Appendix N

Pogo Injection Well Test Program & Modeled Predictions

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Pogo Injection Well Test Program and Modeled Predictions

Pogo Project, Alaska

FINAL REPORT

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SUMMARY

The Pogo mine requires a system to discharge treated mine drainage, which to date has been discharged via two permitted injection wells; INJ-1 and INJ-2. To create sufficient capacity throughout the mine development period, the capacity of the system comprised of INJ-1 and INJ-2 would need to be increased. AMEC was retained to evaluate the aquifer in the vicinity of the existing injection wells by completion and testing a recently installed candidate injection well; INJ-3. The work was also to include modeled assessment of INJ-3 and recommendations for any further wells required to meet project requirements.

Based on the 2001 field investigation and the numerical modeling, the following can be summarized:

- Based on grain size data, INJ-3, a test well and candidate injection well, was constructed by screening 35 feet of the aquifer. A telescopic well screen was installed across the aquifer section from 38.3-75.3 feet bgs. The d_{60} particle diameter was selected as a guide for screen slot size selection. The screen design included (from top to bottom) 10 feet of 60 slot (6/1000 inch aperture), followed by 5 feet of 30 slot, 10 feet of 60 slot, and 10 feet of 30 slot. A 4-foot sump was attached to the bottom of the screen assembly, and a 4-foot sub and K-packer assembly to the top of the well screen assembly.

- Well development at INJ-3 was completed over a 5-hour period. Sediment samples were collected in order to monitor the sediment production from the well. The intent of screen development was to remove 60% of the fines for some distance (typically 1.5-3 feet) adjacent to the screen wall to develop a coarse, natural gravel filter around the screen intake. Five passes across the screen with the development tool were completed during the well development, thereby arriving at a near sediment-free condition.

- A step-pumping test was conducted in INJ-3. Flow and drawdown data collected during the test indicate that INJ-3 demonstrated specific capacity in the range of 50 to 60 gpm per foot of completed well. Typically in unconfined aquifers, injection capacity will provide roughly one-half of the pumping capacity.

- Based on a 72-hour pumping and recovery test, the transmissivity of the Goodpaster River Valley aquifer, in the vicinity of INJ-3, is estimated to be in the range of 0.012-0.017 m^2/s with a mean value of 0.015 m^2/s. The specific yield is estimated to range from 0.003 to 0.09 with a mean value of 0.05.

- Based on water production tests at INJ-3, the aquifer in the vicinity of the initial injection wells and the new test well continues to be laterally extensive and would be suitable for an expanded injection program. Based on water chemistry, iron and manganese oxides and hydroxides may have formed near INJ-1 and INJ-2 but do not appear to have caused aquifer damage.

- The numerical aquifer model MODFLOW was used to simulate the impacts of injecting water at a rate of 200 and 400gpm for a one to three well system on a steady basis. For a three well system, the water was assumed to be equally injected through the three injection wells, all being constructed and having hydraulic characteristics consistent with INJ-3. The modeling demonstrates that a single well with the properties of INJ-3 would be sufficient to provide model capacity but that three wells would provide a high degree of system redundancy.

- Under steady state conditions, water table mounding of 1.6 and 3.2 feet is estimated at the injection wells for the 200 and 400gpm scenarios, respectively.

- Particle tracing from the injection wells for the 200 and 400gpm scenarios show particles approach the area of the river at depth and with perhaps some of flow potentially reporting to the river itself. Purely advective travel times to the subsurface near the river for the 200gpm case were estimated to average almost 1000 days. For the 400gpm case, the estimated average travel time to the Goodpaster River is just over 750 days.

Therefore, in summary, the recently installed candidate injection well, INJ-3, demonstrates modeled capacity for the likely requirements of the development phase of the project. To deal with inherent aquifer inhomongenieties, one or more redundant wells to augment INJ-3, or an equivalence to INJ-3, are recommended. Modeling was carried out with a three-well system at sustained rates of either 200gpm or 400gpm where all three wells have similar characteristics to INJ-3 and such a system can readily handle those sustained flows.

1.0 INTRODUCTION

1.1 Background

The Pogo project is a gold prospect that is currently undergoing a feasibility-level evaluation. The project is a joint venture between Teck-Cominco (40%, formerly Teck Corporation or Teck) and Sumitomo Metal Mining Company (60%). The site is located approximately 38 miles northeast of Delta Junction and 90 miles southeast of Fairbanks, Alaska (see Drawing A0172-05-001).

As part of advanced exploration work on the prospect, an exploration decline and associated water treatment plant were constructed during 1998-1999. Injection wells were placed and permitted to dispose of the treated groundwater that was extracted from the underground workings and processed through the water treatment plant. Two injection wells (INJ-1, INJ-2) were drilled approximately 20 feet apart and both were completed in the sand and gravel deposits located within the Goodpaster River Floodplain. The site layout and injection well locations are shown on Drawing A0172-05-002. These existing injection wells and a new test well (INJ-3), drilled in 2001, are the subject of this report.

1.2 Objectives and Scope of Work

Although the existing injection wells (INJ-1, INJ-2) have met the requisite capacity of treated groundwater discharge at the Pogo site, it was expected that additional injection capacity was required for the remainder of the project development period. The objective of the 2001 program was to review existing data to assess aquifer characteristics so that an injection well program could be designed to support future development. The scope of work included the drilling, installation, and testing of a new candidate injection well (INJ-3) near the existing injection wells. The work scope also included modeling to predict physical behaviour from projected injection rates from this new well as well as for two proposed wells with similar characteristics to INJ-3.

2.0 SITE HYDROGEOLOGY AND EXISTING INJECTION WELL SYSTEM

The physiography of the Pogo project site is characterized by rolling hills and mountains of the Tanana Uplands region. A web work of major creeks drain the local topography in a general west direction towards the Goodpaster River located at about 1300 feet above sea level (ftasl). Pogo Ridge is a major topographical feature at the site and is situated at approximately 4000 ftasl. These upland areas drain to local creeks and into the Goodpaster River, which itself drains into the Tanana River. The confluence of the Tanana and Goodpaster rivers is located some 38 miles to the southwest at Delta Junction.

The local bedrock geology is comprised of a series of meta-sedimentary, igneous, and meta-igneous rocks. Ortho-gneiss (meta-igneous) and para-gneiss (meta-sedimentary) is the dominant rock-type underlying Pogo ridge. The Goodpaster River batholith is a large granitoid body of mid-cretaceous age located to the north of the area and numerous related granite dykes are found intruding gneissic rocks in the vicinity of Pogo Ridge. Gold-bearing quartz veins appear to be roughly parallel and contemporaneous with the granite dykes observed in the area of Pogo Ridge. A diorite intrusive is located within the Liese Creek area and appears younger and unrelated to the mineralization. Bedrock hydrogeology has been previously discussed (Adrian Brown, 2000, Ref. 1) and will not be discussed in this report.

Alluvial sediments that fill the Goodpaster River Valley comprise predominantly coarse sands and gravel. These sediments are in excess of 100 feet thick near the center of the valley with decreased thickness nearer the valley flanks. In the vicinity of the of the injection wells, the sand and gravel deposits are approximately 75 feet in thickness. The hydrogeology of the Goodpaster River Valley has been previously presented in Golder, 1998 (Ref. 2); Teck, April 2000 (Ref. 3)); AMEC, 2000 (Ref 4); AMEC 2001 (Ref 5) and will only be briefly summarized herein.

The Goodpaster River Valley in the vicinity of the Pogo Camp is host to an unconfined sand and gravel aquifer recharged directly by precipitation, the Goodpaster River, and groundwater discharging from drainage areas and surrounding bedrock. The aquifer is subject to permafrost distal to the Goodpaster River's thermal influence. The water table configuration mimics topography and horizontal hydraulic gradients are approximately equal to, and sub-parallel to the Goodpaster River. Groundwater-surface water interactions vary seasonally. The sand and gravel aquifer is recharged by the river during the spring freshette, and groundwater discharges to the Goodpaster River during low flows in the fall and winter seasons. This sand and gravel aquifer, located in the vicinity of the injection wells, is the subject of the enclosed report.

3.0 FIELD PROGRAM METHODOLOGY AND DATA COLLECTION – 2001

3.1 Planning

Prior to commencing the field program, the available data and aquifer modeling study carried out by Golder was reviewed. To meet the conceptual injection rates indicated by the mine inflow work carried out by Adrian Brown Consultants, candidate injection well locations were selected. These locations, INJ-3, INJ-4 and INJ-5, respectively, were approximately positioned to maximize injection efficiency and minimize mounding based upon "first-cut" modeling prior to any aquifer testing. The 2001 field program objective was to complete one test well (INJ-3) in order to facilitate testing of the aquifer. Placement of any additional wells, if indicated by testing and modeling, would be carried out at a later date.

3.2 Drilling and Casing Installation

Drilling was initiated at INJ-3 on July 24, and the hole was completed on July 26, 2001. The Foundex drill rig used to complete the test well was a Helicopter Transportable (HT)-700 equipped with an ODEX system including a downhole hammer and three air compressors connected in tandem; one NCA 200 psi/400CFM, one NCA 200 psi/300CFM, and one NCA 100psi/800CFM. The test hole was drilled and the casing was installed in 5 foot sections, with each section of casing being welded at the joints. The steel well casing used to construct the well was 8.625 inch outside diameter (OD) with a wall thickness of 0.25 inches (8.125 ID). The drill head was also connected to a cyclone to divert the cuttings for removal of sediment and groundwater from the borehole and for sample collection. Drilling was terminated at approximately 5 feet into the top of bedrock (79.5 ftbgs) that was intersected at 74.5 feet below ground surface (ftbgs). No bentonite mud, or similar, was used to place the casing.

The downhole hammer assembly was used to "pull" the casing as drilling proceeds, thereby effectively sealing all geological units from the ground surface to the casing shoe. Once the screen design was complete, the casing was cut just above the casing shoe, the screen assembly installed, and the casing pulled back to expose the screen. This completion is a typical "telescopic" well completion where the surface casing is naturally sealed and typically does not require grouting, as there is no annular space between the casing and the formation. Photographs showing the drill assembly and the hydraulic casing puller are presented in Appendix A.

3.3 Sampling and Grain Size Analysis

A wheelbarrow was placed under the cyclone to collect sediment samples at 5-foot intervals. The contents of the wheelbarrow were placed on a 4ft by 8ft sheet of plywood, evenly distributed, and a 2-3 kg grab sample collected. The sample was place in a plastic sample bag and taken to Teck's on-site sediment and core laboratory.

Grain size analyses (dry sieve) were conducted at the on-site laboratory. The following equipment was used to complete the analysis:

- Humbolt Splitter apparatus, Model H-3992,
- Acculab VI 1200 electronic balance,

- Ro-Tap Model RX-29 sediment shaker apparatus manufactured by W.S. Tyler,
- USA Standard Testing Sieves, ASTME-11 Specification, 1", ¾", 3/8", #4, #10, #20, #40, #60, #140, and #200.

A 1000 g to 1400 g sample was first passed through the splitter apparatus. The sample split (500 g - 700 g) was weighed and recorded before being placed through the 1" to # 10 sieve stack and on the shaker. The shaker was run for 10 minutes and each sieve weighed and recorded, and the contents of the pan placed in sieves #20 to #200 for the second round of shaking. All testing was carried out per ASTM instruction.

Individual sieve samples were also inspected visually and using a hand lens to determine if the samples had been pulverized by the drilling process. In all cases, sand and gravel samples collected were essentially intact, except where cobbles larger than 3" or bedrock was intersected.

Once grain size data was obtained, the data was input into an Excel spreadsheet, a plot generated, and various sediment textural parameters calculated to classify the sample according to the Unified Soil Classification System (USCS). The grain size curves developed and associated information are presented in Appendix B.

3.4 Screen Selection and Well Construction

Based on the grain size data, a 35 foot section of the aquifer was selected for screen installation. A telescopic well screen was installed across the aquifer section from 38.3-75.3 feet bgs. The d_{60} particle diameter was selected as a guide for screen slot size selection. The d_{60} particle diameter is the grain size for which 60% of the formation materials will enter the screen, and 40% will not. In this manner, once fully developed, the 40% coarse fraction of the formational material would remain along the along the length of the screen intake. The screen design included (from top to bottom) 10 ft of 60 slot (6/1000 inch aperture), followed by 5 feet of 30 slot, 10 feet of 60 slot, and 10 feet of 30 slot. A 4 foot sump was attached to the bottom of the screen assembly, and a 4 foot sub and K-packer assembly to the top of the well screen assembly. Photos showing the screen assembly are presented in Appendix A.

The well casing was cut at about 3.5 feet above the casing shoe prior to installing the screen assembly. The screen was then inserted into the drill casing to the base of the hole (79.3 ft bgs) and the well casing pulled back with hydraulic jacks at the surface to expose the well screen. The K-packer assembly remained within the well casing to complete the seal between the casing and the screen. The INJ-3 well completion diagram is presented on Drawing A0172-05-003 and the completion summary is listed below.

- **Location**: N3819433.05, E1808150.44
- **Date of Construction**: August 8, 2000
- **Well Casing Elevation**: 1329.7 ft asl
- **Well head Stickup**: 1.25 ft ags
- **Depth to Bedrock**: 74.5 ft bgs
- **Well Depth**: 79.3 ft bgs
- **Well Casing Inside Diameter:** 8.125 inches

- **Top of Well Screen Assembly**: 34.12 ft bgs
- **Top of Well Screen:** 38.3 ft bgs
- **Bottom of Well Screen:** 75.3 ft bgs
- **Well Screen Inside Diameter:** 6.375 inches
- **Well Screen Slot Openings:** 10 ft-60 slot, 5 ft-30 slot, 10 ft-60 slot, 10 ft -30 slot
- **Bottom of Sump:** 79.3 ft bgs
- **Inside Diameter of Sump:** 6.375 inches
- **Static Water Level:** 6.60 feet below top of casing (m btoc) (October 6, 2001)
- **Maximum Sustained Rate**: 396gpm
- **Pumping Level at Completion of Testing**: 14.62 ft btoc @ 396gpm

3.5 Well Development

Well development was completed using a jetting tool made by drilling small holes in spiral configuration over a 4 foot long steel section of 4" diameter pipe. The tool was fitted to the end of the drill rods and inserted into the screen section of the well. The tool was rotated slowly, and run down each 5 foot section of screen for an hour each pass. Sediment samples were collected in a wheelbarrow in order to monitor the sediment production from the well. The intent of screen development was to remove 60% of the fines for some distance (typically 1.5-3 feet) adjacent to the screen wall so as to develop a coarse, natural gravel filter around the screen intake. This method of well development is common for this type of installation and for water supply well development. A total of 58 hours and a total of five passes were completed in developing the well screen to a near sediment-free condition.

3.6 Hydraulic Testing - Step Test and 72 hour Aquifer Test

Two tests were carried out to assess the efficiency of the newly completed well (step test) and to assess the lateral extent of the sand and gravel aquifer in the area of the injection wells (72 hour test). A 6" diameter, Crown submersible pump (model S6-350) equipped with a 15 hp motor was temporarily installed in the well to a total depth of 35 feet below top of casing (BTOC). Pump curves are provided in Appendix C.

The pump was hung on standard 4" steel pipe with threaded couplings. The wellhead was completed with a 90 degree elbow, flow control valve, and flow meter. A 4" discharge hose was connected to the outlet and water was allowed to flow into the gravel pit area located approximately 500 feet northwest of the well. Photos showing the wellhead arrangement are presented in Appendix A.

4.0 RESULTS OF FIELD TESTING AND DISCUSSION

4.1 Well Development Criteria

Sediment production during well development was monitored as described in Section 3 and is presented in Table 4.1 for the 4th and 5th pass.

Table 4.1: Sediment Production from INJ-3 Well at Pass 4 and 5

Pass #	Screen Interval (feet)	Development Time (hours)	Slot Size	Weight of Sediment (g)
4	40-45	1	60	8000
4	45-50	1	60	3000
4	50-55	1	30	2290
4	55-60	1	60	2270
4	60-65	1	60	1400
4	65-70	1	30	1750
4	70-75	1	30	1750
Total Pass 4 (g) =				**20460**
5	40-45	1	60	6000
5	45-50	1	60	2750
5	50-55	1	30	2700
5	55-60	1	60	2750
5	60-65	1	60	1750
5	65-70	1	30	1750
5	70-75	1	30	2350
Total Pass 5 (g) =				**20050**

The total mass of sand production was monitored over each 5 foot section of screen and was significantly reduced by the 4th and 5th pass. At that time, a test was initiated to assess sediment production over the entire screen. Test results are presented in Table 4.2.

Table 4.2: Sediment Production Test - INJ-3

Test #	Interval (ft)	Time (hours)	Screen Slot	Mass of Sand Produced (g)	Water Flow Rate (gpm)	Total Water Evacuated per Hour (litres/hour)	Fines Production per Unit Water by Weight Removal (%)
1	40-75	1	Full Screen	4,338	100	22,710	0.015
2	40-75	1	Full Screen	3,212	132	36,032	0.0089

The drill rods were pulled back out of the screen assembly and air was injected from that position to evacuate water and sediment from the well. Test #1 was run at 100gpm for one hour and resulted in 0.015% fines per unit volume (by weight) of water. Approximately 3 hours of additional development was completed at the top of the screen assembly before conducting Test #2. Test #2 was run at 132gpm for one hour and resulted in 0.0089% fines per unit volume of water. Based on acceptance criteria of 0.01% (Driscoll, 1980, Ref. 8) for a production well (where water is produced rather than injected), it was determined that the well was adequately developed for use as a test well. Photos taken during well development are presented in Appendix A.

4.2 Aquifer Testing

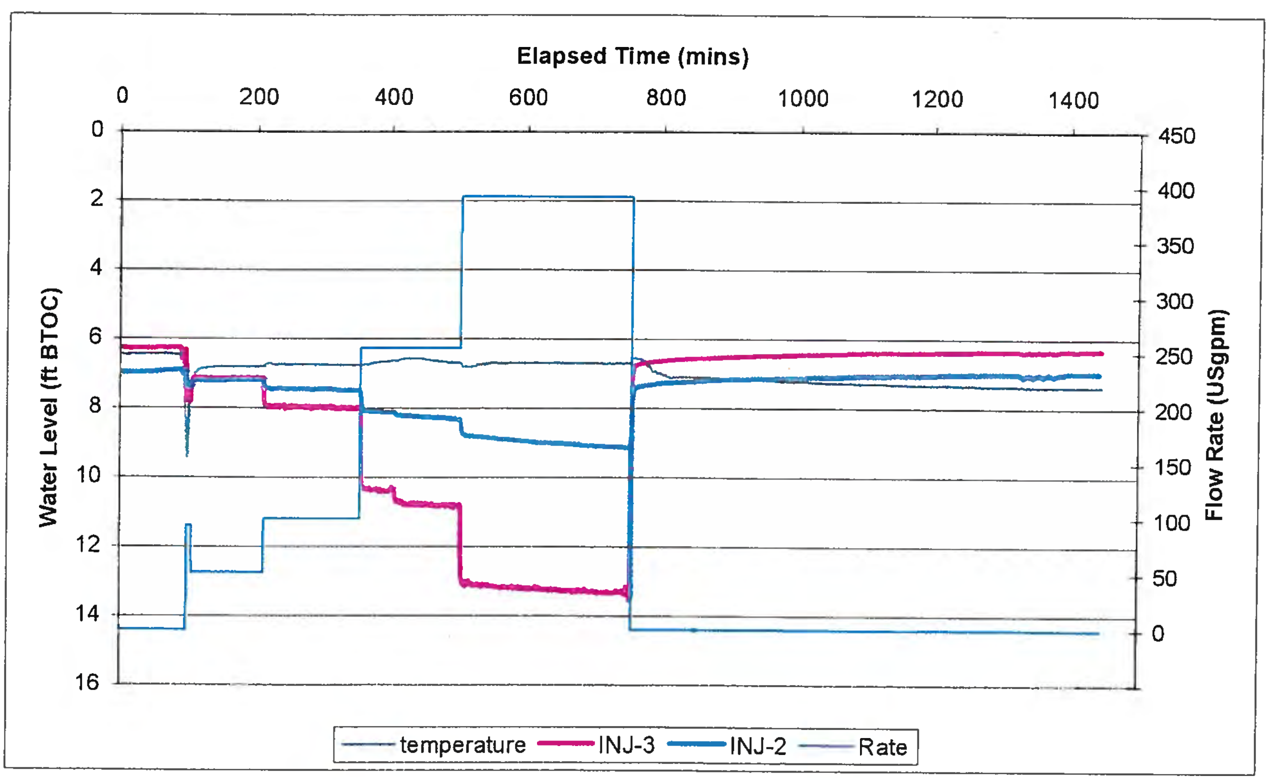
4.2.1 General

INJ-1 was instrumented with a Solinst Level Logger, INJ-2 with an In-Situ-Troll 4000 datalogger, and INJ-3 with an In-Situ-Mini-Troll datalogger. The In-Situ loggers were equipped with a vented cable for barometric pressure compensation, whereas the Solinst Level Logger was not. The following sections discuss the step test and the 72-hour pumping test performed in INJ-3.

