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IDENTIFICATION AND MITIGATION OF HIGH ZINC DISCHARGES TO THE ENVIRONMENT FROM THE WATER DIVERSION SYSTEM AT THE KEMESS SOUTH MINE

Harold Bent, BSc, Scott Frostad, M.A.Sc., P.Geo. and Scott Davidson, M.Sc., P.Geo.,

Kemess Mine, Box: 3519, Smithers, BC V0J 2N0

Abstract: The Water Diversion System at Kemess Mine in north-central British Columbia was found to be releasing total zinc concentrations that exceeded the site water quality objective of 0.03 mg/L. The source of the zinc was determined to be sections of the buried diversion system constructed of galvanized steel. To mitigate this problem, the mine examined several options before deciding on the insertion of a smaller diameter Polyethylene pipe within the original conduit. The insertion of the Polyethylene pipe was completed in November 2000. Monitoring of water quality since the insertion has shown that the zinc water quality objective has been consistently met but for a few exceptions.

1.0 INTRODUCTION

The Kemess open pit gold-copper mine is located in north-central British Columbia and has been owned and operated by Northgate Exploration Ltd since February 2000. The Kemess South porphyry deposit contains an estimated reserve of 163 million tonnes with an average grade of 0.67 grams/tonne gold and 0.23% copper, equating to 3.5 million ounces of gold and 830 million pounds of copper. A major component of the Kemess Mine is the Tailings Storage Facility. Construction of the tailings storage facility resulted in truncating 40% of the South Kemess Creek drainage basin.

To mitigate the effects of flow reductions in South Kemess Creek, a freshwater diversion and release system was constructed in 1997 that would allow for winter low flow period supplementation. After the commissioning of the water diversion system, routine water quality sampling showed elevated zinc concentrations that exceeded the water quality objective of 0.03 mg/1. Sampling along the buried water diversion conduits showed zinc concentrations increased with distance along the two galvanized steel conduits that are an integral part of the diversion system.

As a result of the high zinc concentrations being released into the environment, Kemess Mine began examining methods to reduce zinc in the freshwater diversion system. This paper examines the efforts by Kemess Mine to mitigate the release of zinc into South Kemess Creek.

2.0 SITE LOCATION

The Kemess Mine is located 10 km east of Thutade Lake, in the northern Omineca Mountains of north-central British Columbia and approximately 300 km northwest of Mackenzie. The mine is situated within a mining claim license of approximately 15,057 ha (150 square km). The coordinates of the mine site are latitude 57 00"N, longitude 126 45' W. The insert on Figure 1 shows the general location of the minesite.

3.0 FRESH WATER DIVERSION SYSTEM

The Water Diversion System (WDS) was constructed upstream of the Tailings Storage Facility (TSF). It consists of two earth fill dams, a run-of-the-river intake, two buried diversion conduits and a water release conduit. The functionality of the WDS diverts freshwater around the TSF into the main South Dam reservoir for release into South Kemess Creek during winter low flow periods. The diversion system serves a two-fold purpose of controlling water inputs into the TSF and meeting fisheries compensation agreement commitments between Kemess Mine and federal and provincial government regulatory agencies. Details of the WDS are shown on Figure 1.

The Eastern Diversion Intake (EDI) is a run-of-the-river style intake that diverts water from South Kemess Creek, upstream of the TSF, into the South Diversion Dam (SDD) reservoir for storage and release. The EDI has a catchment area of 330 ha and represents 33% of the WDS catchment basin. The Eastern Diversion Conduit (EDC), which connects the EDI to the SDD, was originally constructed with 1050mm inside diameter (ID) and 1150 mm ID galvanized steel conduit and lesser amounts of 914 mm ID high-density Polyethylene (HDPE) pipe. The total length of the EDC is 4,800 m.

The North Diversion Dam (NDD) is a small earth fill dam that is used to divert water from a small tributary to the SDD reservoir. The NDD has a catchment area of 157 ha and represents 16% of the WDS catchment basin. The Northern Diversion Dam Conduit (NDDC) is comprised of 400 mm and 650 mm galvanized steel conduit and is 600 m in length.

The South Diversion Dam (SDD) is the primary WDS storage reservoir, with a capacity of 350,000 m^3 for low flow supplementation during winter months (mid-December to mid-April). The SDD has a catchment area of 524 ha and represents 51% of the WDS catchment basin. These waters enter the SDD via their natural drainage channels. Outflows; from the SDD are regulated via a sluice gate control assembly and enter the 3,700 metre South Diversion Dam Conduit (SDDC). Prior to entering South Kemess Creek, the outflow waters pass through an energy dissipation basin (Plunge Pool). The SDDC is constructed of welded steel and HDPE pipe and was determined not to be a source of zinc.

