UNDERGROUND MINING OF THE LOWER 163 ZONE THROUGH GROUNDWATER DRAINAGE AT THE EAGLE POINT MINE

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ABSTRACT

The Eagle Point Mine is part of the Cameco Rabbit Lake Operation. The mine produces uranium ore using the long-hole, vertical and horizontal retreat mining method. The majority of the mine workings are under Wollaston Lake and cementitious grouting is used as one of the water control measures. Historical groundwater table in the mining area was close to ground surface. The Lower 163 Zone encompasses an estimated 4.2 million pounds U_3O_8 geological resource that was not considered feasible to mine due to the expected groundwater flows in the area. Cross-hole testing was conducted to better understand the groundwater flow through various geologic units. A local depressurization test was conducted to assess the potential for lowering the water table. Following testing an active depressurization was conducted to lower the groundwater table below the planned mining areas. This resulted in safe and drier mining conditions and allowed for the successful extraction of the ore body.

INTRODUCTION

Background Information

Eagle Point mine (EPM) is part of Cameco's 100% owned and operated Rabbit Lake Operation (RLO) in northern Saskatchewan, Canada. The site is located approximately 400 km north of La Ronge, Saskatchewan, and is accessible year-round by ground and air (Figure 1).

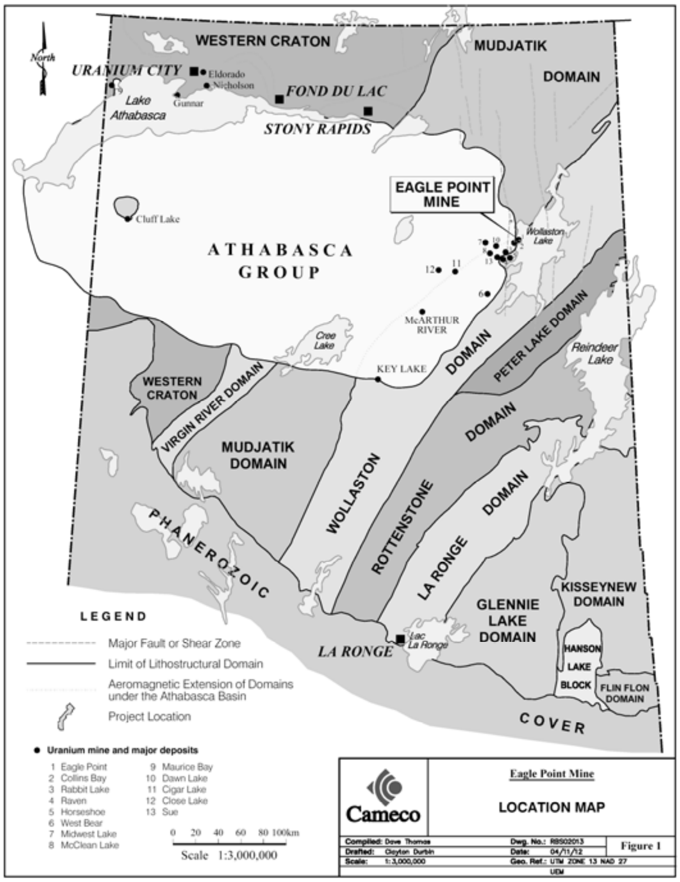

Figure 1: Location of Eagle Point mine in northern Saskatchewan

History

There have been various surface mining activities at Rabbit Lake since the mid-1970s. Eagle Point mine (EPM) is the first underground operation at Rabbit Lake, and was started in 1992. In 1998, mining operations were suspended due to depressed world demand for uranium. The mine was re-opened in 2002 with an expected mine life of only three years. An aggressive underground diamond drilling program was initiated at re-opening, with the aim to increase the life of the mine. Diamond drilling identified several potential ore zones, including the 163 Zone, 141 Zone, 144 South Extension, 02 North Extension (02NExt), and 02 North Extension Footwall (02NFW).

Geology and Hydrogeology

Ore bodies at Eagle Point are hosted within the Wollaston Group of meta-sediments; and consist of veins, lenses, and pods. The Collins Bay fault runs approximately parallel to the Wollaston Group and all of the ore zones at EPM fall within the hanging wall of Collins Bay Fault (Figure 2). The host rock of the ore bodies consists of various types of gneiss, quartzite, calc-silicate, and pegmatite. The veins and lenses are tabular in nature, have a thickness of between 1m and 15m, and dip between 50° and near-vertical. Localized high-grade intersections can exist where two or more mineralized structures intersect each other. With multiple joint systems, the presence of graphite and clay, and the varying degrees of alteration, ground conditions can be quite challenging [1].