4.2.2 Step Test

Once the submersible pump was installed in the INJ-3 well, a step test was initiated in which water was pumped at a rate of 52, 96, 254, and 391gpm in incremental steps. Each step was run until quasi-steady state conditions were achieved. The existing injection wells, due to their nature of development, are not ideal standpipes for pump test monitoring. However, to provide additional data to the available observation wells, INJ-2 was used as an observation well during the step test. Figure 4.1 presents a summary of the test results.

Figure 4.1: Step Test Data – INJ-3



The data demonstrate that the well is behaving very efficiently at all pumping rates tested. Table 4.3 summarizes the specific capacity calculations for each step performed.

Table 4.3: Specific Capacity Calculations for INJ-3

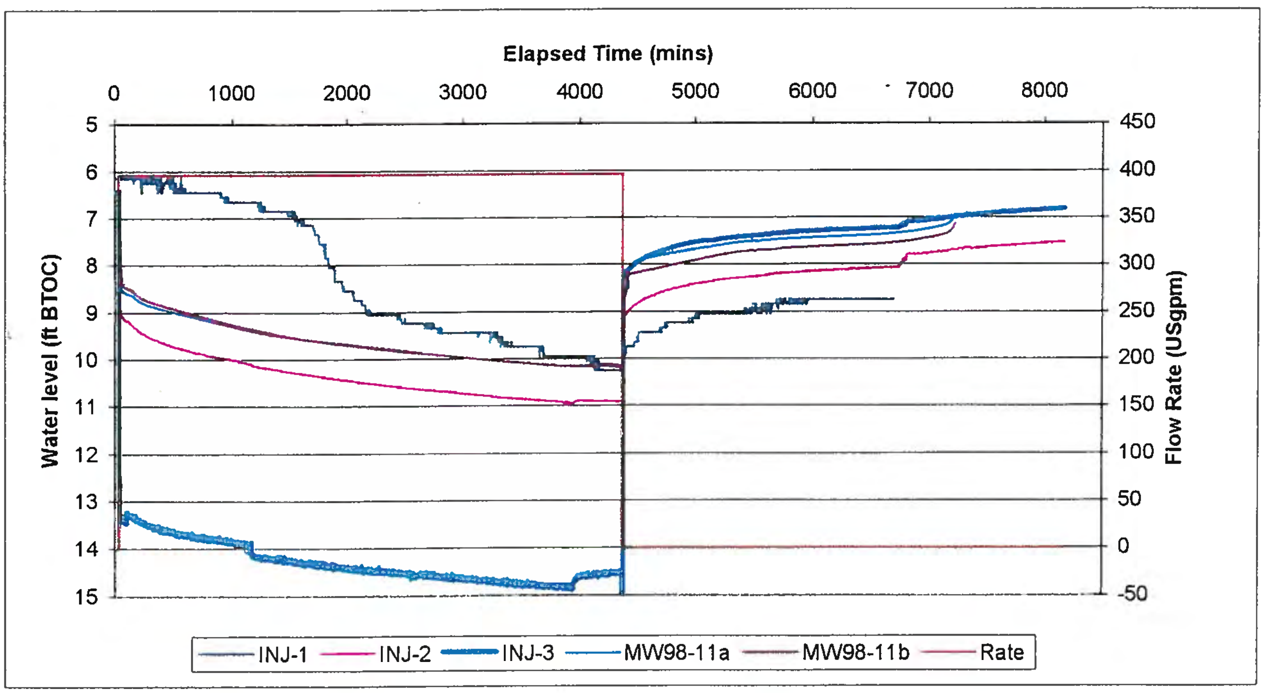
Flow Rate (Gpm)	Drawdown (ft)	Specific Capacity (Gpm/ft)
52	0.84	61.9
96	1.64	58.8
254	4.54	56.0
391	7.04	55.5

In general, it can be expected that for every foot of drawdown observed in a production well at a specified flow rate, up to 2 feet of mounding would result if water were injected in that same well at the same rate. This is a conservative "rule of thumb" for unconfined aquifers.

4.2.3 Long-Term Pumping and Recovery (72-hour)

A 72 hour pumping and recovery test was initiated in INJ-3 on August 27, 2001 at 4:46 pm and terminated on August 30, 2001 at 4:51 pm. Water level recovery was monitored until September 2, 2001. Water level monitoring data are summarized on Figure 4.2.

Figure 4.2: Water Level Hydrographs – 72 Hour Pumping and Recovery Test at INJ-3



A summary of drawdown for INJ-3 (pumping well) and in each of the monitoring wells, after 72 hours of pumping, is presented in Table 4.4.

Table 4.4: Summary of Drawdown in Pumping and Observation Wells

Well ID	Well Type	Static Water Level (ftbtoc)	Screen Interval (ft bgs)	Total Depth (ft btoc)	Well Dia. (in)	Distance From Pumping Well (ft)	Draw Down after 72 hrs of pumping at INJ-3 (ft)
INJ-1	Injection	6.15	63.5-76.5	76.5	6"	60.88	4.84
INJ-2	Injection	7.22	63.5-76.5	76.5	6"	42.20	3.03
INJ-3	Test Well	6.42	38.3-75.3	80.5	8"	0	8.55
MW98-11a	Monitor	6.50	73.0-80.9	80.9	1"	46.55	3.65
MW98-11b	Monitor	6.60	32.5-39.2	39.2	1"	46.55	3.59

As can be seen from Figure 4.2 and the data presented in Table 4.4, all wells monitored reacted to pumping at INJ-3. The apparent drop in water level observed in INJ-3, between approximately 1200 and 4000 minutes elapsed time, was caused by accidental lowering (then raising) of the datalogger during the test. INJ-2 exhibited less drawdown in comparison to INJ-1 that is located 16 feet further away from INJ-3. This behavior is thought to be related to the inefficiency of INJ-2 observed in July 2001. Steady state conditions were observed in INJ-3 during the pumping test indicating that a recharge boundary had been reached.

4.2.4 Hydraulic Parameter Estimates

All analyses were completed using AQTESOLV (Ref. 9). This aquifer test solver provides analytical solutions for evaluating hydraulic parameters in confined, unconfined, leaky, or fractured aquifer systems. In this analysis, evaluating the aquifer test data by visual curve matching to determine the "best fit", and in turn, selecting the most appropriate interpretation to represent aquifer conditions at the site.

The unconfined aquifer, Cooper-Jacob analytical solution (Ref. 10) was used for analysis of the pumping and recovery cycles and the Theis (1935) solution (Ref. 11) was used for analysis of the pumping cycle. Although specific assumptions are made with regard to aquifer characteristics using the data evaluation methods, the following assumptions are implicit with the use of all parametric solutions:

- Aquifer has infinite areal extent;
- Aquifer is homogeneous, isotropic, and of uniform thickness;
- Aquifer potentiometric surface (water table) is initially horizontal;
- Pumping well is fully penetrating; and
- Aquifer has no recharge during the short duration of the pump test, which is a simplifying assumption in the Cooper-Jacob model that is acceptable for short duration pump tests.

These simplifying assumptions lead to conservative conclusions with respect to computed hydraulic parameters.

The results of the aquifer test data analysis are presented in Table 4.5 and the graphical solutions (curve matching) are presented in Appendix D.

Table 4.5: Aquifer Test Data Analysis Results of Pumping Test at INJ-3

Well Data Evaluated	Solution	Transmissivity (m^2/s)	Specific Yield (unitless)
INJ-1	Cooper-Jacob (Early)	0.006943	0.405
	Cooper-Jacob (Late)	0.004116	0.580
	Theis	0.002836	1.016
INJ-2	Cooper-Jacob (Early)	0.01925	0.0051
	Cooper-Jacob (Late)	0.009769	0.131
	Theis	0.0104	0.0513
INJ-3	Cooper-Jacob (Early)	N/A	N/A
	Cooper-Jacob (Late)	0.01629	N/A
	Theis	0.01629	N/A
MW98-11a	Cooper-Jacob (Early)	0.0192	0.00836
	Cooper-Jacob (Late)	0.01183	0.0883
	Theis	0.01668	0.0115
MW98-11b	Cooper-Jacob (Early)	0.02107	0.00288
	Cooper-Jacob (Late)	0.01183	0.0724
	Theis	0.01506	0.0118

The drawdown response to pumping of an unconfined aquifer behaves differently from that of the classical response of a confined aquifer. When drawdown is plotted versus time on logarithmic scale, a reverse S-shape curve characterizes the response of an unconfined aquifer, with a steep segment at early time; a flat segment at intermediate time; and a somewhat steeper segment at later time. In an unconfined setting, water is released from storage by gravity drainage (dewatering) of the aquifer as well as expansion of water and compaction of the porous media. The flat segment at intermediate time is influenced by the effects of gravity drainage. In the third segment, which occurs at a later time, the time-drawdown data conforms to a theoretical Theis-type curve (Freeze and Cherry, 1979; Ref. 12).

The hydraulic parameter estimates vary depending upon the observation point used and as wells are affected by pumping in an unconfined system as described above. Although an analysis of the early pumping data are presented in Table 4.5, results are affected by gravity drainage and not considered representative of aquifer in the vicinity of the injection wells. Model results for data collected from injection wells INJ-1 and INJ-2 (Cooper-Jacob late) and Theis generally indicate lower aquifer transmissivity and higher specific yield in comparison to data collected at INJ-3 and MW98-11a, and MW98-11b. Data from INJ-1 and INJ-2 are also not likely representative of the local aquifer conditions owing to the method of completing the wells in which a bentonite "mudcake" may have been developed along the borehole wall due to the method of well installation at these locations. The bentonite mud would tend to lower the "apparent transmissivity" of the aquifer measured from that location.

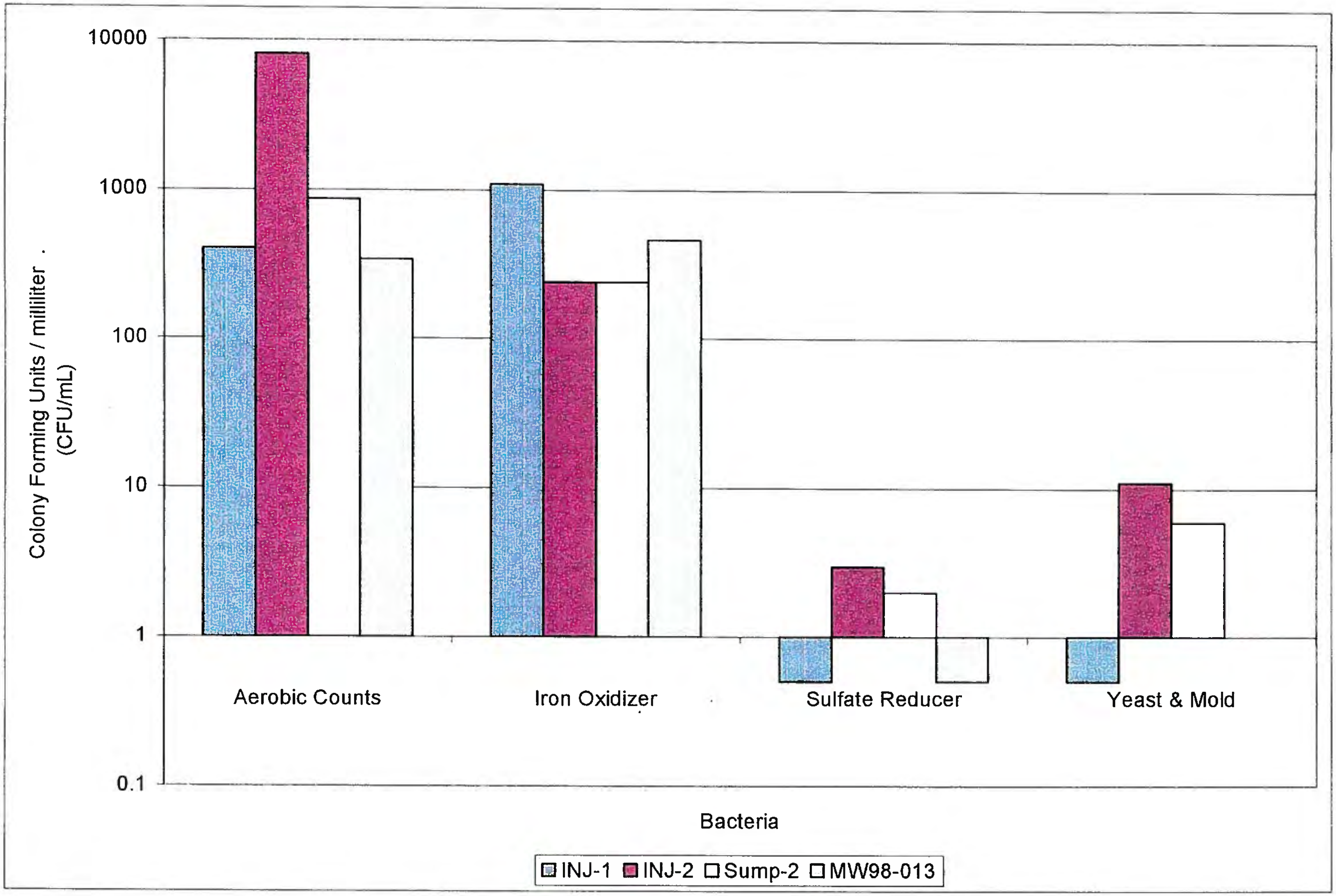
Ignoring aquifer parameter estimates from INJ-1, INJ-2 and the early time data for other monitoring points, the transmissivity of the aquifer is thus estimated to be in the range of 0.012-0.017 m^2/s with a mean value of 0.015 m^2/s. The specific yield is thereby estimated to range from 0.003 to 0.09 with a mean value of 0.05.

4.3 Water Chemistry

The water quality of treated mine water discharged to the injection wells at Pogo is regulated by the State of Alaska. Effluent water quality data is closely monitored. From an operational point of view, chemical parameters such as iron and manganese can be particularly troublesome, as precipitation of iron and manganese hydroxides can render an injection well or ancillary piping non-operable. Iron and manganese may also promote the growth of certain micro-organisms leading to the deposition of a slimy coating in pipelines and on well screens.

Figure 4.3 shows the results of bacteria samples collected from the injection wells on March 2, 2001. The data indicate that aerobic bacterial growth, including iron oxidizers, are present. The well cleaning program conducted in wells INJ-1 and INJ-2 confirms the presence of a thick, black, bacterial slime buildup. Regular well and pipeline maintenance should be conducted to ensure the proper operation of the injection system.

Figure 4.3: Injection Well Bacteria Sampling



5.0 PREDICTED INJECTION PERFORMANCE - INJ-3 TEST WELL

5.1 General

Teck-Pogo Inc. has proposed to discharge treated mine drainage water by injecting the water into the ground by utilizing injection wells. In addition to testing the injection wells by pumping, a numerical model was constructed to predict aquifer performance to water injection and to aid in design of the injection well field for the mine development phase of the project. This section describes the numerical model construction, model calibration and its application to predicting aquifer performance.

5.2 Physical Model

Groundwater flow in the Goodpaster River valley is generally downstream and is largely controlled by the gradient of the Goodpaster River. Flow is constrained by bedrock valley walls and by permafrost. Recharge to the aquifer is from infiltration of precipitation, seepage from the bedrock valley walls, and from the Goodpaster River during high water events. The hydraulic testing on candidate injection well INJ-3 indicates that the aquifer materials are highly permeable and behave as an unconfined aquifer.

The hydraulic testing of injection well INJ-3 provided valuable data for the construction of the numerical model, however there is considerable uncertainty in the distribution of permafrost. Geophysical surveys indicate extensive permafrost in the eastern sections of the model area extending to depths greater than 50 feet. A strong correlation is evident between the surficial vegetation and areas interpreted to be underlain by permafrost. Stunted black spruce dominate in permafrost areas, while larger pines dominate in largely or completely thawed areas.

5.3 Numerical Model

A numerical model was constructed with the industry-standard code MODFLOW (McDonald and Harbaugh, 1988) and Modpath (Pollack, 1990) using Visual MODFLOW from Waterloo Hydrogeologic Inc. The model consisted of 107 rows, 83 columns and 5 layers. The column and row spacings were variable ranging from 5 to 100 feet and the layer thickness were uniform at 20 feet giving a total model domain thickness of 100 feet. Areas of permafrost were included as inactive cells within the finite difference grid. Drawing A0172-05-004 presents the finite difference grid showing the outline of inactive cells representing permafrost and the grid density in the injection well area. Drawing A0172-05-004 also shows candidate locations for two potential injection wells, nominally INJ-4 and INJ-5, that were used for modeling purposes. INJ-4 and INJ-5 were both assumed to have equivalent hydraulic characteristics to INJ-3

The hydraulic conductivity of the aquifer materials were set to uniform values of 7.5 x 10^{-4} m/s horizontally and 4 x 10^{-4} m/s vertically. The storage parameters of the aquifer materials were also uniform with Specific Storage of 5 x 10^{-5} ft^{-1} and an approximate Specific Yield of 0.04. These values are within the range of values estimated by the 72-hour pump test.

Boundary conditions for the model included river elements and constant flux boundaries. The Goodpaster River was simulated with MODFLOW River elements with a gradient ranging from 1325 ft at the northern border of the model domain to 1318.5 ft at the southern border of the domain. Inputs to River Boundary elements include river stage, bottom elevation, and conductance. River elements allow water to flow into or out of the cell depending on the relative difference between the river stage and the water level within the cell containing the river element. The conductance term of the river element controls the rate of flow from or to the river. River conductance includes hydraulic conductivity, length, width and thickness.

Constant flux boundaries were included to simulate flux into the model from outside sources. A constant flux was included at the northern boundary to represent groundwater influx from upstream. Constant fluxes were also set along the bedrock valley walls for both the east and west valley walls and along the southwest boundary to provide groundwater influx from aquifers to the west.

The downstream boundary of the model is an unknown entity. The western drainage will provide a source of water discharging to the Goodpaster River although the volume is not known. Sufficient recharge was applied to this boundary to induce a gradient from the western valley to the Goodpaster River.

5.4 Model Calibration

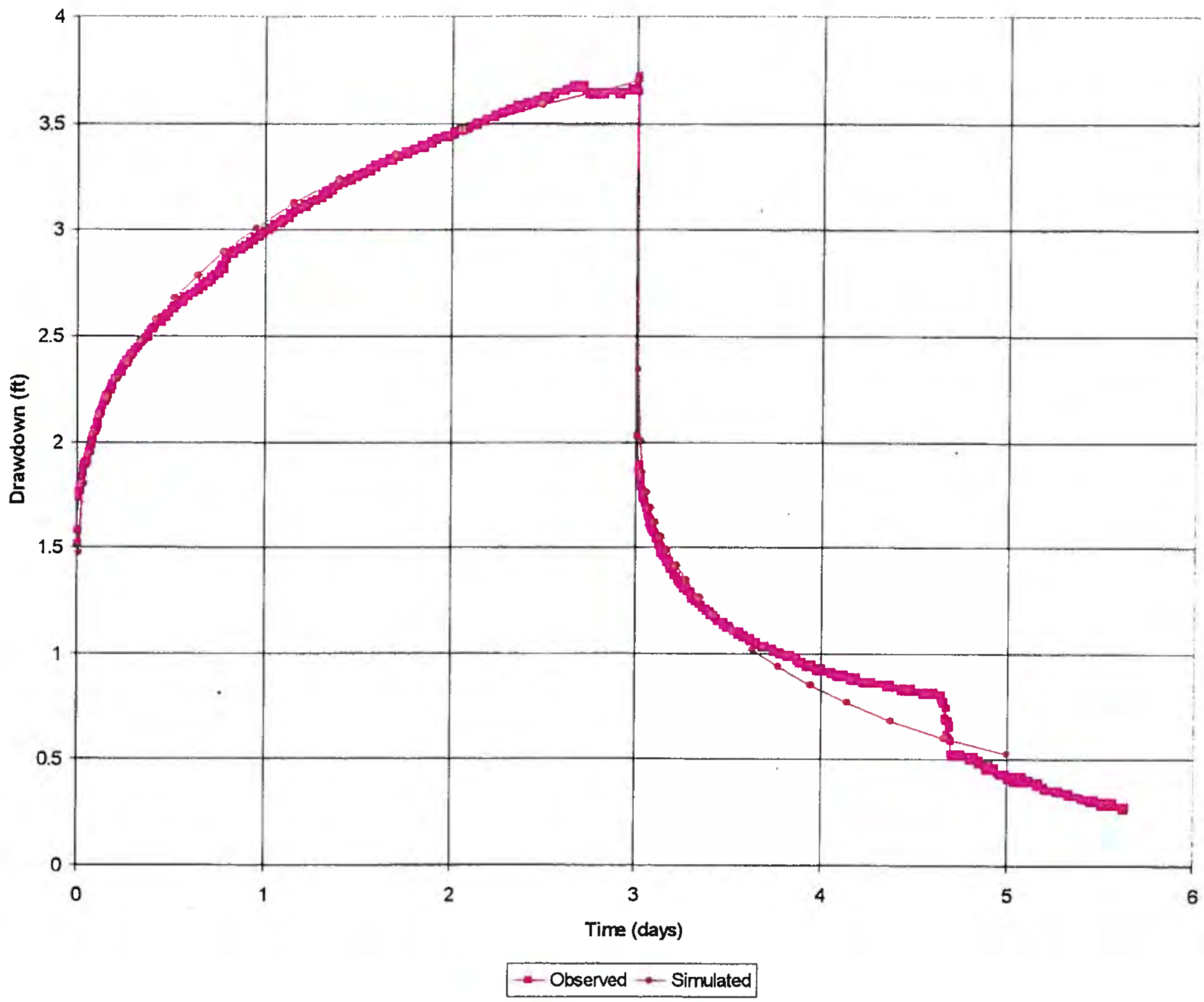
The model was calibrated to water level measurements collected 15 July 2001 and to the 72-hour pump test described in Section 4.