4.0 IDENTIFICATION OF ZINC EXCEEDANCES IN THE WATER DIVERSION SYSTEM

The Environmental Department at Kemess Mine conducts routine monthly water sampling throughout the entire minesite. The Water Quality Objective site (WQO) for South Kemess Creek, WQ-25, is located 150 metres downstream of the Plunge Pool. The peak zinc concentration observed at WQ-25 during 1998 was 0.125 mg/1 on April 28lh, exceeding the 0.03 mg/1 WQO. The concentration of zinc was found to drop during the freshet period indicating that fresh water dilution was occurring. High zinc concentrations occurred again in 1999 during low flow conditions with a peak concentration of 0.409 mg/1 at WQ-25 on March 28th.

On July 24th, 1999, environmental staff sampled all WDS inflow locations and a number of sites along the EDC and NDDC to determine the source(s) of zinc. The results of the sampling showed that the water inflow locations returned zinc concentrations below the laboratory detection limit while the concentration of zinc increased with distance along the EDC (Figure 2) and NDDC diversion conduits. The maximum zinc concentrations returned from the EDC and NDDC were 0.106 and 0.049 mg/1, respectively. Based on the sampling program, the galvanized steel conduit was determined to be the source of the elevated zinc levels.

Following the determination of the source of zinc, Kemess Mine initiated weekly sampling of the diversion conduits, the Plunge Pool (WQ-23), and South Kemess Creek sampling sites (WQ-25 and WQ-05). The purpose of the weekly sampling was to track water quality while mitigation options were examined. On November 25th, 1999, the EDI intake was closed and thereby eliminated the eastern conduit as a source of zinc.

5.0 MITIGATION OPTIONS

A number of mitigation options were explored by Kemess Mines Ltd. once the problem with the WDS galvanized steel conduit was identified. A select number of options were examined in detail and a number of options were only given cursor/ evaluation. The zinc mitigation options included:

- Water treatment
- Coating of the conduit pipe
- Replacing the original conduit with a new pipe
- Insertion of a pipe liner (partial or full)
- Insertion of a Poly-ethylene pipe

Water Treatment

Evaluation of water treatment options focused upon 3 primary objectives: (1) modifying the chemical nature of the inflow water so that it is less aggressive in the removal of zinc, (2) creating a protective coating on the walls of the conduit pipe and (3) removal of the liberated zinc from the water column. Modification of the inflow water chemistry by adjusting pH, and the carbonate and calcium concentrations, would mitigate the aggressive nature of the water and potentially develop a calcium carbonate coating on the pipe. Consideration was also given to the use of chemical inhibitors, such as inorganic phosphate and soluble silicate, to form a protective coating on the conduit and the use of chemical collectors for zinc removal from the water column.

The water treatment option required that the chemical characteristics of the inflow water be examined. This information would dictate the appropriate reagents and concentrations required to prevent zinc release from the conduit. Review of the existing database and supplementary sampling determined the inflow water as being "aggressive", undersaturated in calcite, and unable to form a calcite precipitate on the pipe wall. A qualitative assessment of corrosivity in terms of hardness, alkalinity, carbon dioxide concentration, and chloride and oxygen levels, classified the inflow water as non-corrosive. Since the water was non-corrosive, addition of corrosion inhibiters would not be required.

Identified difficulties with modifying the inflow chemistry and attempting to create a protective coating on the conduit walls were: (1) achieving strict controls on reagent addition with varying water flow rates, (2) operating successfully during the winter months at severe temperatures, (3) achieving complete coverage of the pipe with the coating medium, (4) sustaining the coating for long-term success and (5) continuous year round operation in a high avalanche hazard zone.

Removal of liberated zinc by Silica Encapsulation (SE), a relativity new technology, was also evaluated. Computer modeling of the water chemistry and water volumes assessed the amount of zinc that could be removed from the water column using SE. The results of the modeling demonstrated that SE treatment would not be successful in removing zinc unless the pH was first adjusted to 6. In addition, the modeling demonstrated that adjusting the water at the inlet to pH 9 would produce a zinc oxide that could coat the conduit wall and impair the leaching of zinc. It was concluded that a combination of the two pH adjustments would provide the greatest success for the SE treatment.