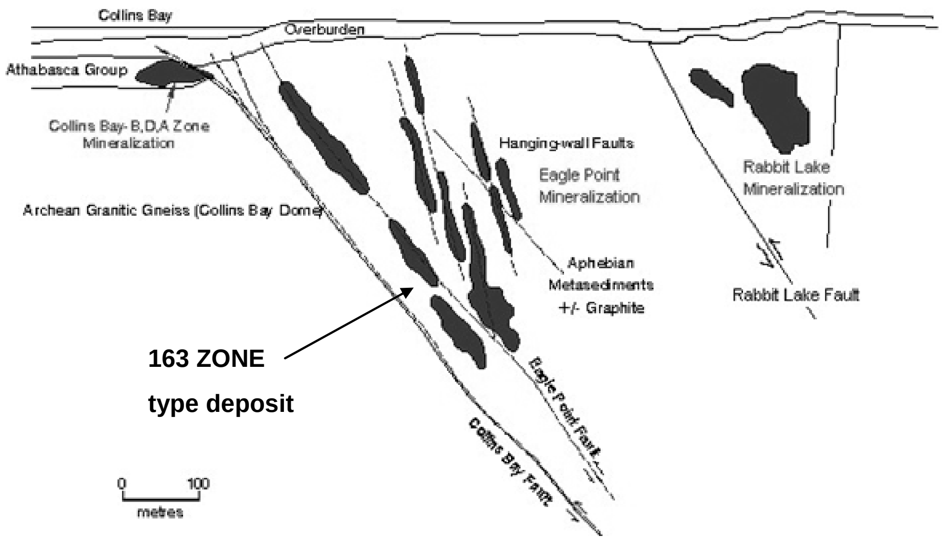

Figure 2: Cross-section of different deposits at Rabbit Lake.

The hydrostratigraphic units at Eagle Point vary widely, but can be divided into three general types: surficial sediments, bedrock units, and structure. Surficial sediment around EPM ranges in thickness from several metres up to 12 metres deep. It is a mix of organic silt and till material, and the hydraulic conductivity for this unit type varies between 10^{-7} m/s to 10^{-4} m/s. The bedrock units surrounding Eagle Point are of greater concern, consisting of granitoid gneiss, and Athabasca sandstone. The Athabasca Sandstone is quite permeable, with a hydraulic conductivity of 10^{-8} to 10^{-5} m/s. However, the Eagle Point deposit does not come into contact with the sandstone. The bedrock units are interlaid with numerous faults and fractures. As the depth increases at EPM, rock is typically less weathered and is under greater stress. A hydraulic conductivity in this region is between 10^{-8} and 10^{-7} m/s [6]. A prominent fault known as the 'quartzite' plays a central role in this technical paper. This fault is a known hydrogeological conduit at certain depths of the mine. As previously mentioned, Eagle Point is a basement-hosted deposit, and does not share the hydrogeological conditions of other Cameco deposits, such as Cigar Lake or McArthur River.

Mining Method

Due to the tabular and steep-dipping nature of the ore-body, EPM utilizes the long-hole stope, vertical retreat mining method in order to extricate the ore. This method involves: developing on the overcut and undercut of the mining block; installing additional ground support (usually 6m to 14m long cablebolts); and establishing a slot-raise. The ore is then blasted into the slot-raise, and is mucked from the undercut by scoop trams into haul trucks. Eagle Point produces approximately 550 tonnes per day (t/d), and also creates 530 t/d of waste rock, the majority of which is used for backfilling stopes.

Problem Definition

Uranium mining in the Athabasca Basin can be challenging. Unconformity-type deposits such as McArthur River and Cigar Lake lie within highly fractured sandstone, with water pressure approaching 5 MPa (~730 psi). The Eagle Point deposit is hosted in basement rock, which is tighter than the sandstone and therefore avoids this problem. However, Wollaston Lake is directly above the mine, and there is the potential for water to seep into the mine through water-bearing structures. Cementitious grouting is one method of minimizing water inflow into the underground workings. The 163 Zone was drilled and identified in the mid-2000s, and extends from the crown pillar (90m depth) to almost 420m depth [1]. The existing infrastructure of the mine (main decline, exhaust raises, etc.) is roughly divided into North and South, with the main decline acting as the divider. The 163 Zone lies in the southern portion of the mine, striking approximately 220°, and dips between -50° and -70° to the east. The 163 Zone is a fairly continuous tabular deposit that is structurally controlled. There is approximately 4.2M lbs of U_3O_8 identified in the lower portion of this zone. In order to get a definitive picture of the extent of the ore body, the zone has been drilled from several different levels, including 100L, 230L, 340L, and 400L. As mentioned above, one of the defining features of the 163 Zone is a fault named the 'quartzite fault'. This fault spans the extent of the mine, and has been known to be a conductor of water in other areas of the mine. Conversely, certain parts of the quartzite fault have been proven to be dry, suggesting that water is fed from an alternative fault structure that intersects the quartzite at a certain depth. This fault could ultimately be connected to the bottom of Wollaston Lake.