Calibration to water level measurements collected 15 July 2001 is shown on Table 5.1. Some of the measurements vary from the calculated results. The reasons for the points of variance are generally due to the condition of the data. Several monitoring wells are periodically frozen, MW98-2, MW98-12 and MW98-14. All of these have observed water levels much higher than calculated and are not consistent with water level measurements from nearby monitoring wells. It is likely that these readings are inaccurate or that the freezing impacts water levels locally. The datum elevation for MW98-7 appears to be estimated and therefore is not accurate. Other readings do not fit with the general aquifer characteristics and are therefore questionable. For example, MW98-4 has a very low reading compared to nearby wells, MW98-9, MW98-3 and MW98-15.

For this model, the most important calibration parameters are storage and hydraulic conductivity although the model was more practically calibrated to observed hydraulic heads. Calibration to the 72-hour pump test provides more confidence in model performance.

Figure 5.1 presents a summary of the calibration to the 72-hour pump test, which shows a very close match between the measured and simulated response of INJ-2 to pumping of INJ-3. The model was not calibrated to INJ-1 because it did not behave as a valid standpipe piezometer due to the method of installation; and therefore it does not react appropriately to short-term pump tests. While INJ-2 was similarly installed, its response was more usable although not ideal. Table 5.2 presents the maximum drawdowns at several piezometers monitored during the pump test compared to the simulated response.

Figure 5.1: Model Calibration to 72 hour Pump Test (INJ-3 Well)



The measured and predicted drawdown results are generally close. The greatest differences are in INJ-1 and in INJ-3 itself. As mentioned earlier, the installation of both INJ-1 and INJ-2 was not optimal for their use as standpipes for monitoring pump tests.

Table 5.1: Water Level Elevations for Calibration

Well ID	Easting	Northing	Observed (ftamsl)	Estimated (ftamsl)
MW98-2	1,808,155	3,820,019	1329.14	1322.53
MW98-3	1,807,875	3,819,087	1321.62	1321.86
MW98-4	1,807,629	3,819,130	1318.74	1321.83
MW98-5	1,807,487	3,819,613	1322.28	1322.15
MW98-6	1,807,498	3,819,863	1322.63	1322.38
MW98-7	1,807,490	3,820,267	1327.35	1322.72
MW98-9	1,807,796	3,819,123	1323.51	1321.87
MW98-11A	1,808,171	3,819,400	1322.76	1322.12
MW98-11B	1,808,171	3,819,400	1322.69	1322.11
MW98-12	1,808,360	3,821,150	1331.32	1323.21
MW98-13	1,808,240	3,820,750	1325.1	1323.00
MW98-14	1,808,300	3,820,300	1330.83	1322.71
MW98-15	1,807,920	3,819,100	1321.87	1321.89
MW98-16	1,807,742	3,818,627	1319.97	1321.57
INJ-1	1,808,207	3,819,454	1324.28	1322.16
INJ-2	1,808,192	3,819,441	1323.6	1322.15

The difference in INJ-3 drawdown values was largely due to parameters related to well hydraulics cannot be readily incorporated into the MODFLOW model.

Drawing A0172-05-005 presents the groundwater equipotentials calculated from the calibrated model. The plot shows groundwater following the river gradient and some groundwater entering the model from the western valley.

In order to calibrate the model to observed hydraulic heads, the following hydraulic parameters were used:

- Hydraulic Conductivity 7.5×10^{-4} m/s;
- Specific Storage 5×10^{-5} ft^{-1}; and
- Specific Yield 0.04.

Table 5.2: Comparison of Measured and Simulated Drawdown

Well ID	Measured Drawdown (feet)	Simulated Drawdown (feet)
INJ-1	4.84	3.48
INJ-2	3.66	3.77
INJ-3	8.55	7.84
MW98-11A	3.65	3.88
MW98-11B	3.59	3.11

5.5 Model Sensitivity

The model of the aquifer is a simplified representation of the actual aquifer and was constructed with relatively limited calibration data. The far field water levels and groundwater flow patterns are not known in detail and therefore cannot be calculated accurately by the groundwater flow model. The calibration to the pump test performed on INJ-3 gives some confidence in the hydraulic behavior of the area between and around INJ-2 and INJ-3. These hydraulic characteristics have been applied uniformly to the remainder of the aquifer in the assumption that material properties do not vary markedly over the aquifer. From work done in 2000 on the aquifer near the mouth of Liese Creek for the potential Soil Absorption System, this assumption appears to have merit.

There are other combinations of aquifer hydraulic characteristics that could have produced an equivalently calibrated model; i.e. the modeled solution is not unique. The conductance term of the river boundary conditions can be modified from the assumed values to simulate a different degree of hydraulic connection to the Goodpaster River. Changing these values has an impact on the pump test calibration. Variations in the distribution of permafrost also have an impact on the pump test calibration. A different calibration can probably be achieved with both different river boundary conductance and different permafrost distributions. However, without compelling reasons to do so, it does not appear to be necessary to perform multiple calibrations, as the aquifer is relatively straightforward and the test results somewhat “textbook” for an unconfined aquifer.

5.6 Results

The model was used to simulate the impacts of injecting water at a rate of 200 gpm and 400gpm on a steady basis assuming steady state conditions.

One of the steady state simulations utilized three wells, each well was modeled as injecting either 67 or 133 gpm for a total of 200 and 400 gpm, respectively. The wells are all in the area of INJ-3 as shown on Drawing A0172-05-005. Included with the existing wells are the potential additional wells INJ-4 and INJ-5. For modeling purposes, INJ-3, 4 and 5 were taken to be the operating system with all three wells having the characteristics of INJ-3. With this arrangement, both the changes in water table and water pressures in the injection well screened interval were estimated by comparing computed heads in different layers. The upper layer represents water table conditions and layer four represents the center of the injection well screened intervals. Under steady state conditions with the three well system, water table mounding of 1.5 to 2.9 feet was estimated at each injection wells for the 200 and 400 gpm scenarios, respectively. Having 400 gpm injected into a single well, say INJ3, resulted in an estimate of roughly 4 feet of mounding. The groundwater table in the area of the proposed injection system averages 4 to 5 feet bgs with some minor fluctuation on an annual basis. The estimate of mounding for INJ-3 as a single well system is less than would be predicted empirically by the pumping test completed in 2001 (e.g. Table 4.3). In reality, experience indicates the actual mounding would be similar to the modeling for a single well but natural inhomongenieties and anisotropy in the aquifer can affect the results. Consequently, use of at least one additional well is typically recommended. For the proposed enhancement of the Pogo system, a three well system similar to that modeled would provide a high degree of redundancy to maintain sufficient capacity with reasonable mounding.

Particle traces from the injection wells are shown on Drawings A0172-05-006 and A0172-05-007 for the 200 and 400 gpm scenarios respectively. The figures show particles entering the area beneath Goodpaster River south and west of the injection site. Estimated travel time to the river ranged from about 260 days to over 4000 days for the 200 gpm case with an average travel time of 921 days. For the 400 gpm case, the minimum travel time was about 160 days, the maximum was over 6000 days and the estimated average travel time of 669 days. These travel times are for pure advection. Any given chemical constitute would have some degree of retardation so these estimates are conservative if the model truly reflects the actual aquifer response.

The average estimated travel times to both monitoring wells MW-3 and MW-15 are approximately 100 days. Groundwater chemistry measurements at MW-3 showed a marked increase in electrical conductivity at about ±100 days in response to injection into the existing wells, INJ-1 and INJ-2, that began in 1999. The same pattern can be shown for MW-15. These trends lend a good degree of credibility to the advection transport estimates, particularly the average rates shown in Table 5.3, provided by the MODFLOW simulations.

These modeled results suggest that the injection wells, one or more, may be capable of accepting water injection of at least 400 gpm on a continuous basis without having mounding to a degree that would create a surface flow component. As noted, use of more than one well is suggested to provide good performance without concern over isolated aquifer inhomongenieties.

5.7 Summary

A groundwater model has been used to predict the impacts of injecting mine drainage water into one to three wells at sustained rates of either 200 or 400 gpm. The model predicts a water table mound of 1.5 to 2.9 feet, respectively, as the result of injecting 200 and 400gpm on a sustained basis to a three well system. All injection water discharges to the aquifer materials beneath the Goodpaster River southwest of the injection site at times of roughly 750 to 1000 days as summarized in Table 5.3.

Table 5.3: Summary of Advective Transport Modeling Results

Injection Rate (gpm)	Estimated Maximum Mounding at INJ-3, 4 or 5 (ft)	Estimated Average Transient Time to Aquifer beneath Goodpaster River (days)*
200	1.5	921
400	2.9	669

*Based upon pure advection. Not ion specific.

6.0 PROPOSED INJECTION WELL COMPLETION AND OPERATION

6.1 Overview

This section summarizes issues related to completing and operating the candidate injection well(s).

6.2 Well Head Completion

Following the 2001 testing program, the INJ-3 wellhead was left with a 1.25-foot stick up and was temporarily covered with a secure cap. The two existing injection wells (INJ-1, INJ-2) were outfitted with a Clayton, pressure-sustaining valve (PSV) that allows specific pressures to be applied downhole. This configuration helps to minimize the volume of air injected into the formation by keeping the pipeline full of water. The pressure at the water treatment plant depends on the dynamic head in the pipeline and this pressure increases with flow.

6.3 Injection and Performance Testing

Based on water production tests at INJ-3, it was evident that the aquifer in the vicinity of the existing injection wells, and the new test well was laterally extensive and did not appear to have been compromised hydraulically by past injection. The data collected during the 2001 field season indicates that the INJ-3 test well is highly efficient and that the aquifer is highly productive. Based on this information, the INJ-3 well should be further considered for use as an injection well. As noted in the predictive modeling results, some system of redundancy would involve about two more wells with similar characteristics to INJ-3.

7.0 RECOMMENDATIONS

Based on the 2001 injection well investigation program the following recommendations are presented for consideration:

- The data collected during the 2001 field season indicate that the INJ-3 test well was highly efficient and the Goodpaster River Valley aquifer was highly productive. Based on this information, the INJ-3 well should be further considered for use as an injection well.

- The installation of a pressure control valve (PSV) at the injection wellhead is recommended as it could help prevent air-locking. Air-locking would reduce injection efficiency.

- The aquifer modeling suggests that one well equivalent to INJ-3 would likely be sufficient for the envisioned injection rates during the mine development period. However, to be prudent and deal with inherent aquifer inhomongenieties, some redundancy in the injection system is recommended. Assuming that INJ-3 was one of these wells, two wells other could be placed approximately 100 feet away (each) from INJ-3 with final location optimization to be carried out in the field. The locations should be similar locations to the candidate INJ-4 and INJ-5 noted in the field in July 2001 and modeled in this report. Such a system should provide the project with an efficient injection system through the project development period.

Recommendations presented herein are based on a preliminary hydrogeological evaluation of the information available as noted. If conditions other than those reported are noted during subsequent phases of the project, AMEC Earth & Environmental should be given the opportunity to review and revise the current recommendations, if necessary. Recommendations presented herein may not be valid if an adequate level of review or inspection is not provided during construction of any additional injection wells.

This report has been prepared for the exclusive use of Teck-Pogo Inc. for the Pogo Project for specific application to the area within this report. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC Earth & Environmental accepts no responsibility for damages, suffered by any third party as a result of decisions made or actions based on this report. The report has been prepared in accordance with generally accepted hydrogeological practices. No other warranty, expressed or implied, is made.

Respectfully submitted,

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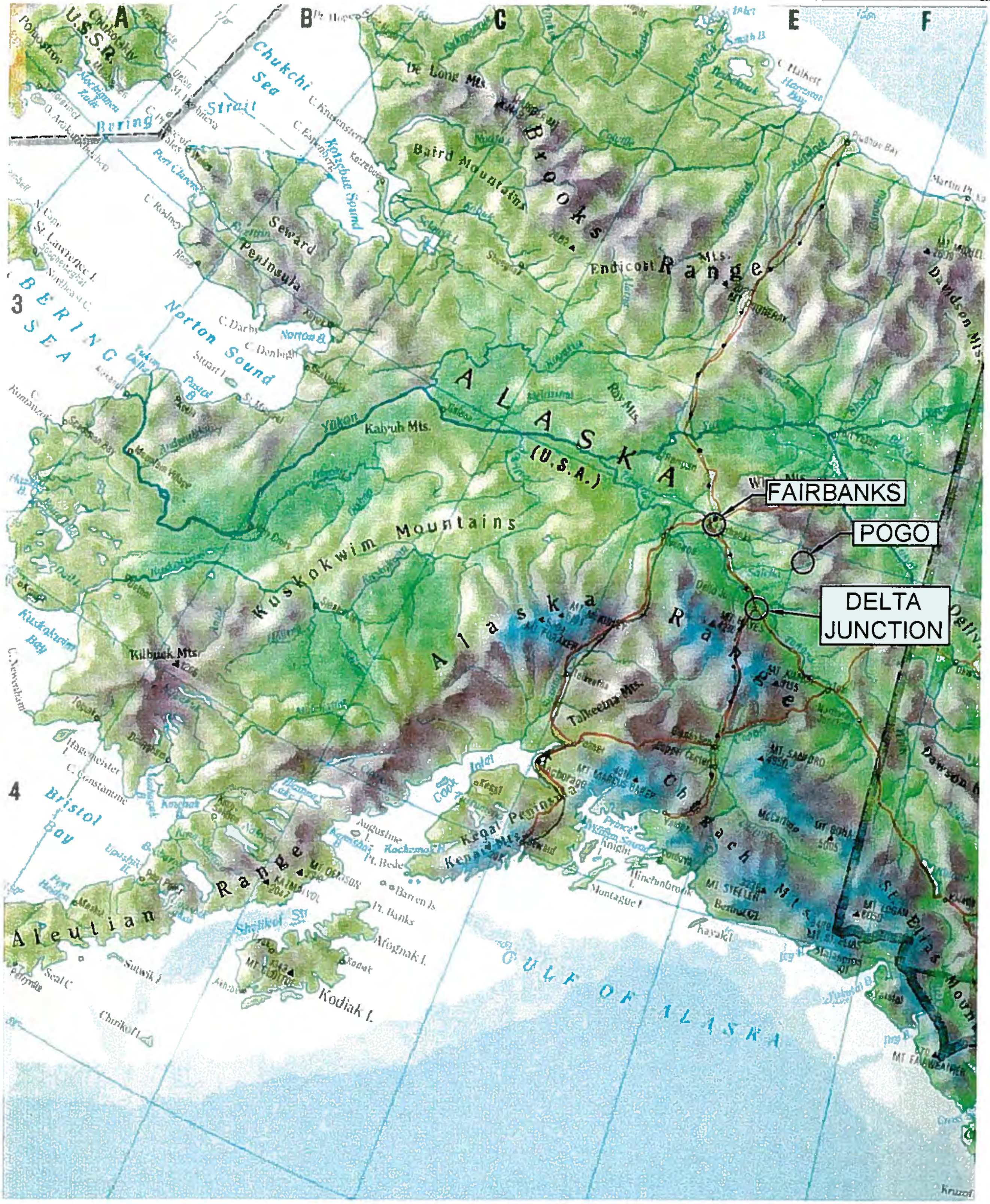
DRAWINGS



SOURCE: COMPLETE ATLAS OF THE WORLD, 1998, BRAMLEY BOOKS D118.

0 200 400
SCALE (Km)

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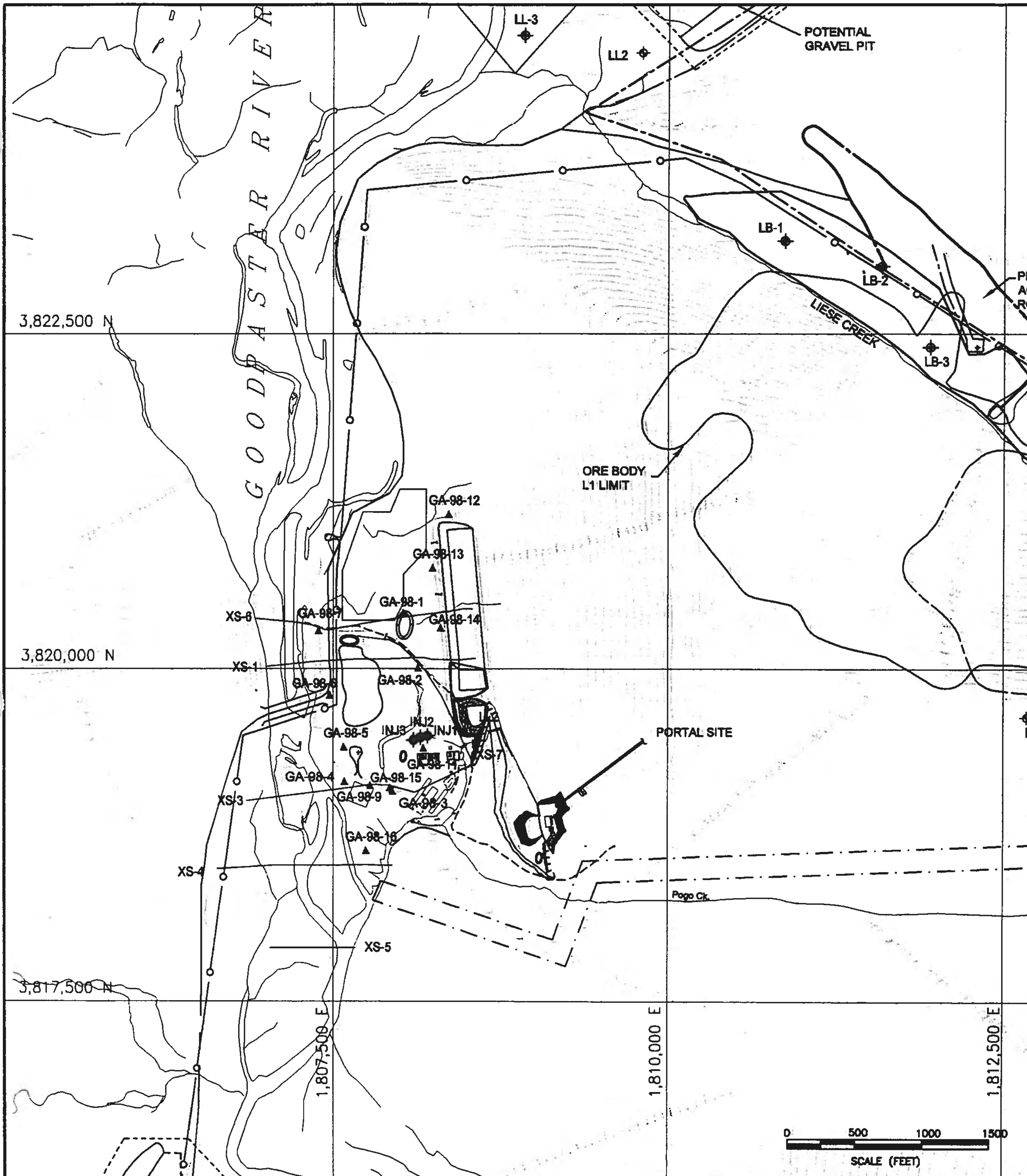
POGO INJECTION WELL TEST PROGRAM & MODELED PREDICTIONS

POGO SITE LOCATION PLAN

DWN BY:	CHK'D BY:	APP.	DATE:
SM	LS	MPD	NOV. 2001
PROJECT NO: VM00172-V-2	REV. NO.: -	SCALE: AS SHOWN	FIGURE No. A0172-05-001



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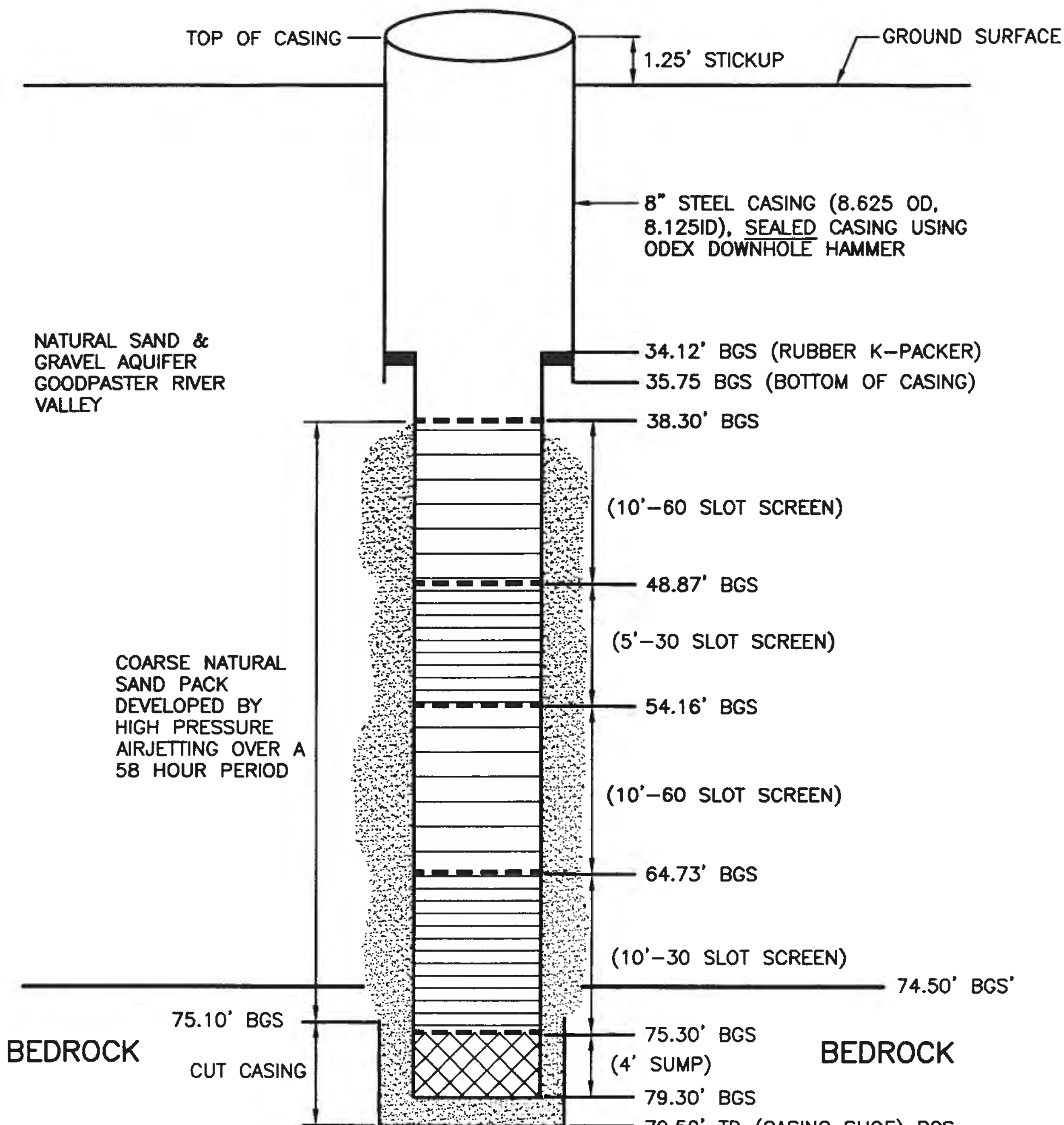
POGO INJECTION WELL TEST
PROGRAM & MODELED PREDICTIONS

INJECTION SITE LAYOUT

DWN BY:	CHK'D BY:	APP.	DATE:
YW/RW	LS		NOV. 2001
PROJECT NO: VM00172-V-2	REV. NO.:	SCALE: AS SHOWN	FIGURE No. A0172-05-002



NOTES

1. 8" TELESCOPIC WELL SCREEN, (7.5"OD, 6.375ID)
2. EACH SLOTTED SECTION OF SCREEN HAS 0.25' FLUSH THREADDED COUPLING BETWEEN 5' SCREEN SECTION.
3. DATE COMPLETED AUGUST 8, 2001.
4. ALL DEPTHS REPORTED IN FEET BELOW GROUND SURFACE (BGS).