The inherent difficulties with zinc encapsulation included: (1) the 2 stages of pH adjustment for optimum SE success, (2) providing the necessary residence time for the silica encapsulation to be successful, (3) the stability of zinc oxide to reduce the concentration of zinc release from the conduit, (4) operation of the dispensing systems under winter conditions. The silica encapsulation appears to be better suited for a closed system that allows for easy precipitate removal and provides the capacity required for optimum residence time.

Conduit Pipe Coatings

Epoxy coatings, modified asphaltic emulsion paint, and a shot concrete coating were evaluated as potential long-term protective coverings to prevent the release of zinc from the conduit.

One of the potential concerns with an epoxy application was the release of solvents and residuals. A new product developed in the United States was undergoing testing for USEPA Approval. This product had the benefit of not containing any constituents that would pose an environmental concern (i.e. solvent free). Provided that the product testing was successful and approved for commercial use, there were logistical considerations that were still unknown. These logistical considerations were compounded by the limited access to the buried line since the primary application and preparation techniques would be conducted robotically from the surface. The epoxy product did not complete its approval application process within the time frame for consideration.

Asphaltic emulsion paint was considered as a potential surface coating material. A consideration specific to asphaltic base products was ensuring that the product would not release solvent residuals after application, in particular organic solvents. Another consideration was the ambient air temperature within the conduit during application and product curing.

The primary concerns for all of the coatings examined were: (1) the success of applying the product within a buried conduit, (2) the level of surface preparation prior to application, (3) the adhesive success of the product to a galvanized surface and (4) the longevity of the product in a relatively "high" velocity flow environment.

Replacement Conduit

The installation of a completely new line separate from the original conduit readily met the environmental objectives, however, it was an expensive option. In conjunction with the cost of purchasing a new conduit, this option did not utilize the existing buried pipe. Additional cost would have been incurred to remove the buried pipe, prepare a new subgrade and bury the new pipe. The relatively short field/construction season at the Kemess Mine site was another consideration.

Pipe Liner Insert

The installation of a pipe sleeve (partial or full) within the original conduit required securing the liner to the existing conduit. The sleeve would need to be anchored within the original conduit so that shifting of the sleeve would not result in water overflowing the liner or cause the liner to buckle. In either scenario, there would be stress placed upon the liner at its "anchor" points and potentially, the liner being lifted or damaged within the anticipated time of usage.

Polyethylene Pipe Insert

Upon examination of all considered possible options, the insert pipe was chosen as the preferred option. The advantages of the polyethylene pipe insert included, but was not limited to, the following: (1) polyethylene product, (2) longevity of the product and (3) utilization of the existing buried conduit.

The insertion of the polyethylene pipe into the existing buried conduit posed a significant challenge, however, challenges existed for all the options considered. The ultimate objective was to locate a solution that would provide the environmental protection that Kemess Mine demanded and provide the security of operational and longevity success. The insert pipe was determined to best meet these objectives.

6.0 INTERIM MITIGATION MEASURE

On November 25th, 1999, the fresh water inflows destined for the EDI were redirected into the Tailing Storage Facility (TSF'). The EDD conduit was not operated again until the 2000 freshet. Directing this additional water into the TSF was possible due to the available freeboard and the reduced water flows during the winter months. This interim mitigation measure resulted in an immediate positive impact upon the quality of the discharge waters from the WDS. The positive result is attributed to the elimination of the primary zinc contributor, when decreased water volumes and longer residence time causes elevated zinc concentrations within the conduit. The objective of the interim mitigation measure was to lessen the potential impact of elevated zinc waters from the WDS during the selection and installation of the ultimate mitigation solution.

7.0 IMPLEMENTATION OF CHOSEN MITIGATION SOLUTION

The product selected for the insertion into the existing buried water conduit was the Boss 2000 "Big O" HDPE Pipe. The pipe was delivered to the minesite in 9 metre lengths with two inside diameter sizes of 750mm ID and 600mm ID. The insert pipe diameters and total length of each diameter size were predetermined using the same hydrological data for the original water conduit calculations. An external consulting firm verified the pipe size specifications.

A total of 2,840 m of 7.50 mm ID PE pipe and 1,840 m of 600 mm ID PE pipe were delivered to the mine site. The individual 9 metre pipe sections were fused together forming lengths up to a maximum of 180 metres. Custom couplers secured the fused lengths of pipe after insertion into the existing conduit and heat shrink-wrap at each fused joint provided greater flexibility strength of the pipe.