For mining scheduling purposes, the 163 Zone was divided into several different blocks. The lower 163 Zone was divided into two blocks – one spanning from 230L to 280L, and the second spanning from 300L to 420L. The first level to be developed into this area occurred on the 275L. As the development approached the quartzite vein, water appeared in the back and face of the heading. Since Eagle Point is a uranium mine, this water could contain radon, which on contact with air could result in the emanation of radon gas and radon progeny, the implication of which is a potentially elevated radiation exposure level for the workers. Multiple attempts were made to grout around the drift in order to prevent water from entering the drift. These efforts were met with minimal success, in large part because the drift had already exposed the water-bearing structure. At this point, the 275L development was put on hold, and development began on 280L. 280L development progressed to a point before it was projected to intersect the water-bearing structure. A grouting program began on 280L, but again due to the multiple fault structures in the area, the water inflows on 275L remain unchanged. At this point in time, Eagle Point technical staff began to look at alternative options to remove the water from the drift development area.

HYDROGEOLOGICAL TEST PROGRAM

Introduction

As mentioned previously, the 163 Zone had been drilled from several different locations. There were a number of holes drilled from 340L, most of which were grouted after the drill program was completed. However, four holes were left open by installing standpipes and shut-off valves and provided initial data readings for the test program. These holes produced between 35 to 120 US gallons per minute (USGPM) when allowed to flow individually. The pressure readings from these holes indicated that the ground water table was in the area of 150 metres above mean sea level (mAMSL) (Figure 3), and was later confirmed by drilling on 280L. It is important to note that Collins Bay of Wollaston Lake has an elevation of approximately 397mAMSL, and when the mine first opened in 1992, test reports indicated that the groundwater table was approximately 385mAMSL. This suggests that as result of previous mining activities, the water table has undergone a passive depressurization of about 235m [10].

As also mentioned earlier, the development on 280L was halted before the projected intersection of the water-bearing structure. A hydrological program was planned to better understand the hydrogeology of the 163 Zone. As part of the program, 12 holes were drilled from 280L using a diamond drill (Figure 4). The program targeted the different areas around the quartzite to see if the vein is the main water-bearing unit and if the hanging wall and footwall are fed from it. As shown in Figure 5, two holes were drilled into the footwall of the quartzite. Three holes were drilled to the contact between the footwall and quartzite, then pressure-grouted. This was followed by drilling through the grout and into the quartzite using a smaller diameter drill bit. Two holes were then drilled to the contact between the quartzite and hanging wall. Once again, these holes were pressure grouted, and then re-entered with a smaller diameter drill bit. Finally, three holes were drilled into the quartzite and hanging wall. The purpose of separating the different areas was to hydrogeologically isolate each area and determine whether or not there was hydraulic connection between them by conducting a cross-hole test. The testing procedure used was similar to that which is described by Carlson [7].