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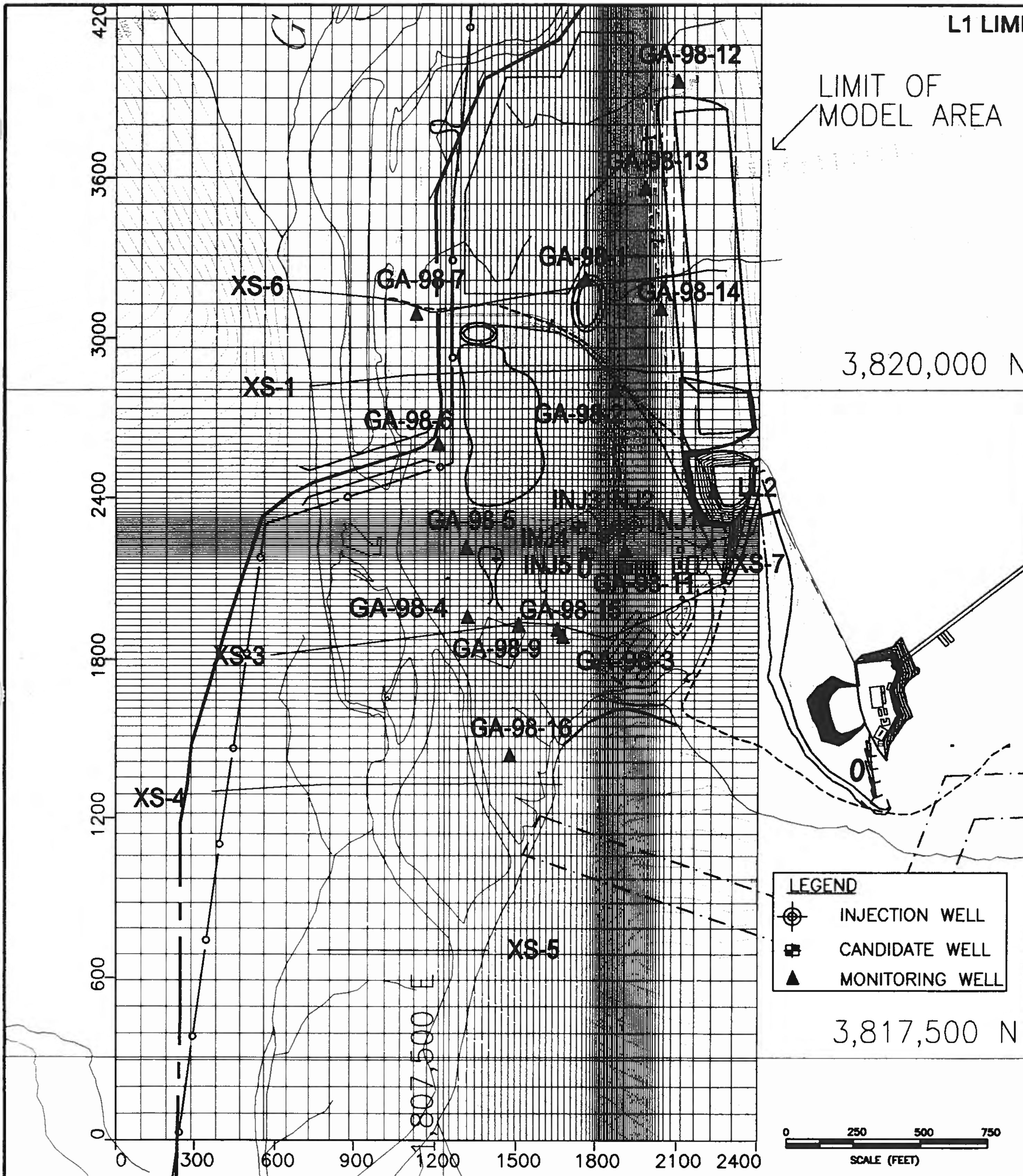
POGO INJECTION WELL TEST PROGRAM & MODELED PREDICTIONS

INJ-3 COMPLETION DETAILS

DWN BY: DD/SM	CHK'D BY: DD	APP. MPD	DATE: OCT. 2001
PROJECT NO: VM00172	REV. NO.: -	SCALE: NTS	FIGURE No. A0172-05-003

*PLOT 1:1=A0 S:\MIN\PROJECTS\VM00172 - Pogo\Injection Wells\W summary report\figures\ A0172-05-003.dwg Thu. Dec. 13 4:32pm 2001 INJ3 YUon



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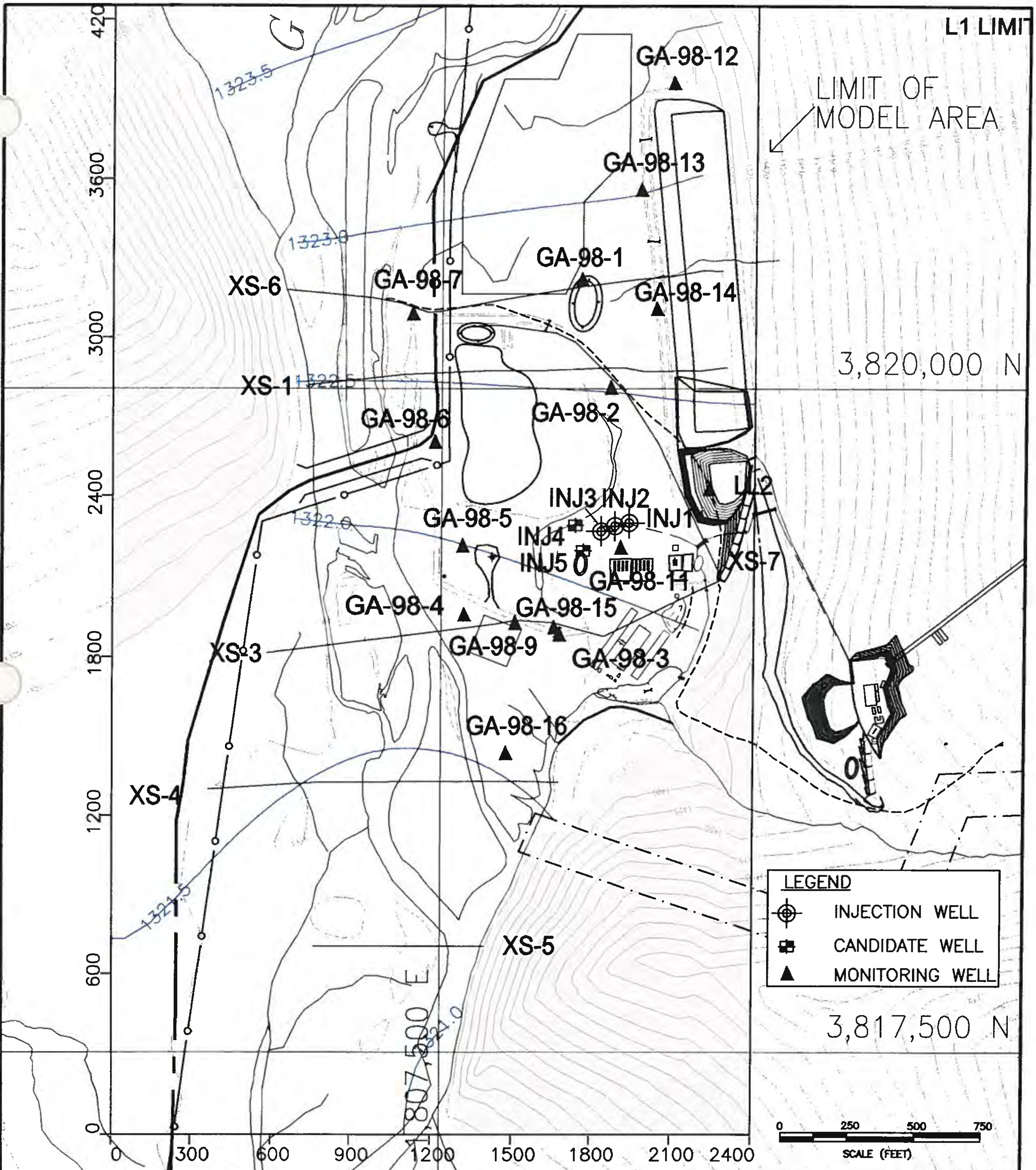
		POGO INJECTION WELL TEST PROGRAM & MODELED PREDICTIONS	
DWN BY: YW/RW	CHK'D BY: LS	APP.	DATE: NOV. 2001
PROJECT NO: VM00172-V-2	REV. NO.:	SCALE: AS SHOWN	FIGURE No. A0172-05-004

FINITE DIFFERENCE GRID



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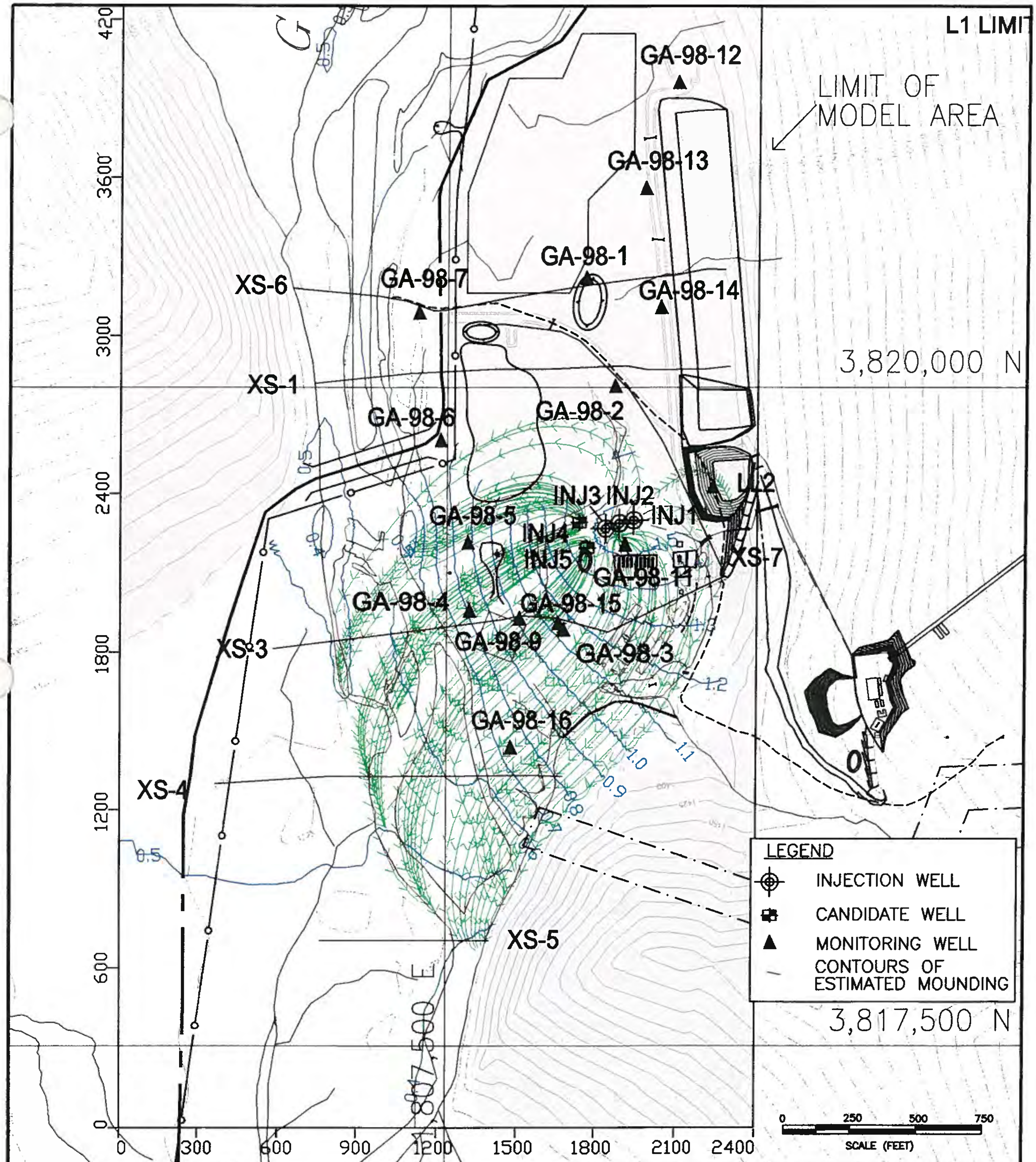
POGO INJECTION WELL TEST PROGRAM & MODELED PREDICTIONS

MODEL EQUIPOTENTIAL LINES

DWN BY: YW/RW	CHK'D BY: LS	APP.	DATE: NOV. 2001
PROJECT NO: VM00172-V-2	REV. NO.:	SCALE: AS SHOWN	FIGURE No. A0172-05-005



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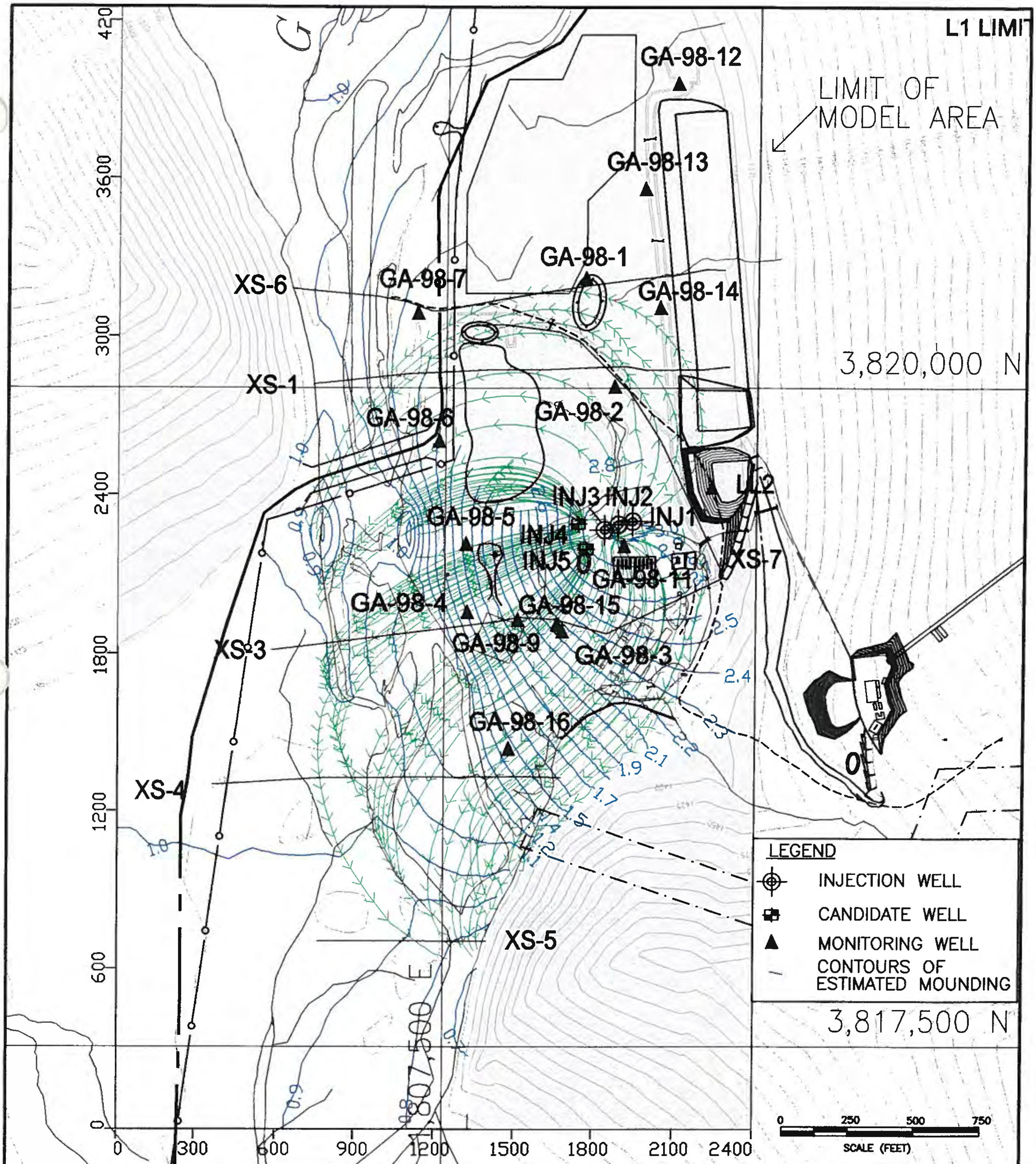
DWN BY:	CHK'D BY:	APP.	DATE:	
YW/RW	LS		NOV. 2001	WATER MOUNDING AND PARTICLE TRACES at 200 gpm INJECTION RATE
PROJECT NO: VM00172-V-2	REV. NO.:	SCALE: AS SHOWN	FIGURE No. A0172-05-006	



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DWN BY: YW/RW	CHK'D BY: LS	APP.	DATE: NOV. 2001
PROJECT NO: VM00172-V-2	REV. NO.:	SCALE: AS SHOWN	FIGURE No. A0172-05-007

WATER MOUNDING AND PARTICLE TRACES at 400 gpm INJECTION RATE

APPENDIX A

Photographic Plates

Photo 1: Air rotary drill assembly used to direct drill cuttings to the surface.

Photo 2: INJ-3 screen and tailpipe assembly


Photo 3: INJ-3 screen installation.

Photo 4: Hydraulic jacks used to pull the well casing and expose the telescopic screen assembly after the casing was cut above the casing shoe.

Photo 5: Hydraulic jacks used to pull the well casing and expose the telescopic screen assembly after the casing was cut above the casing shoe.


Photo 6: Well development.

