limit set*
Bismuth (Bi)	*ug/L*	<1.0	*No limit set*
Boron (B)	*ug/L*	<50	*5000*
Cadmium (Cd)	*ug/L*	<0.01	*5*
Chromium (Cr)	*ug/L*	<1.0	*50*
Cobalt (Co)	*ug/L*	<0.5	*No limit set*
Copper (Cu)	*ug/L*	<0.2	*1000*
Iron (Fe)	*ug/L*	83.4	*300*
Lead (Pb)	*ug/L*	<0.2	*10*
Lithium (Li)	*ug/L*	<5.0	
Manganese (Mn)	*ug/L*	**167**	*50*
Mercury (Hg)	*ug/L*	<0.05	*1*
Molybdenum (Mo)	*ug/L*	<1.0	*No limit set*
Nickel (Ni)	*ug/L*	<1.0	*No limit set*
Selenium (Se)	*ug/L*	<0.1	*10*
Silicon (Si)	*ug/L*	12,100	*No limit set*
Silver (Ag)	*ug/L*	<0.02	*No limit set*
Strontium (Sr)	*ug/L*	128	*No limit set*
Thallium (Tl)	*ug/L*	<0.05	*No limit set*
Tin (Sn)	*ug/L*	<5.0	*No limit set*
Titanium (Ti)	*ug/L*	<5.0	*No limit set*
Uranium (U)	*ug/L*	<0.1	*20*
Vanadium (V)	*ug/L*	<5.0	*No limit set*
Zinc (Zn)	*ug/L*	<5.0	*5000*
Zirconium (Zr)	*ug/L*	<0.5	*No limit set*
Calcium (Ca)	*mg/L*	34.8	*No limit set*
Magnesium (Mg)	*mg/L*	11.9	*No limit set*
Potassium (K)	*mg/L*	2.77	*No limit set*
Sodium (Na)	*mg/L*	14.3	*200*
Sulphur (S)	*mg/L*	3.6	*No limit set*

** Canadian Drinking Water Guidelines (2010)*