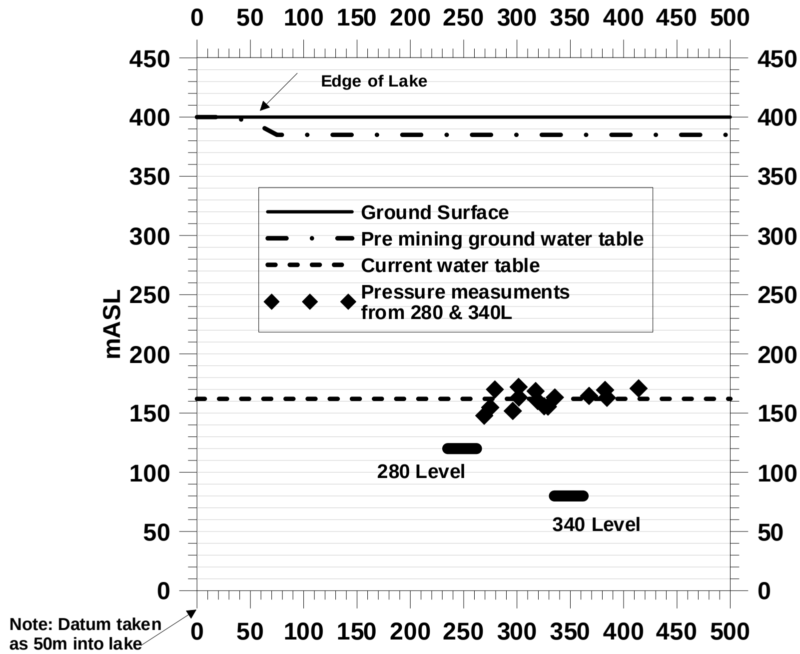

Figure 3: Water table elevation prior to the depressurization test**.**

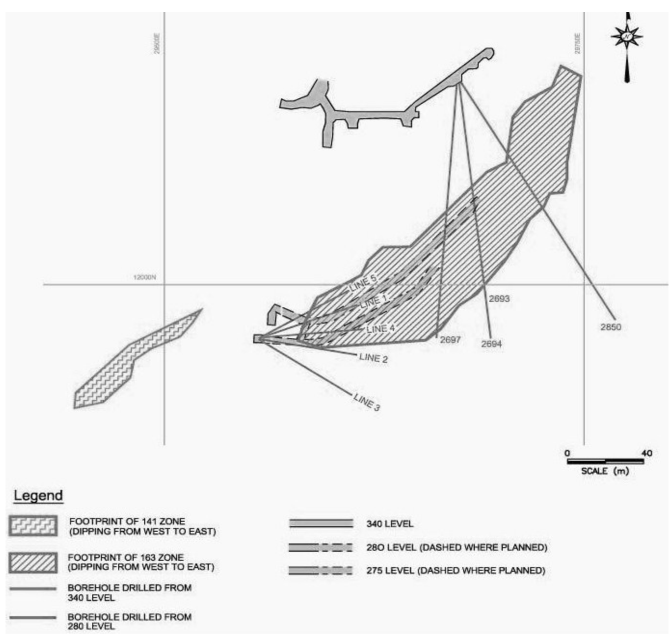

Figure 4: Plan view showing the footprint of the 163 Zone, and monitoring holes on 280L and 340L.

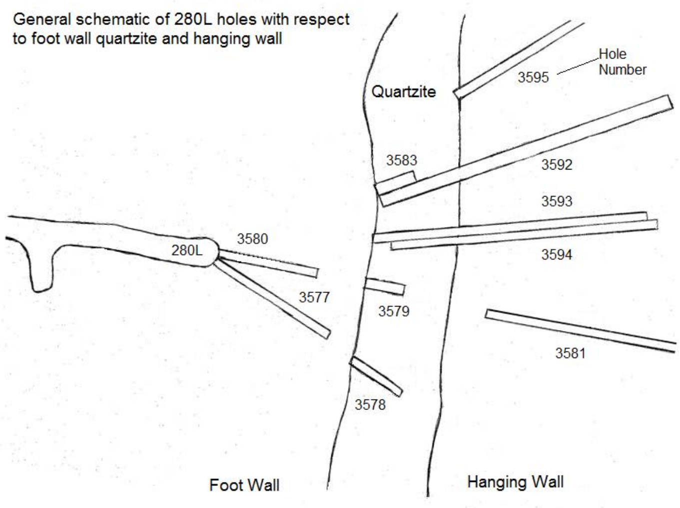

Figure 5: General schematic of 280L holes with respect to footwall, quartzite, and hanging wall.

Cross-Hole Testing at 280L

On 280L, the cross-hole testing began by allowing one hole to be opened, and then monitoring the pressure in the other holes. After the flow had stabilized, the hole was closed and the recharge rate was observed in all of the holes. The Jacob-Lohman equation [9] was used to calculate hydraulic conductivity of the various units. Based on the measurements it was evident that the quartzite is the most conductive and water-producing unit compared to the footwall and hanging wall. However the results of the cross-hole test were rather inconclusive in determining if there is sufficient connection between the footwall, quartzite and hanging wall. The cross-hole test at 280L was followed by allowing two of the existing holes on 340L to flow with pressure monitoring at all holes at 280L. The results clearly indicated that the discharge at 340L resulted in depressurization in the quartzite, hanging and the footwall, indicating connectivity to a single source. Unfortunately due to pumping constraints, the holes at 340L were only allowed to flow for a couple of hours and long-term effects of discharge on 280L could not be captured

Three-Day Depressurization Test at 340L Exploration

The hydrogeological testing on 280L was rather inconclusive in terms of clearly identifying if the quartzite region is the only main supplier of water in this area. After the data was analyzed, it was decided to continue development of the 275L. As the development continued, an uncontrolled inflow of 45 USGPM was encountered and development was halted. As described above, the measurements from 340L and 280L indicated that the groundwater table in the area has been lowered due to historical mining activity. Moreover the limited discharge at 340L indicated the potential for lowering the water table. Following the uncontrolled inflow on 275L, an assessment of the potential for further lowering the groundwater table was conducted via a controlled discharge from 340L. Before this could happen, a risk assessment and job hazard analysis (JHA) were conducted in order to minimize unforeseen events from occurring. One of the major challenges of the test was the potential to overwhelm the EPM dewatering system – both in the underground mine and the surface water handling facilities. Once all the risks were assessed, a start date was established.