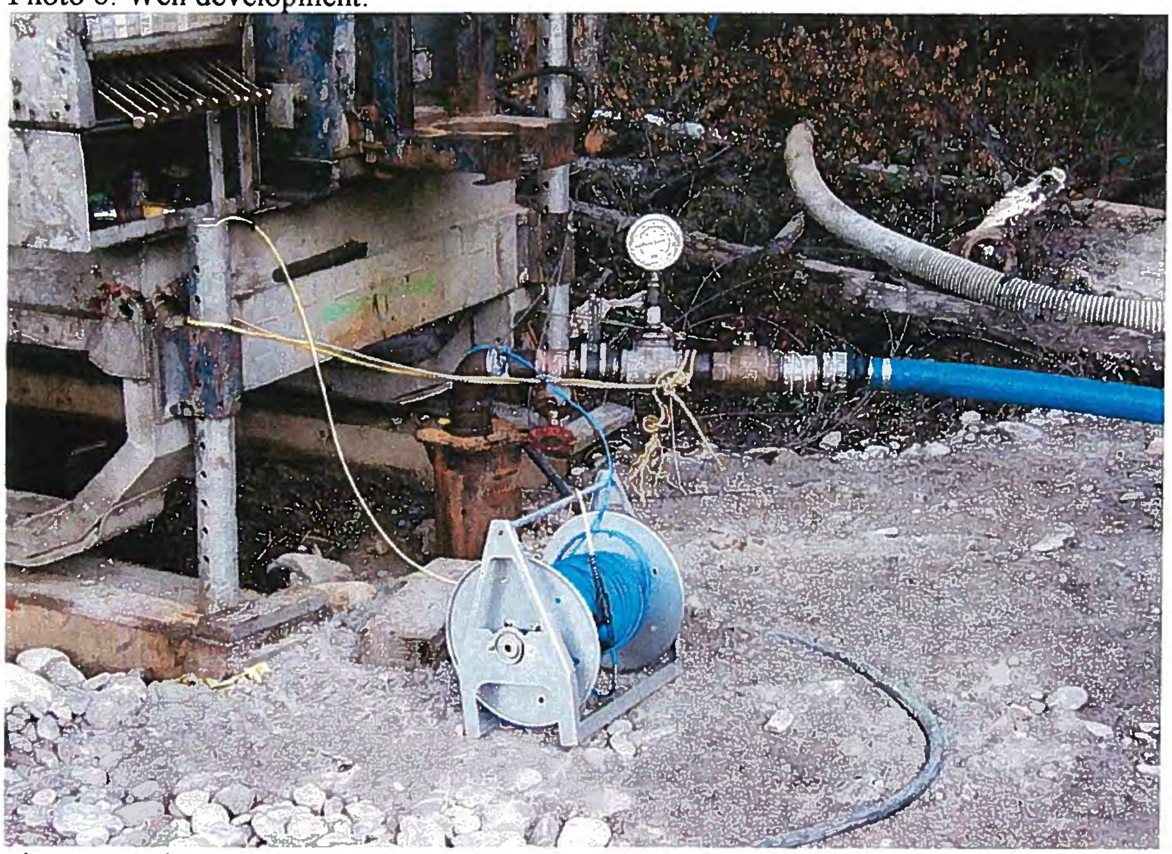



Photo 7: 72-hour pump test apparatus.


Photo 8: Pumping the step test and 72-hour pump test water to the gravel pit

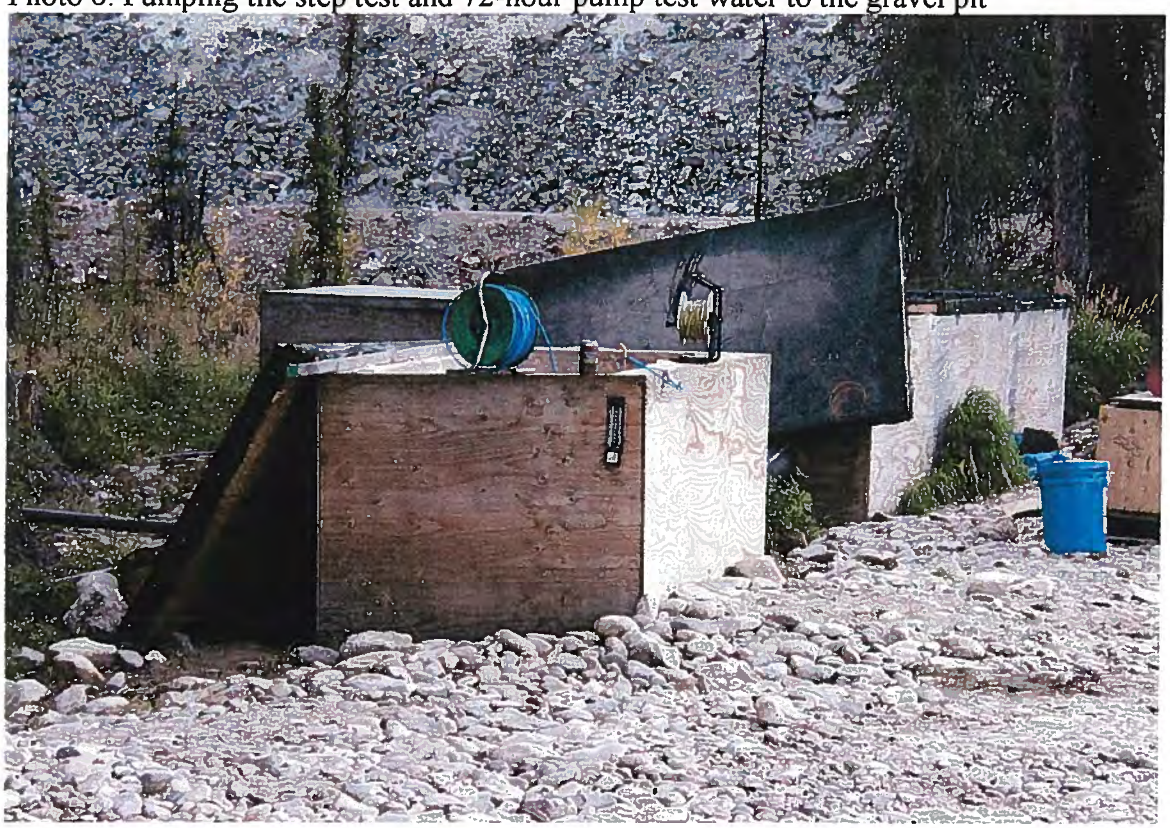
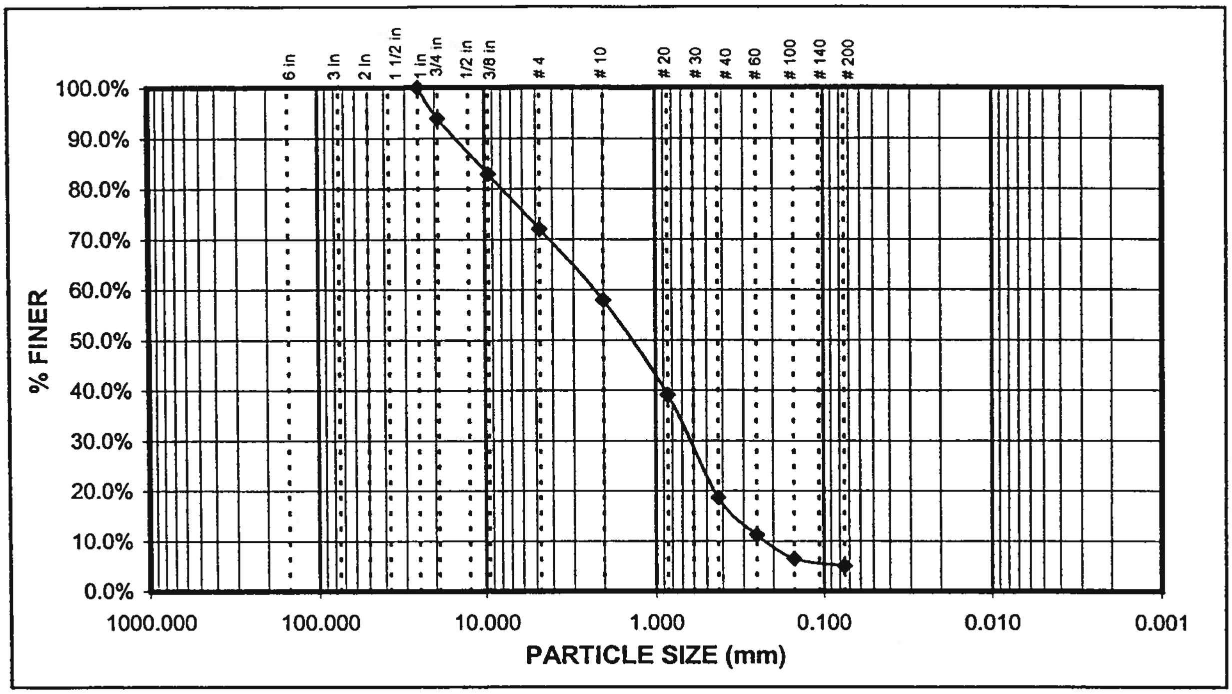


Photo 9: Dataloggers and water level meters monitored INJ-1 and INJ-2 during testing.


Photo 10: Monitoring wells MW11A & B monitored water level changes near INJ-3.

APPENDIX B Grain Size Analysis

PARTICLE SIZE DISTRIBUTION REPORT



Cobbles	% Gravel	% Sand	% Silt	% Clay
-	28.0%	67.0%	5.0%	

Sieve Size		% Finer
	mm	
1"	25.000	100.0%
3/4"	19.000	93.9%
3/8"	9.500	82.9%
#4	4.750	72.0%
#10	2.000	58.0%
#20	0.850	39.1%
#40	0.425	18.6%
#60	0.250	11.2%
#140	0.150	6.5%
#200	0.075	5.0%

Sample Number: INJ3 -8
Location: Injection Well #3
Source of Sample: ODEX Borehole
Sample Depth: 29.5' - 34.5'
Date Sampled: 7/25/01
Sampled by: B. Lyons
Date Tested: 7/26/01
Test Preformed By: B. Lyons

Soil Description:
Gravely SAND with trace silt.

USCS Classification: SP-SM

Coefficients:

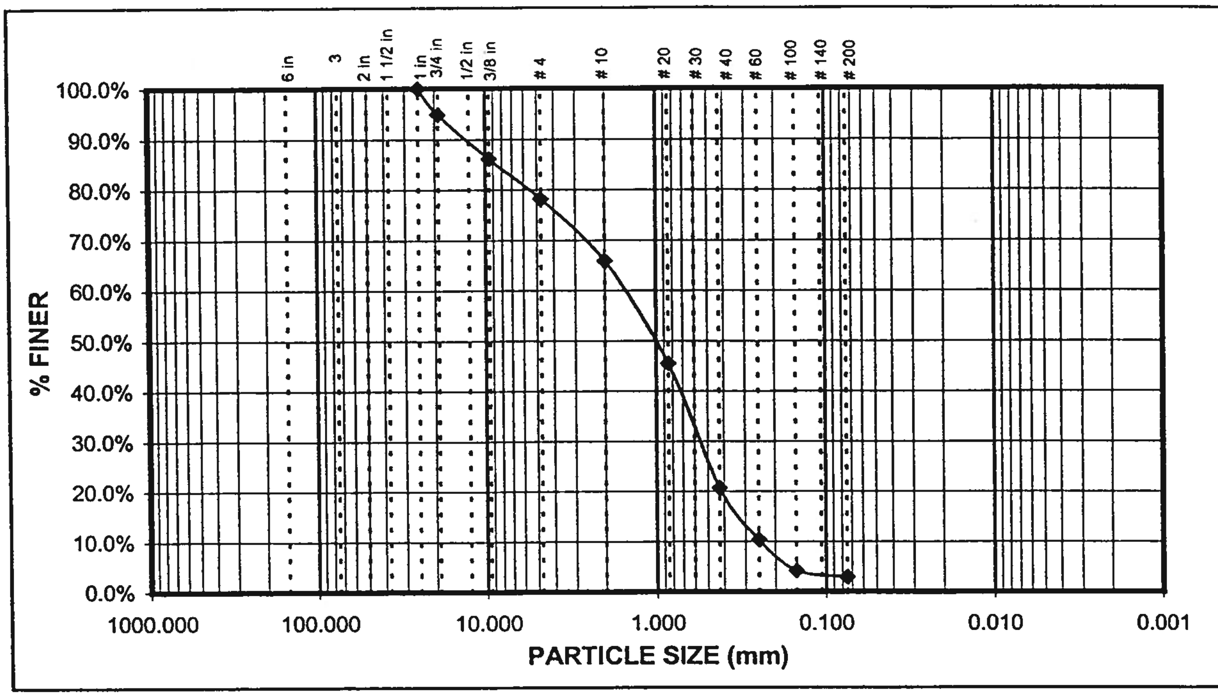
D_{85}	10.83	D_{60}	2.27	D_{50}	1.39
D_{30}	0.62	D_{15}	0.33	D_{10}	0.22
C_u	10.34	C_z	0.79		

Max particle size: mm

Hydraulic Conductivity (estimated from Hazen formula)
4.80E-04 **m/s**

Notes:
Most of the particles in sieve 1" through #10 appear to be broken off portions of larger particles.

PARTICLE SIZE DISTRIBUTION REPORT



Cobbles	% Gravel	% Sand	% Silt	% Clay
-	21.8%	75.3%	2.9%	

Sieve Size		% Finer
	mm	
1"	25.000	100.0%
3/4"	19.000	94.9%
3/8"	9.500	86.1%
#4	4.750	78.2%
#10	2.000	65.9%
#20	0.850	45.5%
#40	0.425	20.7%
#60	0.250	10.4%
#140	0.150	4.2%
#200	0.075	2.9%

Sample Number: INJ3 - 9
Location: Injection Well #3
Source of Sample: ODEX Borehole
Sample Depth: 34.5' - 39.5'
Date Sampled: 7/25/01
Sampled by: B. Lyons
Date Tested: 7/26/01
Test Preformed By: B. Lyons

Soil Description:
Gravely SAND trace silt.

USCS Classification: SP

Coefficients:

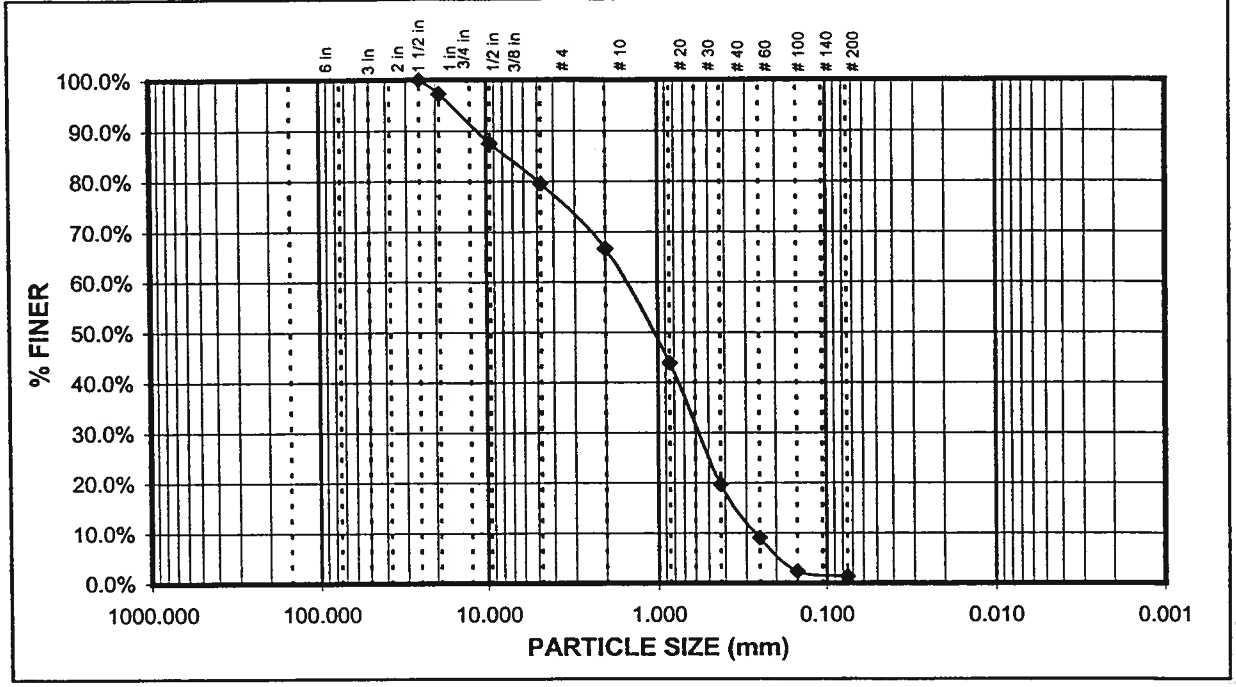
D_{85}	8.60	D_{60}	1.56	D_{50}	1.03
D_{30}	0.55	D_{15}	0.32	D_{10}	0.24
C_u	6.45	C_z	0.80		

Max particle size: mm

Hydraulic Conductivity (estimated from Hazen formula)
5.89E-04 **m/s**

Notes:
Most of the particles in sieve 1" through #10 appear to be broken off portions of larger particles.

PARTICLE SIZE DISTRIBUTION REPORT



Cobbles	% Gravel	% Sand	% Silt	% Clay
-	20.4%	78.3%	1.3%	

Sieve Size		% Finer
	mm	
1"	25.000	100.0%
3/4"	19.000	97.3%
3/8"	9.500	87.5%
#4	4.750	79.6%
#10	2.000	66.7%
#20	0.850	43.9%
#40	0.425	19.7%
#60	0.250	9.0%
#140	0.150	2.3%
#200	0.075	1.3%

Sample Number: INJ3 - 10
Location: Injection Well #3
Source of Sample: ODEX Borehole
Sample Depth: 39.5' - 44.5'
Date Sampled: 7/25/01
Sampled by: B. Lyons
Date Tested: 7/26/01
Test Preformed By: B. Lyons

Soil Description:
Gravely SAND

USCS Classification: SP

Coefficients:

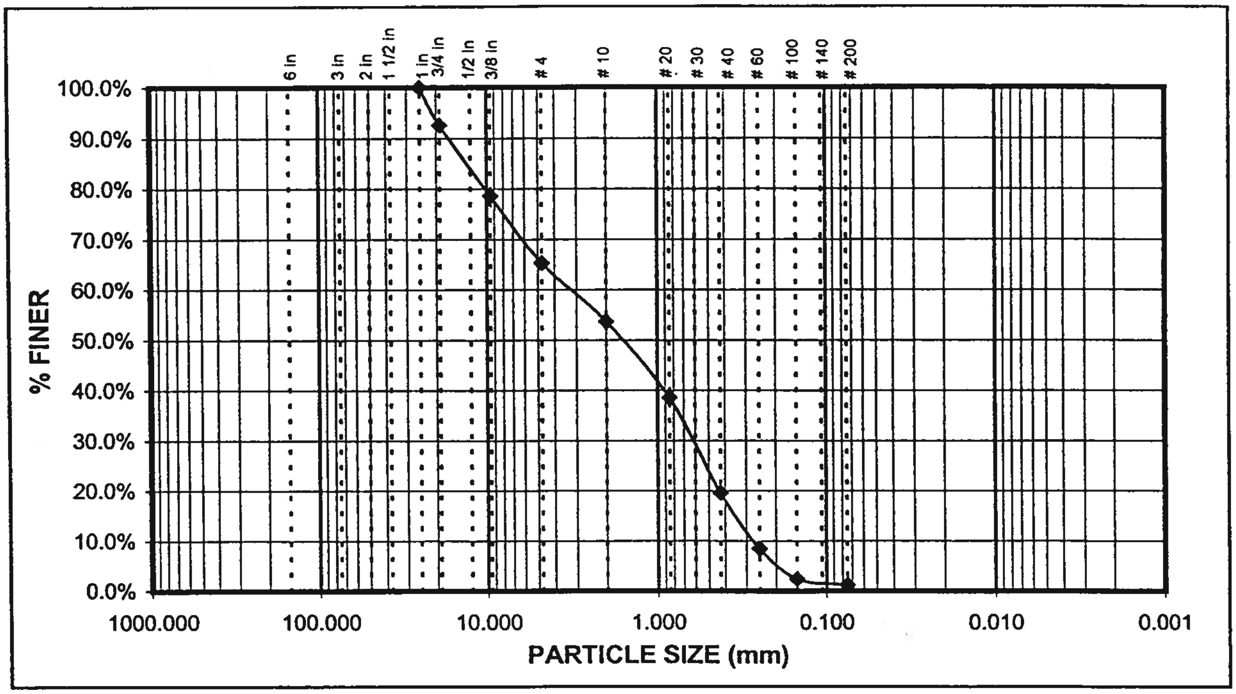
D_{85}	7.63	D_{60}	1.56	D_{50}	1.07
D_{30}	0.57	D_{15}	0.34	D_{10}	0.26
C_u	5.92	C_z	0.80		

Max particle size: mm

Hydraulic Conductivity (estimated from Hazen formula)
6.91E-04 **m/s**

Notes:
Most of the particles in sieve 1" through #10 appear to be broken off portions of larger particles.