The insertion project was initiated proximal to the SDD and proceeded up gradient to the EDC inlet. Access ports were excavated into the existing buried conduit to facilitate the insertion of the new pipe. Water flows within the buried conduit were regulated during the insertion program via a gate valve on the Eastern Diversion Inlet. Upon completion of the pipe insert, concrete anchors were poured in 6 locations for additional stabilization and all excavated access ports were backfilled.

The equipment used for the fusing and insertion of the pipe consisted of a Hitachi 200 excavator, a 750 Cat loader, a Christie Fusing Machine and a steel cable with a nose cone pulling head.

8.0 SUMMARY OF WATER QUALITY SAMPLING FOR THE DIVERSION SYSTEM

The Water Diversion System was commissioned in January 1998 and monitoring of the diverted waters commenced on February 18, 1998. The water quality objective site for this portion of the mining property is located in South Kemess Creek, 150 metres downstream of the WDS outlet and is designated as WQ-25. The water quality objective for zinc at WQ-25 is 0.03 mg/1 (30ppm). The recorded zinc concentrations at WQ-25 from February 1998 to July 2001 are presented in Figure 3.

The data presented in Figure 3 represents the zinc concentrations in South Kemess Creek during 3 distinct operating phases of the Water Diversion System: (1) Pre-Treatment Period, (2) Interim Mitigation Period and (3) Post Treatment Period (including the pipe installation period).

Pretreatment Period

Monitoring during the pre-treatment period showed the zinc levels at WQ-25 to exceed the 0.03 mg/1 Zn WQO, primarily during the winter low flow periods. The recorded zinc values during spring freshet, and throughout the summer and fall seasons, drop substantially due to dilution, however, there were still zinc exceedences at WQ-25 during this time. The average zinc concentration during the pre-treatment period was 0.11 mg/1 and the recorded high value was 0.409 mg/1.

Interim Mitigation Period

Redirecting EDC waters into the Tailings Storage Facility from November 1999 to May 2000 resulted in a significant lowering of zinc concentrations at WQ-25. Although, the SDD reservoir still contained elevated concentrations greater than Zn 0.03 mg/1, the average zinc concentration at WQ-25 was reduced by approximately 50% as compared to the pretreatment period. The average zinc concentration at WQ-25 during the interim mitigation period was 0.062 mg/1 and the recorded high value was 0.092 mg/1.

Post Treatment Period (including pipe installation)

The water quality monitoring continued during the pipe installation project. The flow of water through the EDC was intermittent during this time and sampling reflects various stages of completion of the project. Upon completion of the pipe installation, the water quality monitoring continued on a weekly basis. The data shows that there has been a significant decrease in zinc concentrations. The average zinc concentration since initiation of the pipe insertion program has been 0.019 mg/1 and the recorded high value was 0.042 mg/1.

9.0 CONCLUSION

Kemess Mines Ltd. identified zinc exceedence of the Water Quality Objectives for South Kemess Creek. A comprehensive sampling program identified the Eastern Diversion and Northern Diversion galvanized conduits as the source of zinc. Determination of the optimal mitigation solution included the evaluation of the following options: (1) water treatment, (2) coating of the conduit pipe, (3) replacing the original conduit with a new pipe, (4) insertion of a pipe liner (partial or full) and (5) insertion of a polyethylene pipe.

Kemess Mines Ltd. has achieved its objective of identifying and implementing a mitigation solution that provided the greatest security of effectiveness and long-term operational success. The Boss 2000 "Big O" HDPE Pipe was identified as that solution after considering of a variety of diverse options and has been inserted into the Eastern Diversion Conduit.

Since the installation of the polyethylene pipe the water quality objectives for zinc have been achieved at WQ-25 consistently, with only a few recorded exceptions (a maximum exceedence of 0.012 mg/1).