The test procedure was established to initiate flow from two holes on 340L, while monitoring the pressure on the remaining holes in 340L and 280L. In addition, a weir was constructed on 275L in order to ascertain water inflow volumes during the test. In the second quarter of 2008, the flow and shut-in test began on 340L. The test began by monitoring the initial pressure head on both of the levels. The 340L is 80mAMSL and had initial pressure readings of 65 to 70m H_2O (100 psi), while 280L is 120mAMSL and had initial pressure readings of 25 to 35m H_2O (40 psi). After the flow at 340L was initiated, pressure and flow readings were taken regularly in the first few hours, and then less frequently as the test progressed. The inflow rate on 275L was also monitored repeatedly. As this level has the highest elevation of all monitoring locations, it was expected to provide an early indication if the water table could be effectively lowered below the mine development.

As demonstrated in Figure 6, the two holes on 340L initially produced 100 and 35 USGPM respectively and later stabilized to 75 and 25 USGPM. The initiation of flow at 340L resulted in pressure drops at both 280L and 340L. The readings indicated that the pressure steadily dropped from 100 psi and stabilized to 60 psi after a period of 48 hours. Pressure readings on 280L, which for the sake of brevity were not shown in Figure 6, dropped steadily and essentially became zero. This was consistent with the observation of water flow at 275L, which was reduced to almost zero, and is shown in Figure 7.