PARTICLE SIZE DISTRIBUTION REPORT



Cobbles	% Gravel	% Sand	% Silt	% Clay
-	34.7%	64.2%	1.2%	

Sieve Size		% Finer
	mm	
1"	25.000	100.0%
3/4"	19.000	92.6%
3/8"	9.500	78.6%
#4	4.750	65.3%
#10	2.000	53.7%
#20	0.850	38.5%
#40	0.425	19.5%
#60	0.250	8.4%
#140	0.150	2.4%
#200	0.075	1.2%

Sample Number: INJ3 - 11
Location: Injection Well #3
Source of Sample: ODEX Borehole
Sample Depth: 44.5' - 49.5'
Date Sampled: 7/25/01
Sampled by: B. Lyons
Date Tested: 7/26/01
Test Preformed By: B. Lyons

Soil Description:
SAND with Gravel

USCS Classification: SP

Coefficients:

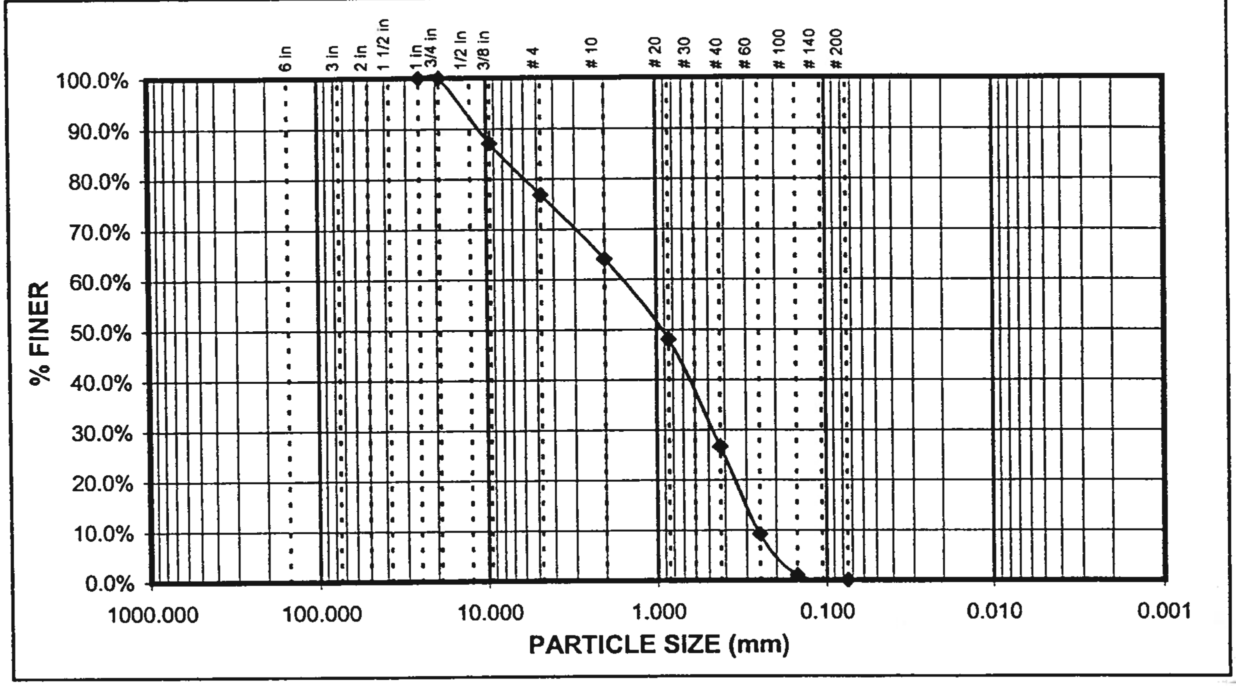
D_{85}	13.05	D_{60}	3.20	D_{50}	1.62
D_{30}	0.62	D_{15}	0.34	D_{10}	0.27
C_u	11.88	C_z	0.45		

Max particle size: mm

Hydraulic Conductivity (estimated from Hazen formula)
7.26E-04 **m/s**

Notes:
Most of the particles in sieve 1" through #10 appear to be broken off portions of larger particles.

PARTICLE SIZE DISTRIBUTION REPORT



Cobbles	% Gravel	% Sand	% Silt	% Clay
-	23.1%	76.9%	0.0%	

Sieve Size		% Finer
	mm	
1"	25.000	100.0%
3/4"	19.000	100.0%
3/8"	9.500	87.1%
#4	4.750	76.9%
#10	2.000	64.1%
#20	0.850	48.0%
#40	0.425	26.6%
#60	0.250	9.2%
#140	0.150	1.0%
#200	0.075	0.0%

Soil Description:
Gravely SAND

USCS Classification: SP

Coefficients:

D_{85}	8.24	D_{60}	1.61	D_{50}	0.94
D_{30}	0.47	D_{15}	0.30	D_{10}	0.26
C_u	6.29	C_z	0.55		

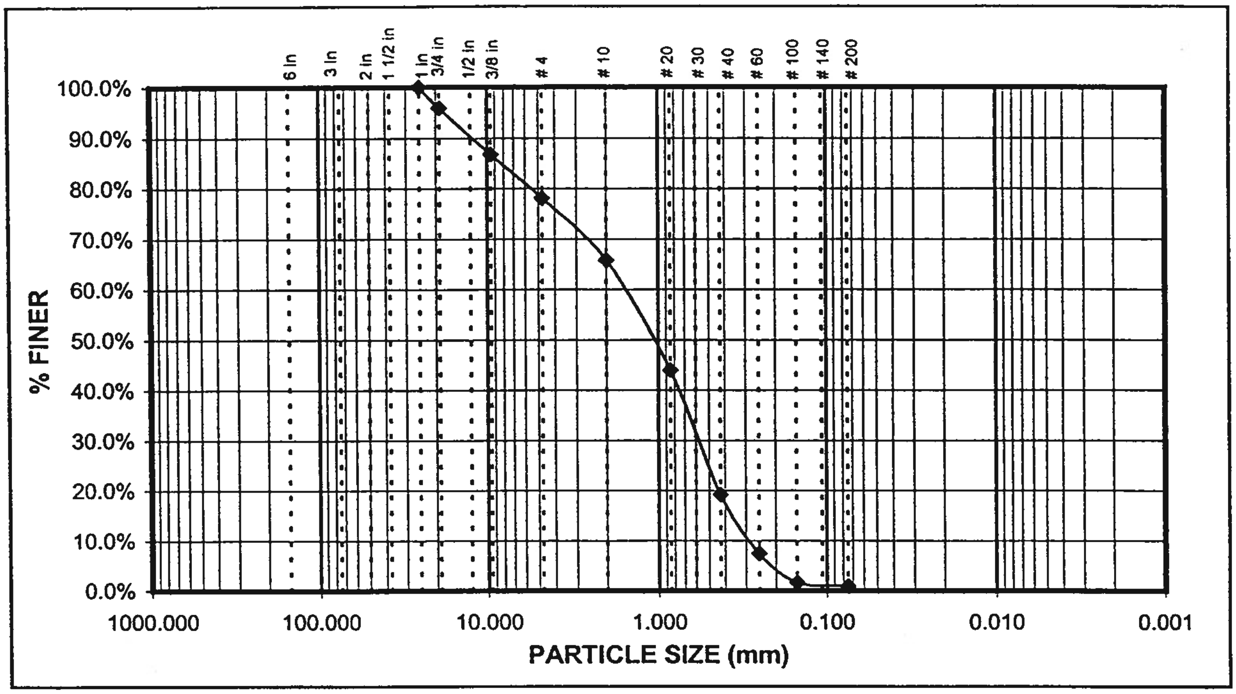
Max particle size: mm

Hydraulic Conductivity (estimated from Hazen formula)
6.56E-04 **m/s**

Notes:
Most of the particles in sieve 1" through #10 appear to be broken off portions of larger particles.

Sample Number: INJ3 - 12
Location: Injection Well #3
Source of Sample: ODEX Borehole
Sample Depth: 49.5' - 54.5'
Date Sampled:
Sampled by: B. Lyons
Date Tested: 7/26/01
Test Preformed By: B. Lyons

PARTICLE SIZE DISTRIBUTION REPORT



Cobbles	% Gravel	% Sand	% Silt	% Clay
-	21.9%	77.2%	0.9%	

Sieve Size		% Finer
	mm	
1"	25.000	100.0%
3/4"	19.000	95.9%
3/8"	9.500	86.8%
#4	4.750	78.1%
#10	2.000	65.8%
#20	0.850	43.9%
#40	0.425	19.2%
#60	0.250	7.4%
#140	0.150	1.6%
#200	0.075	0.9%

Sample Number: INJ3 - 13
Location: Injection Well #3
Source of Sample: ODEX Borehole
Sample Depth: 54.5' - 59.5'
Date Sampled:
Sampled by: B. Lyons
Date Tested: 7/26/01
Test Preformed By: B. Lyons

Soil Description:
Gravely SAND

USCS Classification: SP

Coefficients:

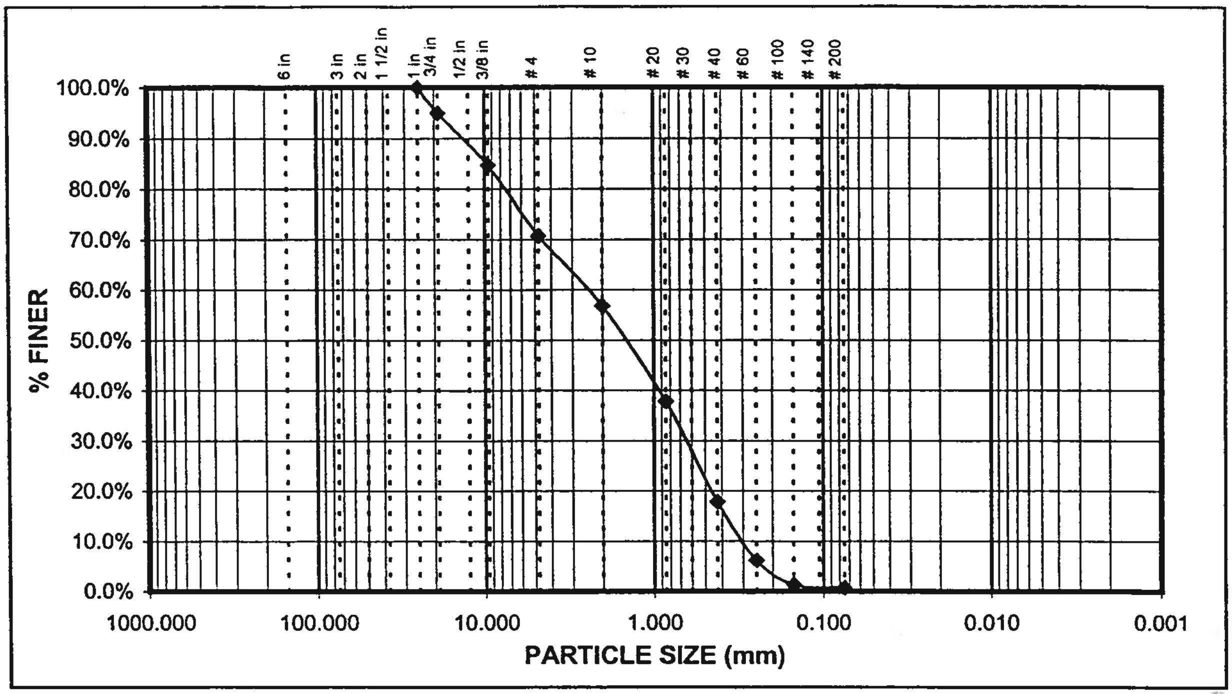
D_{85}	8.24	D_{60}	1.59	D_{50}	1.08
D_{30}	0.58	D_{15}	0.35	D_{10}	0.28
C_u	5.67	C_z	0.74		

Max particle size: mm

Hydraulic Conductivity (estimated from Hazen formula)
7.90E-04 **m/s**

Notes:
Most of the particles in sieve 1" through #10 appear to be broken off portions of larger particles.

PARTICLE SIZE DISTRIBUTION REPORT



Cobbles	% Gravel	% Sand	% Silt	% Clay
-	29.3%	70.0%	0.7%	

Sieve Size		% Finer
	mm	
1"	25.000	100.0%
3/4"	19.000	95.0%
3/8"	9.500	84.6%
#4	4.750	70.7%
#10	2.000	56.8%
#20	0.850	37.8%
#40	0.425	17.8%
#60	0.250	6.1%
#140	0.150	1.3%
#200	0.075	0.7%

Sample Number: INJ3 - 14
Location: Injection Well #3
Source of Sample: ODEX Borehole
Sample Depth: 59.5' - 64.5'
Date Sampled: 7/25/01
Sampled by: B. Lyons
Date Tested: 7/26/01
Test Preformed By: B. Lyons

Soil Description:
Gravely SAND

USCS Classification: SP

Coefficients:

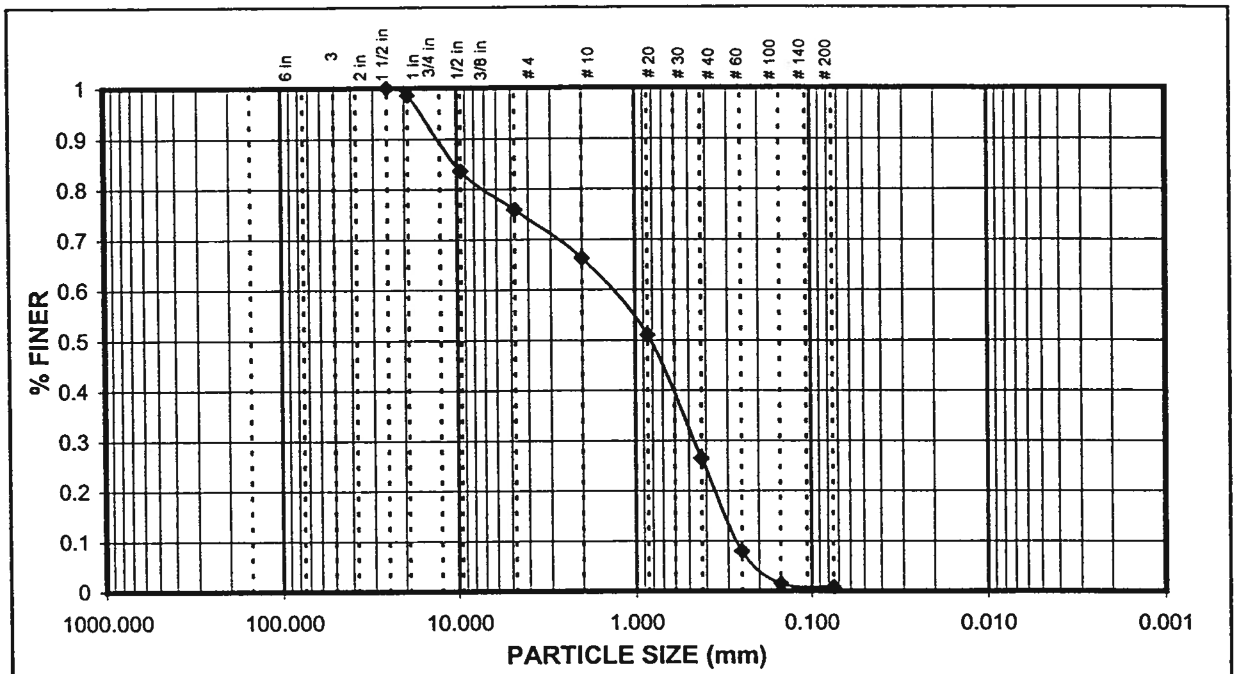
D_{85}	9.73	D_{60}	2.44	D_{50}	1.47
D_{30}	0.65	D_{15}	0.37	D_{10}	0.30
C_u	8.18	C_z	0.58		

Max particle size: mm

Hydraulic Conductivity (estimated from Hazen formula)
8.87E-04 **m/s**

Notes:
Most of the particles in sieve 1" through #10 appear to be broken off portions of larger particles.

PARTICLE SIZE DISTRIBUTION REPORT



Cobbles	% Gravel	% Sand	% Silt	% Clay
-	24.1%	75.1%	0.8%	

Sieve Size		% Finer
	mm	
1"	25.000	1
3/4"	19.000	98.6%
3/8"	9.500	83.7%
#4	4.750	75.9%
#10	2.000	66.3%
#20	0.850	51.1%
#40	0.425	26.5%
#60	0.250	7.9%
#140	0.150	1.5%
#200	0.075	0.8%

Soil Description:
Gravely SAND

USCS Classification: SP

Coefficients:

D_{85}	10.11	D_{60}	1.40	D_{50}	0.83
D_{30}	0.47	D_{15}	0.31	D_{10}	0.27
C_u	5.30	C_z	0.59		

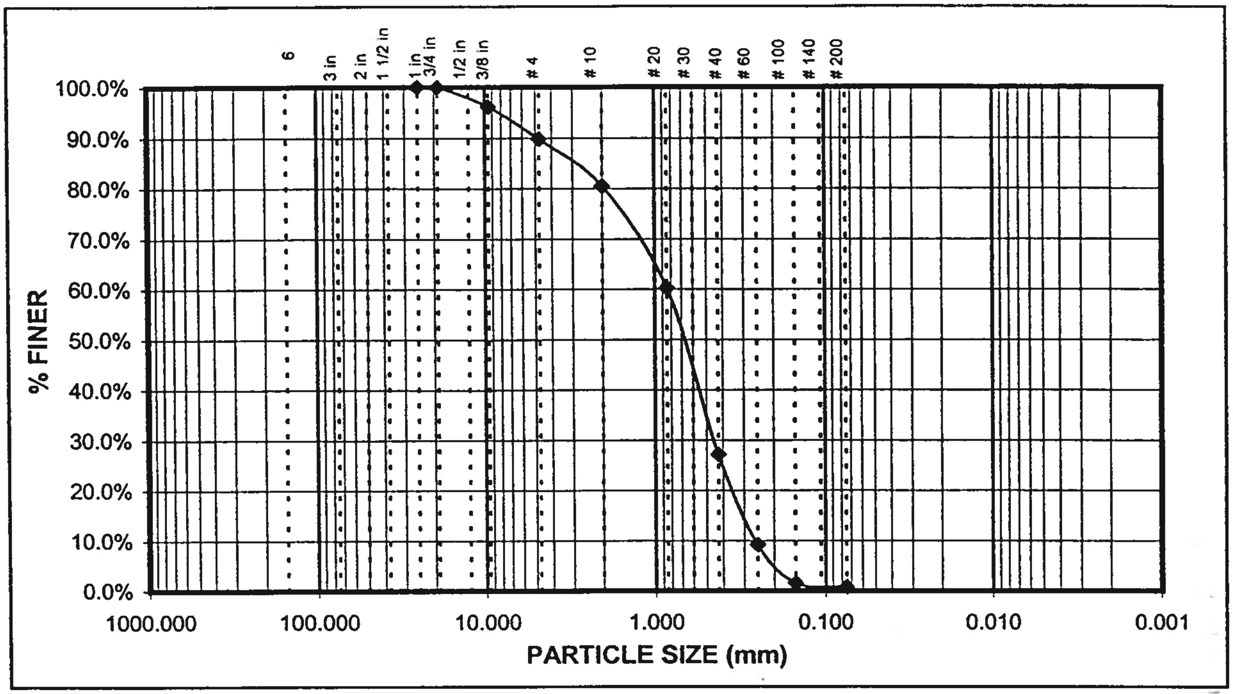
Max particle size: mm

Hydraulic Conductivity (estimated from Hazen formula)
7.03E-04 **m/s**

Notes:
Most of the particles in sieve 1" through #10 appear to be broken off portions of larger particles.

Sample Number: INJ3 - 15
Location: Injection Well #3
Source of Sample: ODEX Borehole
Sample Depth: 64.5' - 69.5'
Date Sampled: 7/25/01
Sampled by: B. Lyons
Date Tested: 7/26/01
Test Preformed By: B. Lyons

PARTICLE SIZE DISTRIBUTION REPORT



Cobbles	% Gravel	% Sand	% Silt	% Clay
-	10.2%	89.0%	0.8%	

Sieve Size		% Finer
	mm	
1"	25.000	100.0%
3/4"	19.000	100.0%
3/8"	9.500	96.2%
#4	4.750	89.8%
#10	2.000	80.5%
#20	0.850	60.3%
#40	0.425	27.2%
#60	0.250	9.2%
#140	0.150	1.5%
#200	0.075	0.8%

Sample Number: INJ3 - 16
Location: Injection Well #3
Source of Sample: ODEX Borehole
Sample Depth: 69.5' - 74'
Date Sampled: 7/26/01
Sampled by: B. Lyons
Date Tested: 7/26/01
Test Preformed By: B. Lyons

Soil Description:
Gravely SAND

USCS Classification: SP

Coefficients:

D_{85}	3.04	D_{60}	0.84	D_{50}	0.69
D_{30}	0.45	D_{15}	0.30	D_{10}	0.26
C_u	3.30	C_z	0.94		

Max particle size: mm

Hydraulic Conductivity (estimated from Hazen formula)
6.55E-04 **m/s**

Notes:
Most of the particles in sieve 1" through #10 appear to be broken off portions of larger particles.