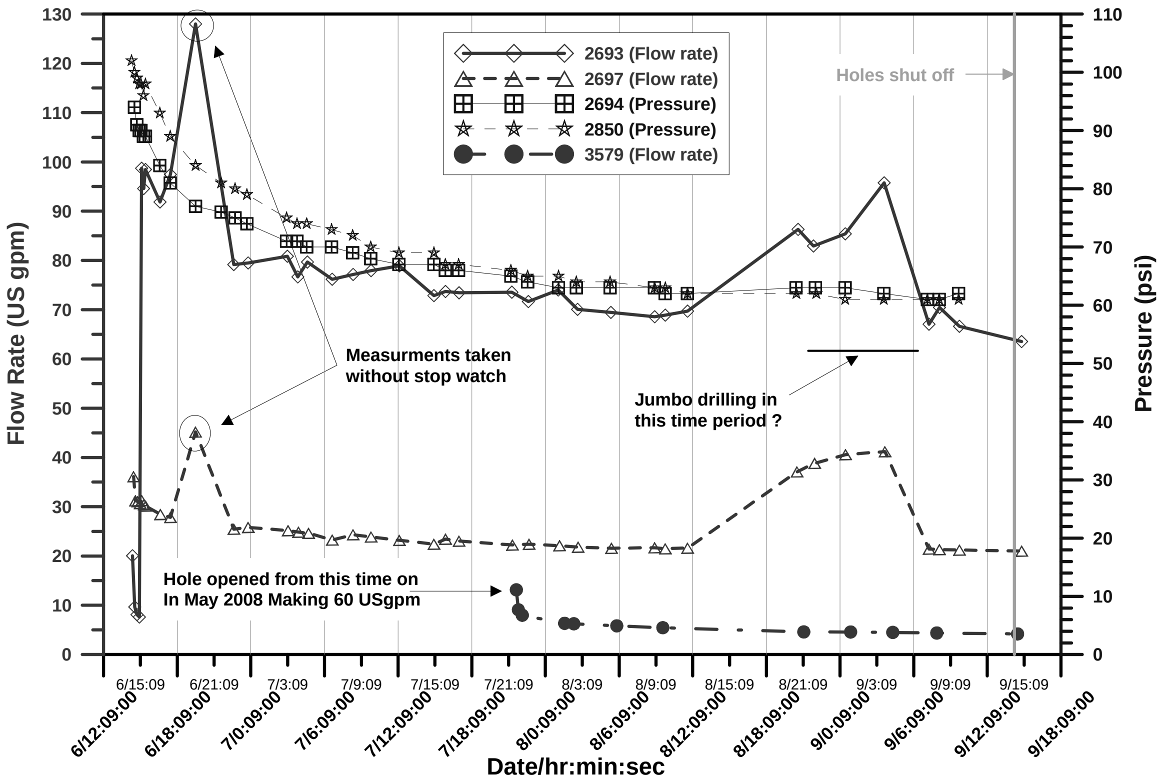

Figure 6: Flow and pressure data during the three-day depressurization test**.**

After three days flow from 340L, the holes were shut off. The pressure was monitored at 340L and 280L to look at the recoveries. Moreover, the flow rate at 275L was also monitored. The recovery data is shown in Figure 8 and was equally important in assessing if there was a permanent drop in the groundwater table and how fast the recharge was occurring. The results indicated that the groundwater table recovered to pre-test levels, with the bulk of recovery occurring in the first 24 hours. This was consistent with the observation of flow rate at 275L seen in Figure 7, despite damage to the weir, which occurred as a result of mining activity.

The test data provided the necessary details of the hydrological setting surrounding the lower 163 Zone. The analysis highlighted the feasibility of lowering the water table in the area by controlled discharge.

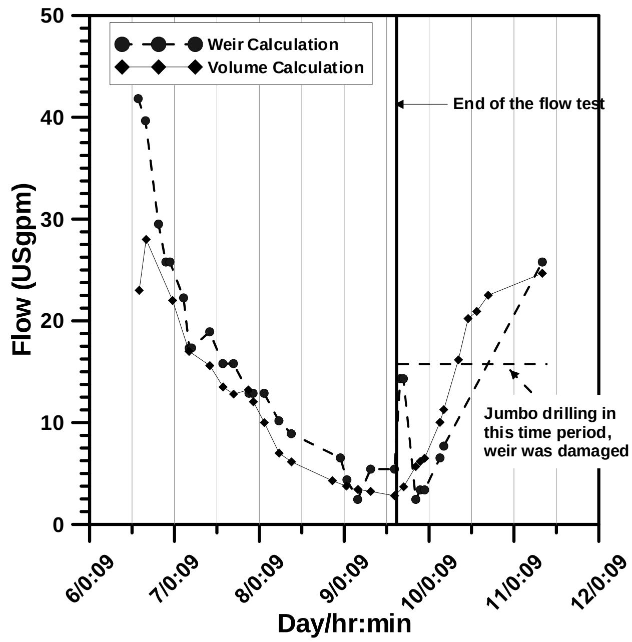

Figure 7: Water flow readings on 275L during the three-day depressurization test

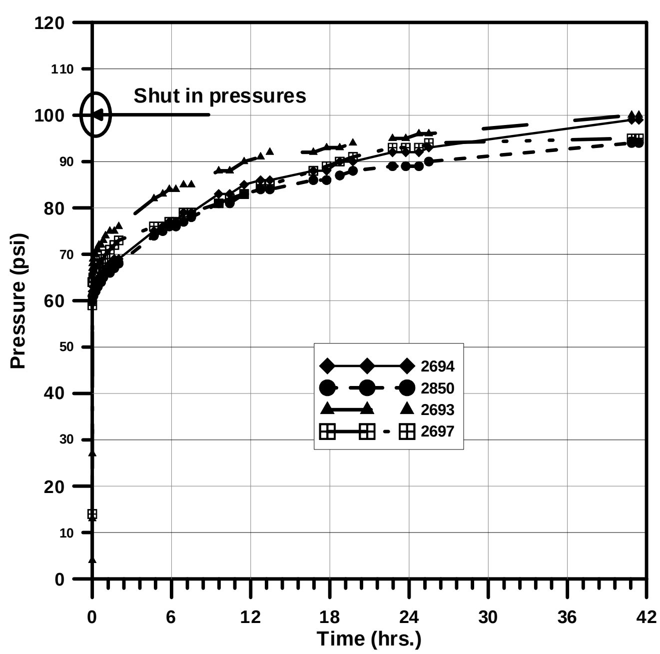

Figure 8: Recharge values as a function of time for 340L following the three-day depressurization test.

Implementation of Active Depressurization

The results from the three-day depressurization test indicated that the groundwater table in the 163 Zone could be lowered by a controlled discharge from 340L. A controlled discharge was initiated in the following weeks and the flow rate was adjusted to maintain the water level below the 280L mining elevation. This resulted in safer mining conditions for the operators, in addition to reducing the potential exposure to radon gas emanating from this water.

Following the active depressurization, 280L has been successfully mined out, and ore blocks between 280L and 275L have been extracted as a result of these tests. The 340L has been kept as a monitoring station, with pressure and flow rate data collected on a regular basis.

As mentioned earlier, the lower 163 Zone consisted of ore stretching to depths of approximately 420m below surface. With the new understanding of the hydrological setting of this area, Eagle Point then began to evaluate if the results could be emulated by drilling drainage holes from the 400L diamond drill bay.

Two-Day Depressurization Test on 400L

As a follow-up study to the three-day depressurization test on 340L, a two-day test was conducted from the newly established diamond drill holes on 400L. The purpose and procedure of the test was very similar to the test at 340L. It was of interest to research if discharging water at 400L as opposed to 340L could further lower the ground water table. Two drill holes were opened on 340L and 400L, and the remaining holes were left shut to monitor pressure.

The two-day flow and shut in test were similar to those from the test at 340L. During the two-day drainage test, pressure data from 400L indicated that the ground water can be lowered below 340L (Figure 9). This was confirmed by zero flow and pressure readings at 340L.

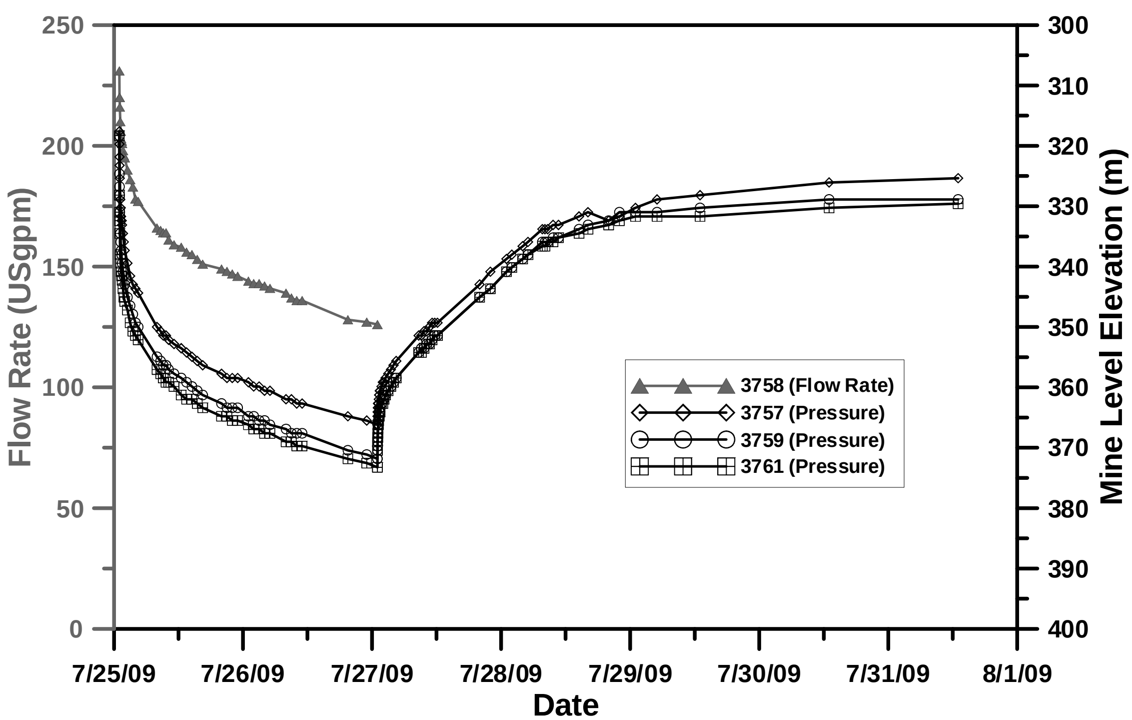

Figure 9: Flow and pressure data from the drill holes on 400L.

The test was able to demonstrate that the water table could be lowered further, with similar discharge rates currently observed at 340L, and that safe mining is possible in the lower regions of the 163 Zone. As a result of this, a comprehensive mine plan was developed to extract the remaining ore in 163 Zone. Development in this area is expected to begin in the second half of 2010.

Figure 10 summarizes the sequence of events, hydrogeological testing, and current hydrogeological understanding of 163 Zone. The figure clearly shows the affect of passive depressurizing due to mining activities, hydrogeological testing as well successful implementation of active depressurization.