APPENDIX C

Pump Curves for Model S6-350 Submersible Pump

ATTN: MIKE

2 pages

MODEL S6-350

GENERAL DATA

RPM: 3600 NOMINAL, 60HZ.
MAX. O.D. W/CABLE GUARD 5 7/8"
MINIMUM WELL SIZE 6"
DISCHARGE SIZE 4" STANDARD

BOWLS : CAST IRON
IMPELLERS : BRONZE
SHAFT : STAINLESS STEEL

IMPELLER DATA

IMPELLER NO.: 615
TYPE : ENCLOSED
EFFECTIVE EYE AREA : 7.0 SQ.IN
TRIM DIAMETER
A - 4.725
B - 4.550
C - 4.275
D -
E -

THRUST CONSTANT K: 3.1
NO. OF VANES : 7
IMPELLER SKIRT CLEARANCE : .015"
EFFICIENCY CORRECTION
1 STAGE - 3%
2 STAGE - 2%
3 STAGE - 1%
4 STAGE - 0%

BOWL DATA

BOWL NO. : 561
DIAMETER : 6.5"
CONNECTION : THREADED

SHAFT BEARING CLEARANCE : .010"
BEARING MATERIAL: CUTLESS RUBBER
PUMP SHAFT DIAMETER : 1"

SPECIAL MATERIALS AVAILABLE - CONTACT FACTORY

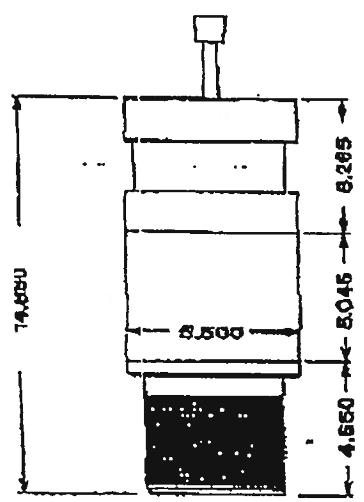
NOTE EFFICIENCY PERFORMANCE BASED ON A-TRIM, CAST IRON BOWLS, POLISHED BRONZE IMPELLERS, AND 6 FEET SUBMERGENCE.

THIS CHARACTERISTIC CURVE IS BASED ON FACTORY TESTS WHEN PUMPING CLEAR, NONAERATED WATER AT A TEMPERATURE NOT EXCEEDING 85 F. AND UNDER SUCTION CONDITIONS AS INDICATED. SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

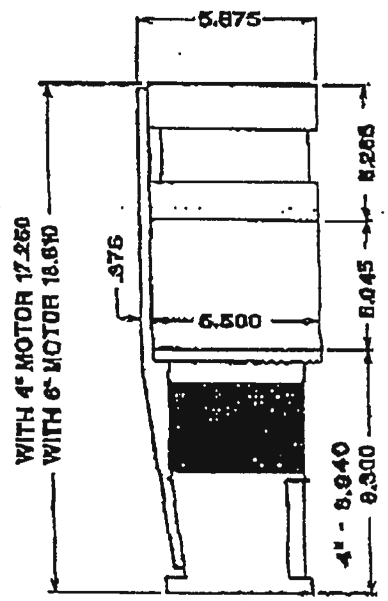
PUMP PERFORMANCE RATING IS FOR THE DESIGNATED POINT ONLY AND IS SUBJECT TO TEST TOLERANCES AND PROCEDURES AS SPECIFIED IN THE STANDARD OF THE HYDRAULIC INSTITUTE.

DISCHARGES AVAILABLE
3" FEMALE
4" MALE
4" FEMALE

WEIGHT
1 STAGE PUMP : 41#
ADD. STAGE : 16#



VERTICAL TURBINE



SUBMERSIBLE

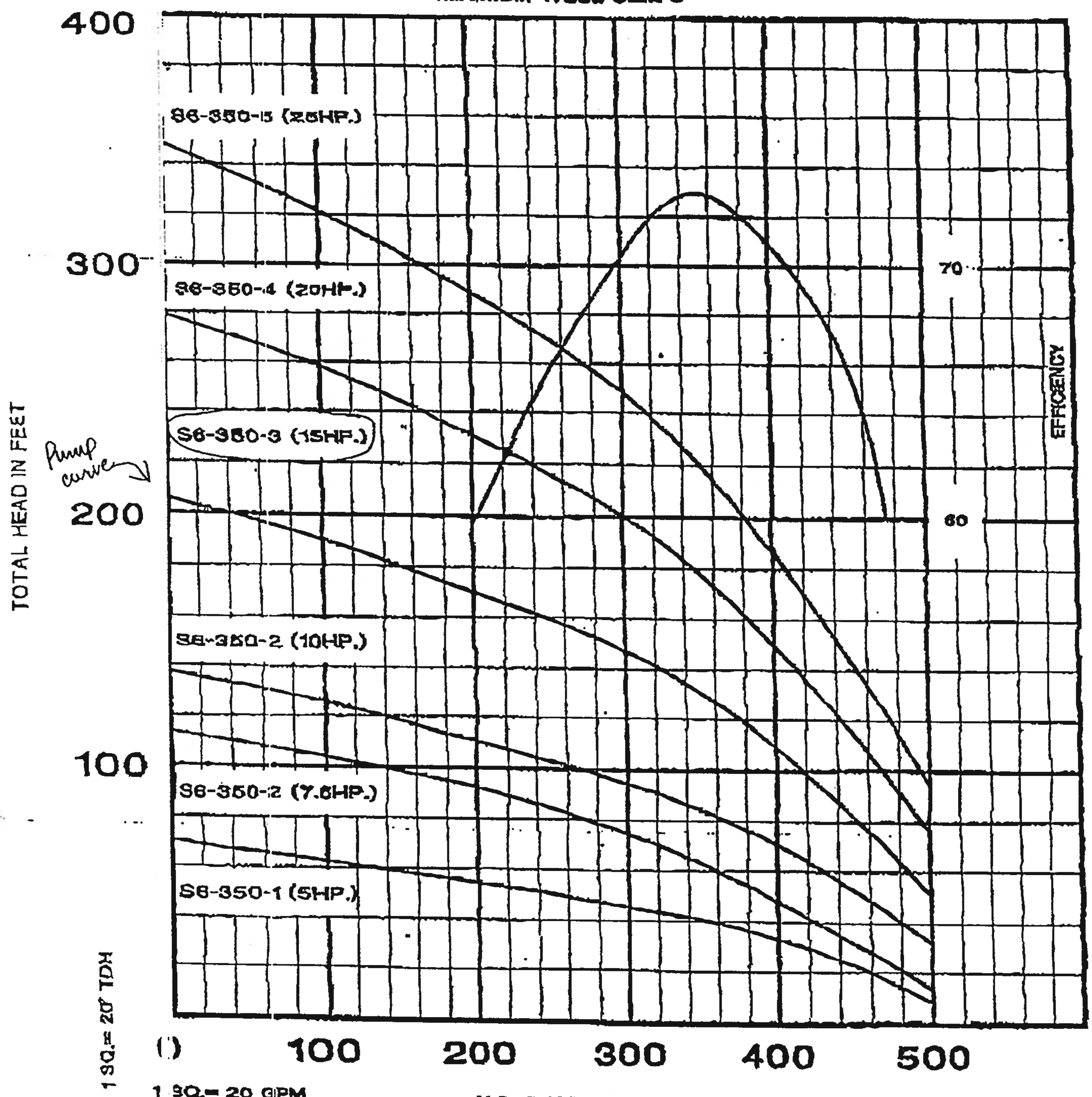
DISCHARGES AVAILABLE
6" FEMALE
4" MALE
4" FEMALE

WEIGHT
1 STAGE PUMP : 54#
ADD. STAGE : 16#

CROWN S6-350

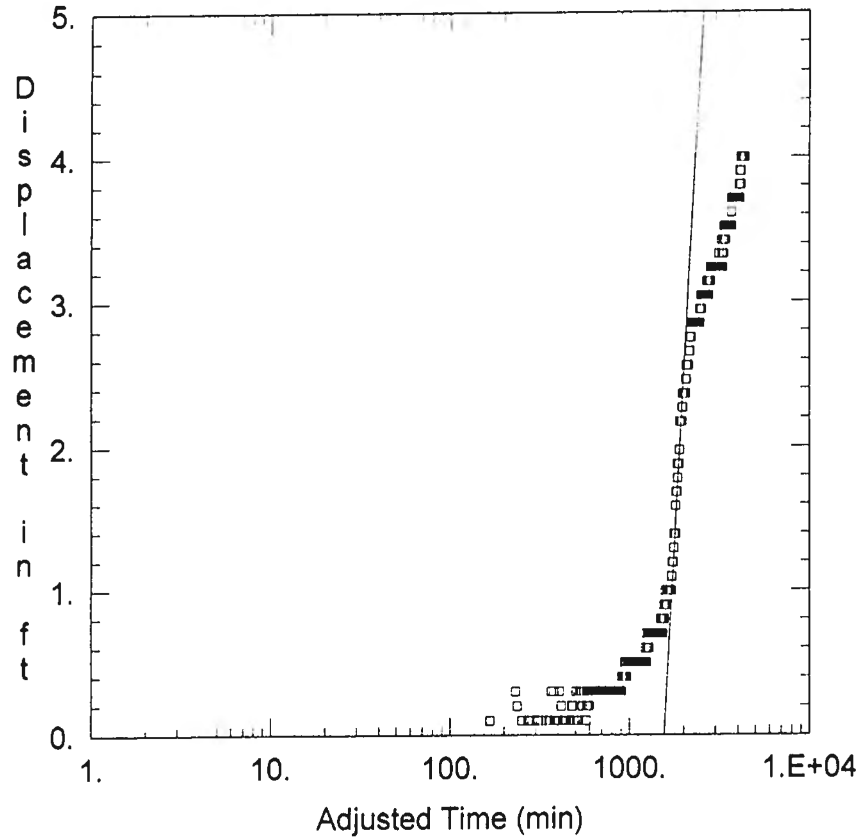
MODEL S6-350
PERFORMANCE CHARACTERISTICS

MINIMUM WELL SIZE 8"



CROWN CROWN PUMP CORPORATION, HIGHWAY 16 & BIVAR, DE LEON, TEXAS

APPENDIX D
AQTESOLV Data



INJ-3 TEST

Data Set: C:\DATA\WL0188~1\INJ1CJ1.AQT
Date: 11/21/01 Time: 21:07:51

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob
T = 0.0006422 m^2/sec
S = 0.3919

AQUIFER DATA

Saturated Thickness: 80. ft
Anisotropy Ratio (Kz/Kr): 0.1

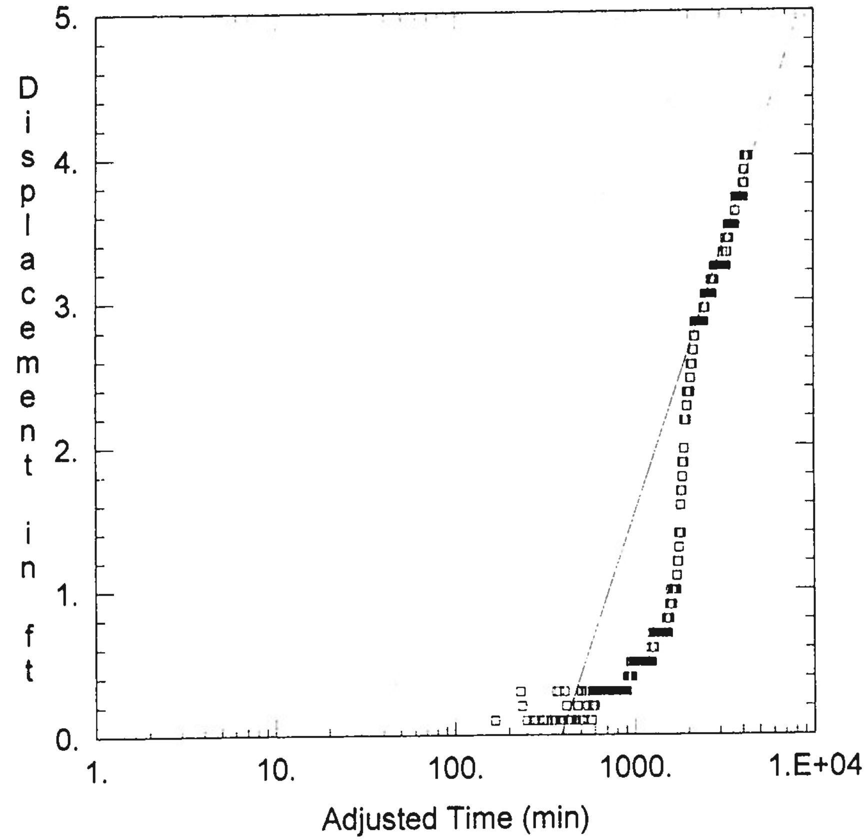
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-2	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ INJ-1	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: D:\IW3GR~13\INJ1CJ2.AQT
Date: 11/21/01 Time: 21:00:19

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 0.004006 m^2/sec
S = 0.6136

AQUIFER DATA

Saturated Thickness: 80. ft

Anisotropy Ratio (Kz/Kr): 0.1

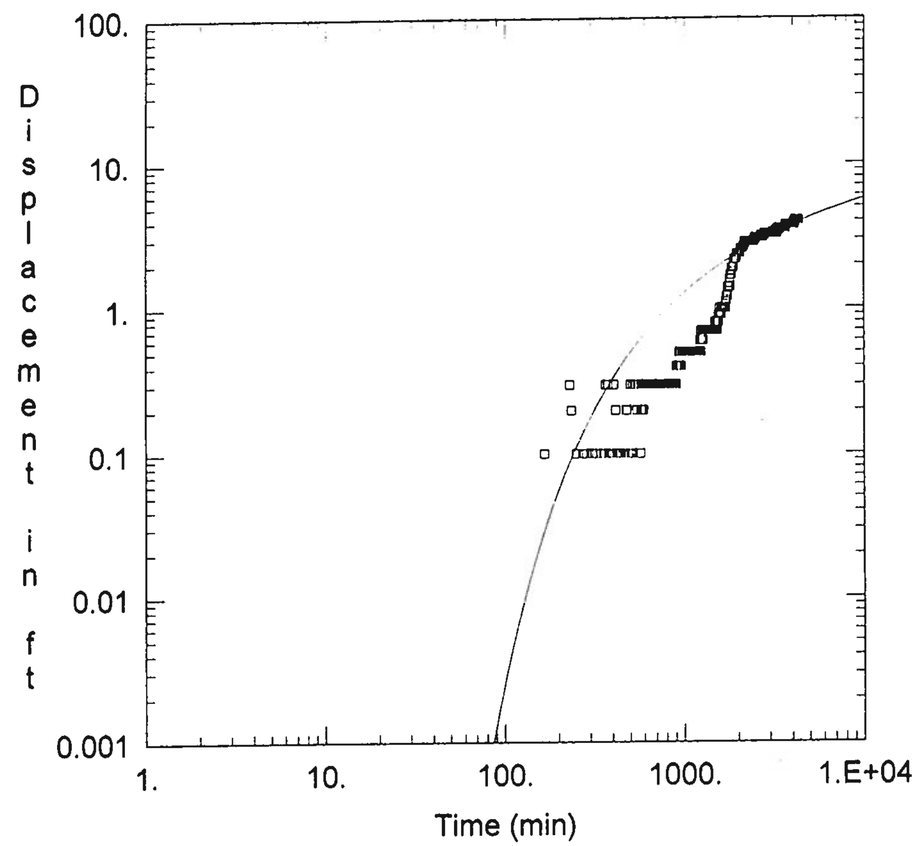
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-2	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
□ INJ-1	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: C:\DATA\WL0188~1\INJ1THIS.AQT
Date: 11/21/01 Time: 21:12:45

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis
$T = 0.00285\ m^2/sec$
$S = 1.004$

AQUIFER DATA

Saturated Thickness: 80. ft
Anisotropy Ratio (Kz/Kr): 0.1

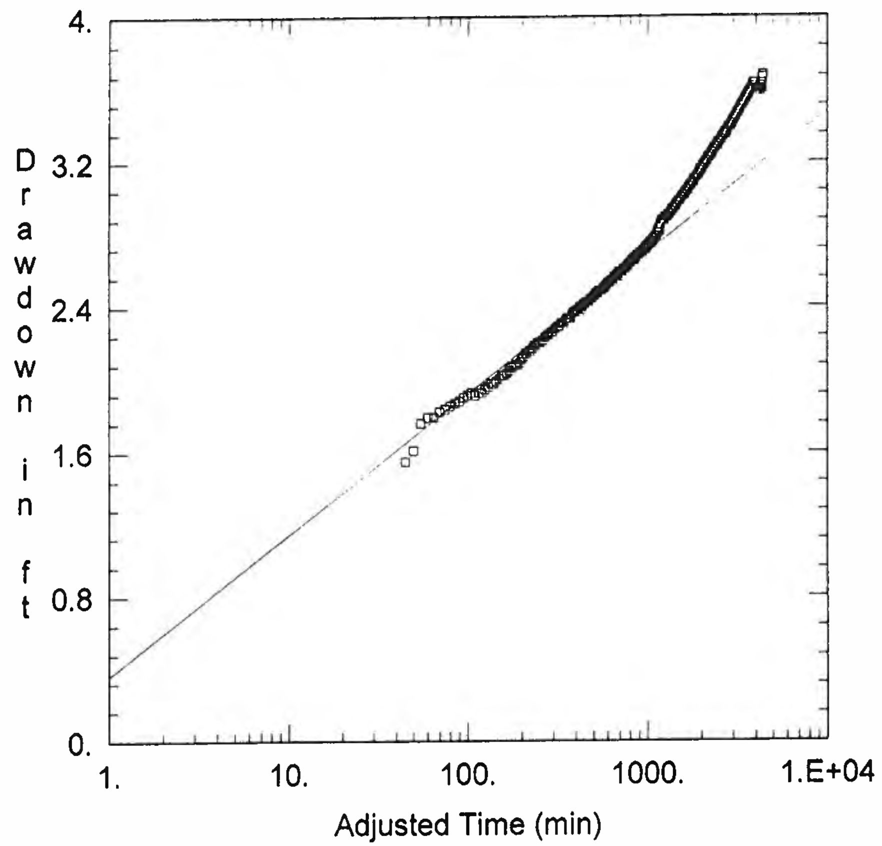
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-2	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ INJ-1	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: C:\DATA\WL0188~1\INJ2CJ2.AQT
Date: 11/21/01 Time: 21:23:35

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob
T = 0.01929 m^2/sec
S = 0.005351

AQUIFER DATA

Saturated Thickness: 80. ft
Anisotropy Ratio (Kz/Kr): 0.1

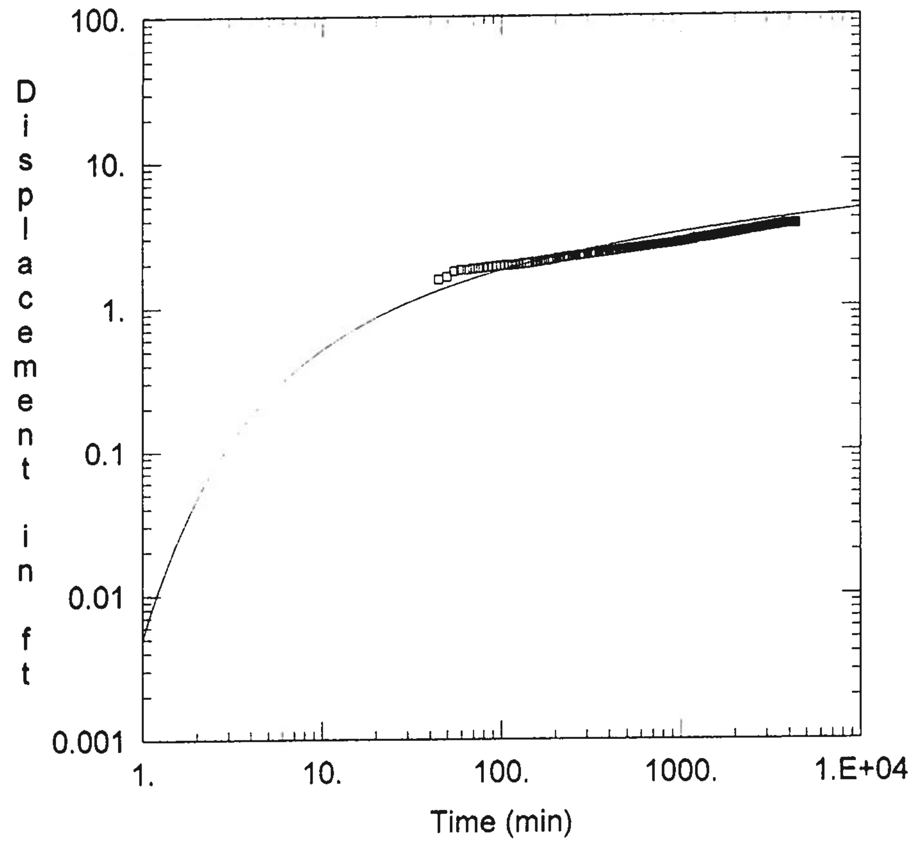
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-2	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ INJ-2	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: D:\IW3GR~13\INJ2TH.AQT
Date: 11/21/01 Time: 21:37:05

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis
T = 0.01041 m^2/sec
S = 0.05131

AQUIFER DATA

Saturated Thickness: 80. ft

Anisotropy Ratio (Kz/Kr): 0.1

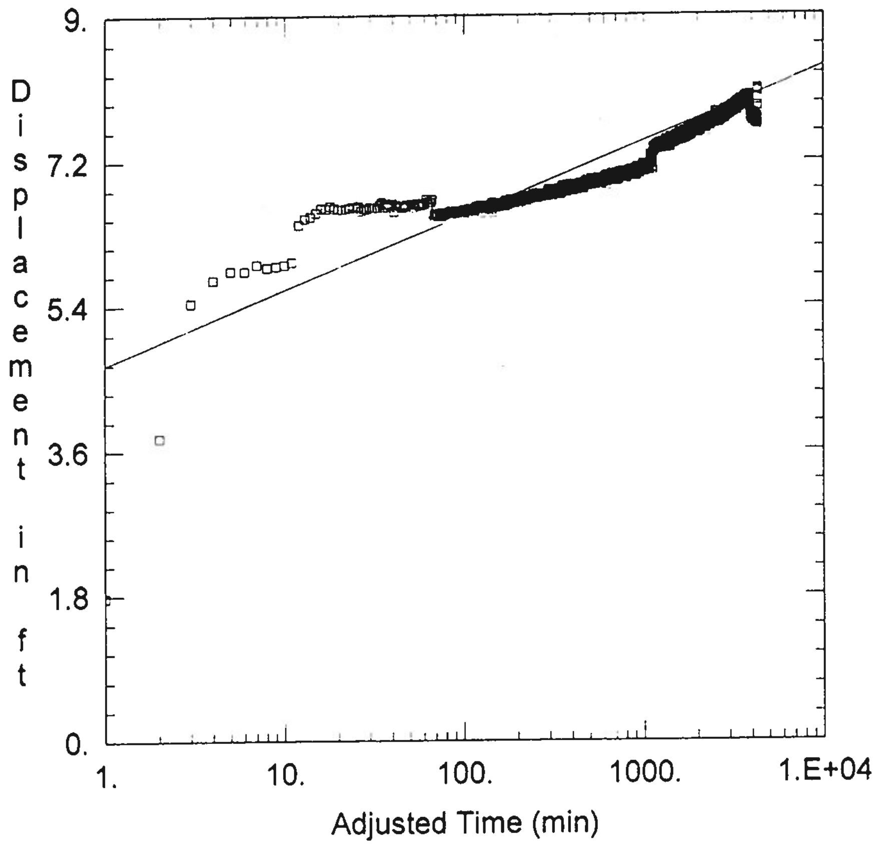
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-2	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ INJ-2	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: C:\DATA\WL0188~1\INJ3CJ.AQT
Date: 11/21/01 Time: 22:24:50

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 0.01629 m^2/sec
S = 0.001541

AQUIFER DATA

Saturated Thickness: 80. ft

Anisotropy Ratio (Kz/Kr): 0.1

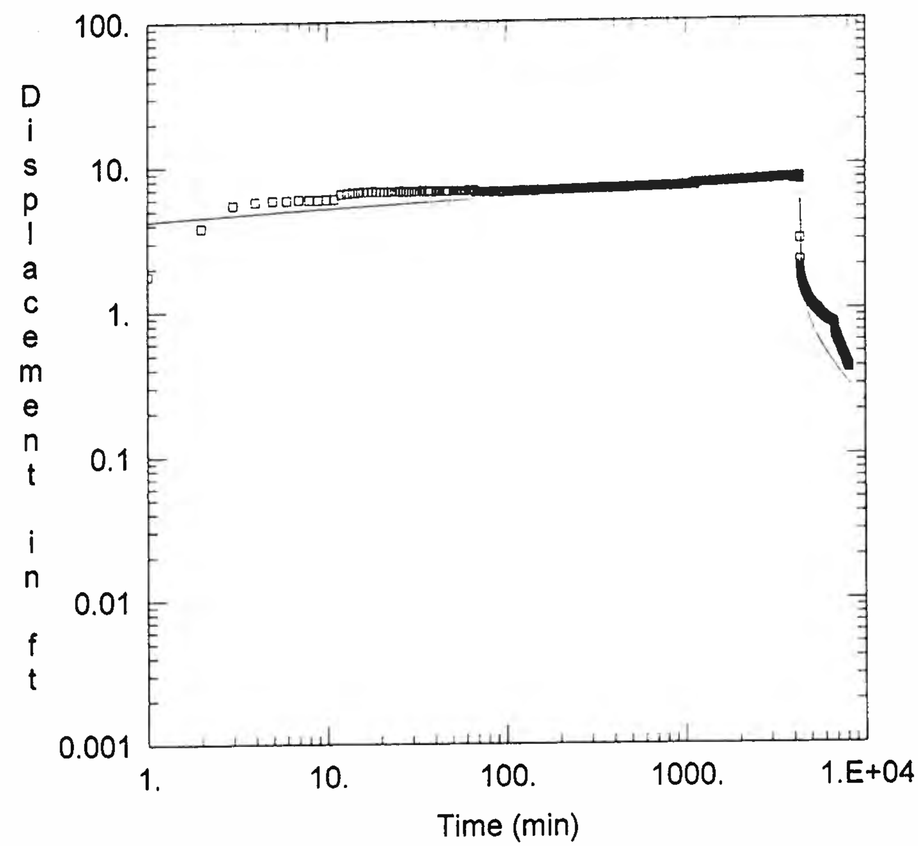
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-3	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ INJ-3	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: D:\IW3GR~13\INJ3TH.AQT
Date: 11/21/01 Time: 21:53:24

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis
T = 0.01641 m^2/sec
S = 0.004442

AQUIFER DATA

Saturated Thickness: 80. ft
Anisotropy Ratio (Kz/Kr): 0.1

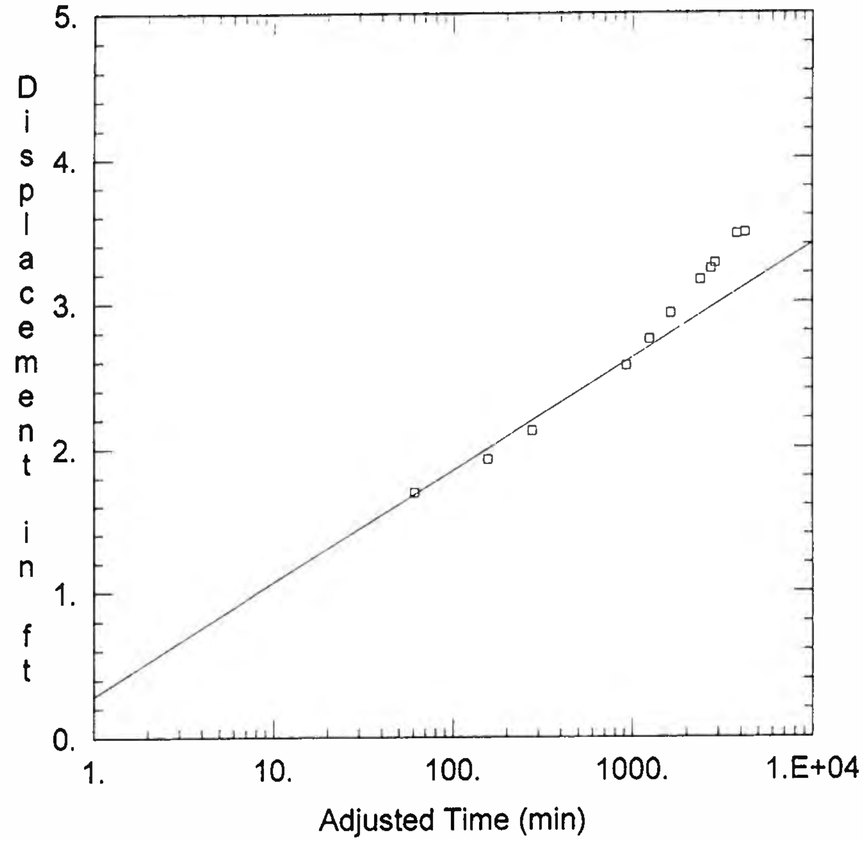
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-3	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
□ INJ-3	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: C:\DATA\WL0188~1\MW11ACJ1.AQT
Date: 11/21/01 Time: 22:30:16

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 0.01929 m^2/sec
S = 0.0079

AQUIFER DATA

Saturated Thickness: 80. ft

Anisotropy Ratio (Kz/Kr): 0.1

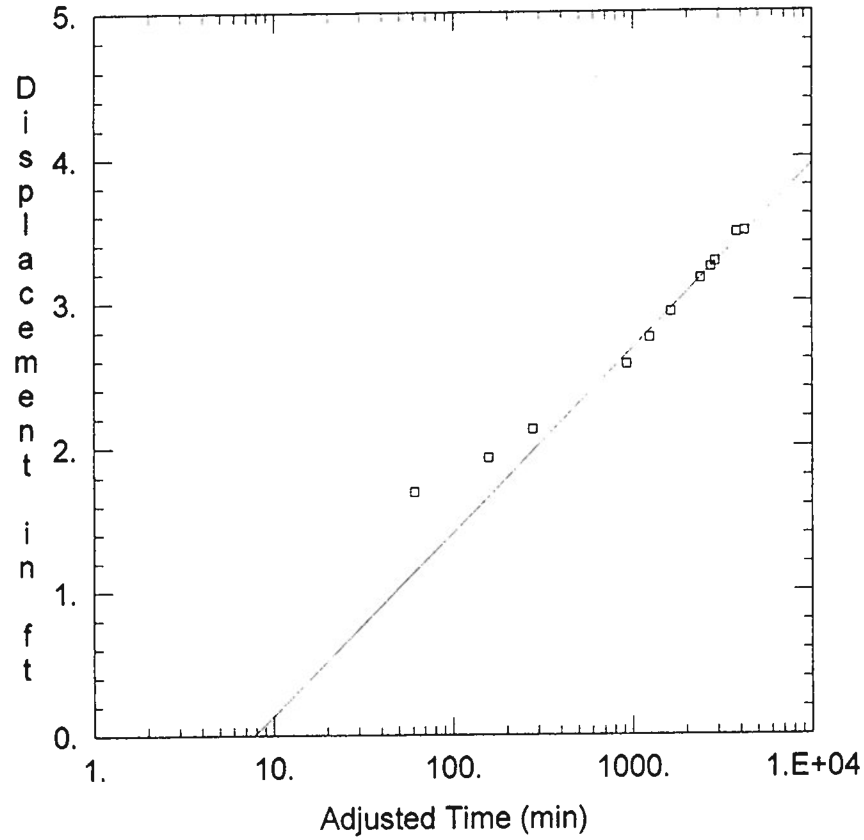
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-3	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
□ MW98-11a	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: D:\IW3GR~13\MW11ACJ2.AQT
Date: 11/21/01 Time: 22:27:33

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob
T = 0.01183 m^2/sec
S = 0.08827

AQUIFER DATA

Saturated Thickness: 80. ft

Anisotropy Ratio (Kz/Kr): 0.1

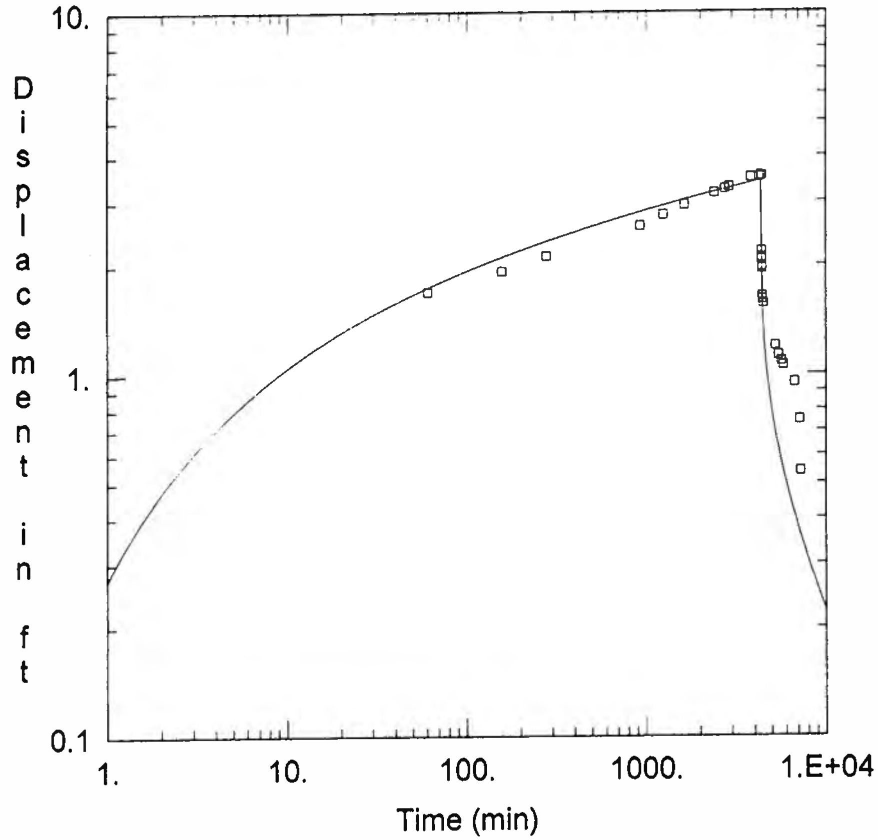
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-3	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW98-11a	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: C:\DATA\WL0188~1\MW11ATH.AQT
Date: 11/21/01 Time: 22:32:00

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 0.01668 m^2/sec
S = 0.01152

AQUIFER DATA

Saturated Thickness: 81. ft

Anisotropy Ratio (Kz/Kr): 0.1

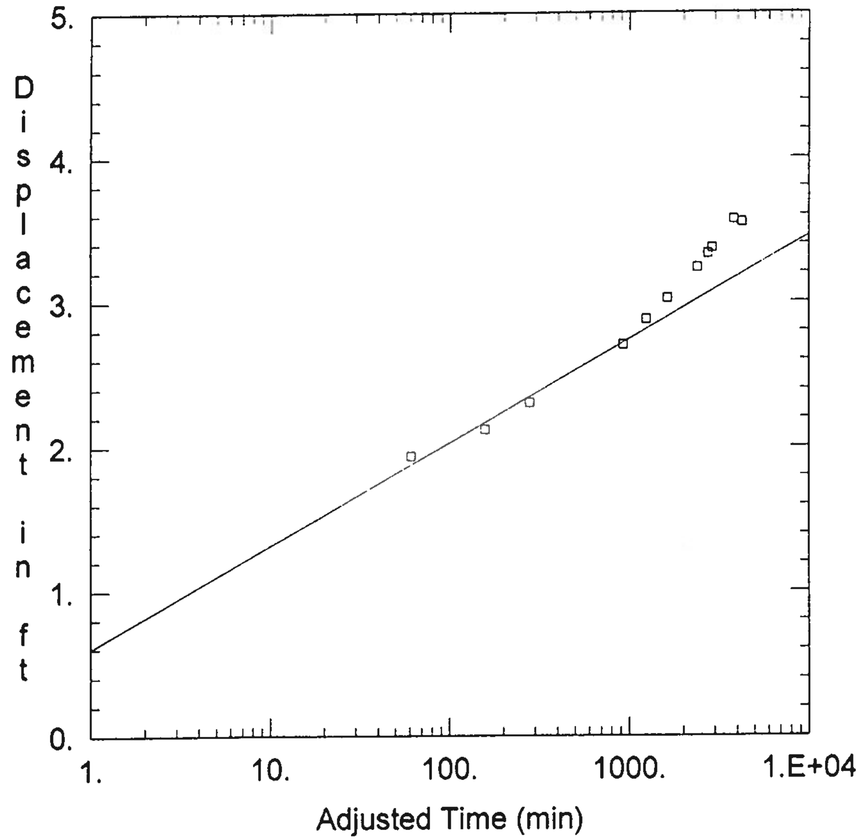
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-3	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW98-11a	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: C:\DATA\WL0188~1\MW11BCJ2.AQT
Date: 11/21/01 Time: 22:34:20

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob
T = 0.02107 m^2/sec
S = 0.002876

AQUIFER DATA

Saturated Thickness: 81. ft

Anisotropy Ratio (Kz/Kr): 0.1

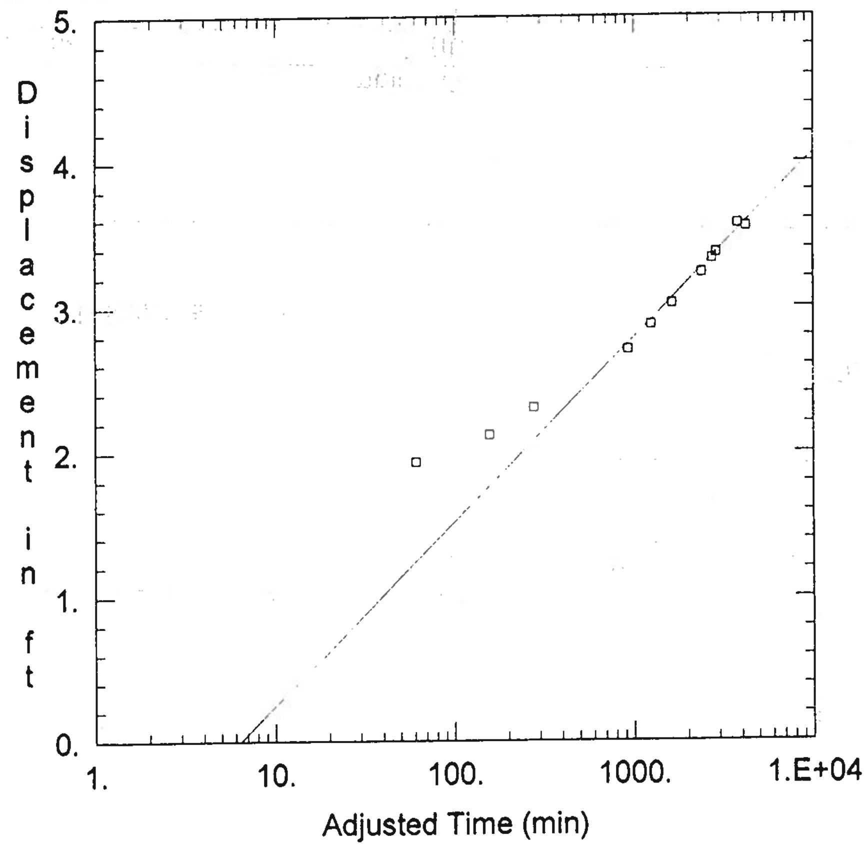
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-3	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW98-11b	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: C:\DATA\WL0188~1\MW11BCJ1.AQT
Date: 11/21/01 Time: 22:33:25

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob
T = 0.01183 m^2/sec
S = 0.0724

AQUIFER DATA

Saturated Thickness: 81. ft

Anisotropy Ratio (Kz/Kr): 0.1

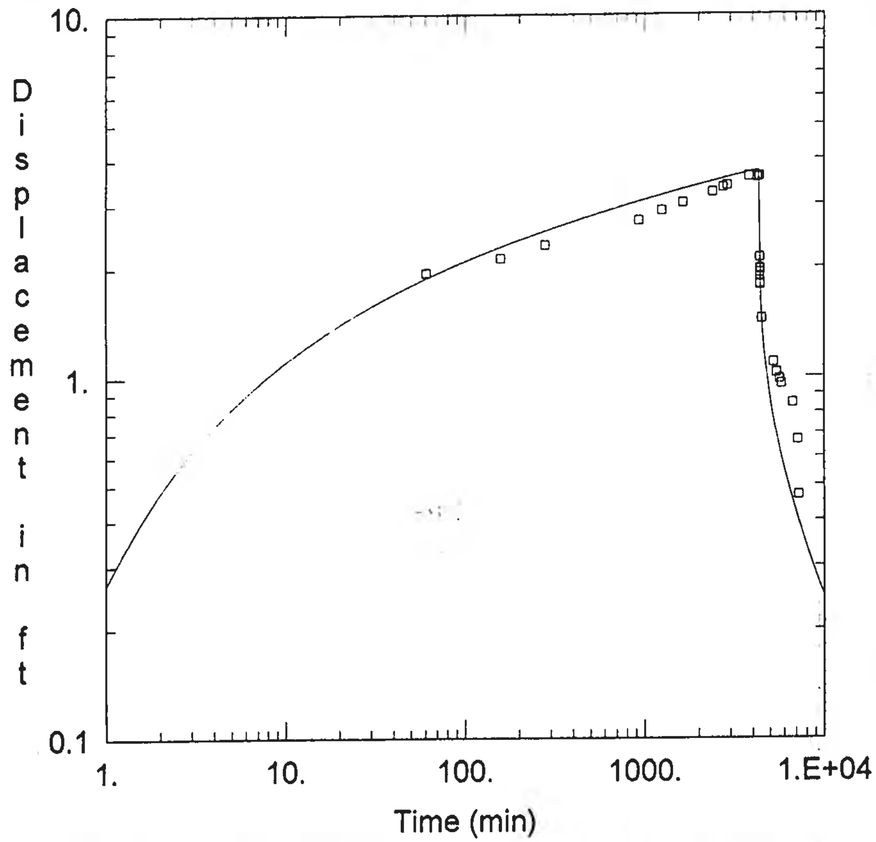
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-3	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW98-11b	3.819E+006	1.808E+006



INJ-3 TEST

Data Set: C:\DATA\WL0188~1\MW11BTH.AQT
Date: 11/21/01 Time: 22:36:11

PROJECT INFORMATION

Company: Waterline Resources
Client: Teck Corporation
Project: WL01-882
Test Location: Pogo Mine
Test Well: INJ-3
Test Date: August 27, 2001

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 0.01506 m^2/sec
S = 0.01182

AQUIFER DATA

Saturated Thickness: 81. ft

Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
INJ-3	3.819E+006	1.808E+006

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW98-11b	3.819E+006	1.808E+006