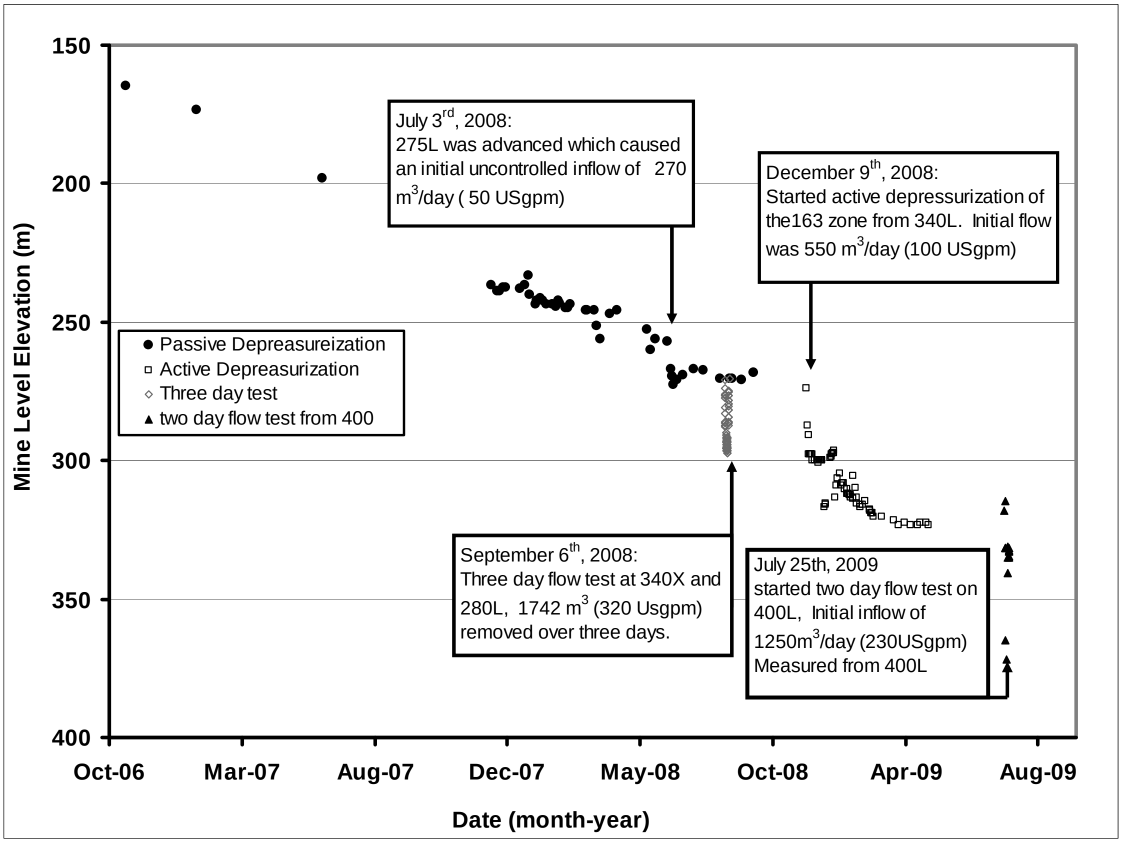

Figure 10: Pressure readings of the lower 163 Zone groundwater table.

141 Zone

During original diamond drilling of the 163 Zone, a second parallel structure was identified named the 141 Zone (Figure 4). This zone has similar geological characteristics of the 163 Zone, and when drilling began in this area, high-pressure water was also intersected. The initial diamond drilling resulted in intersections of mineralization, but several unknown factors that may influence ore extraction were identified. Initially it was not understood if hydrologically 141 Zone was connected to the 163 Zone. As the 163 Zone drainage program continues, the 141 Zone has seen renewed exploration activity. In the first quarter of 2010, a diamond drill was established to further define the 141 Zone. At the time of writing this paper, multiple holes have been drilled into this area, and they have all been essentially dry. It appears that the 141 Zone is hydraulically connected to the 163 Zone. With this in mind, the 141 Zone could potentially represent a future source of production for Eagle Point mine.

CONCLUDING REMARKS

Hydrogeological testing and controlled discharge in the lower 163 Zone, added several million pounds of U_3O_8 to minable reserves at EPM. This realization will contribute to Cameco's goal of achieving safe production, and providing clean electricity through the use of nuclear power.

The work presented in this paper clearly demonstrates that by having a better understanding of hydrological setting, unplanned and uncontrolled inflows can be avoided by simple water management. It also highlights the fact that hydrological data gathered during the exploration stage can go a long way in determining the nature of the hydrological setting of a particular zone or deposit. Empirical data such as flow rate, pressure, and depth of intersection are all critical data that would lead to a more comprehensive conceptual hydrogeological model. Collecting this data should be ranked equally with collecting geological data such as mineralization, faulting, and alteration.

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