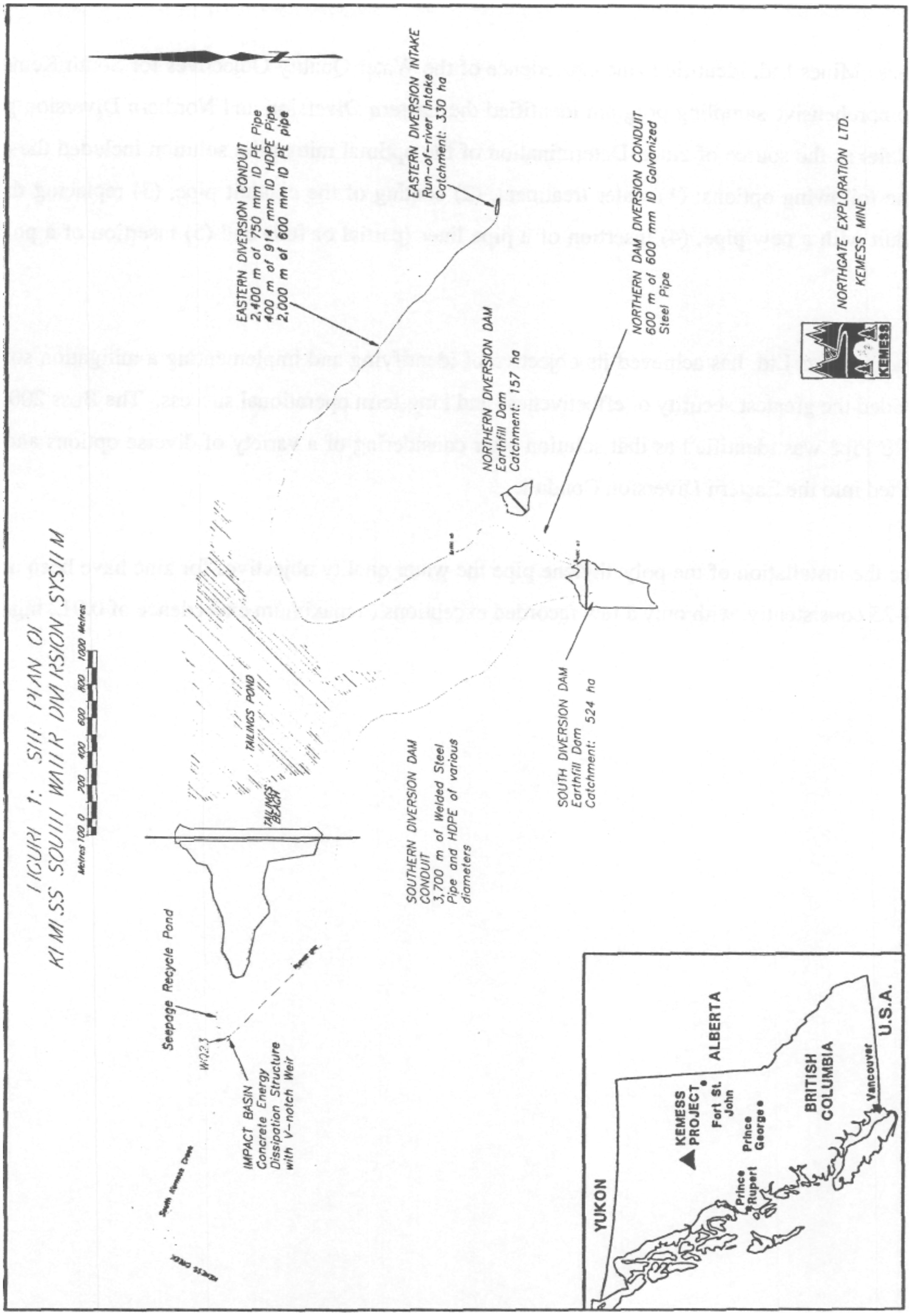
FIGURE 1: SITE PLAN OF
KEMESS SOUTH WATER DIVERSION SYSTEM
Metres 100 0 200 400 600 800 1000 Metres
EASTERN DIVERSION CONDUIT
2,400 m of 750 mm ID PE Pipe
400 m of 914 mm ID HDPE Pipe
2,000 m of 600 mm ID PE pipe
EASTERN DIVERSION INTAKE
Run-of-river Intake
Catchment: 330 ha
NORTHERN DIVERSION DAM
Earthfill Dam
Catchment: 157 ha
NORTHERN DAM DIVERSION CONDUIT
600 m of 600 mm ID Galvanized
Steel Pipe
NORTHGATE EXPLORATION LTD.
KEMESS MINE
KEMESS
TAILINGS POND
TAILINGS BEACH
SOUTH DIVERSION DAM
Earthfill Dam
Catchment: 524 ha
SOUTHERN DIVERSION DAM
CONDUIT
3,700 m of Welded Steel
Pipe and HDPE of various
diameters
Seepage Recycle Pond
W023
IMPACT BASIN
Concrete Energy
Dissipation Structure
with V-notch Weir
YUKON
ALBERTA
KEMESS PROJECT
Fort St. John
Prince George
Prince Rupert
BRITISH COLUMBIA
Vancouver
U.S.A.

Figure 2. Zinc Concentrations in Eastern Diversion Conduit (July 24,1999)

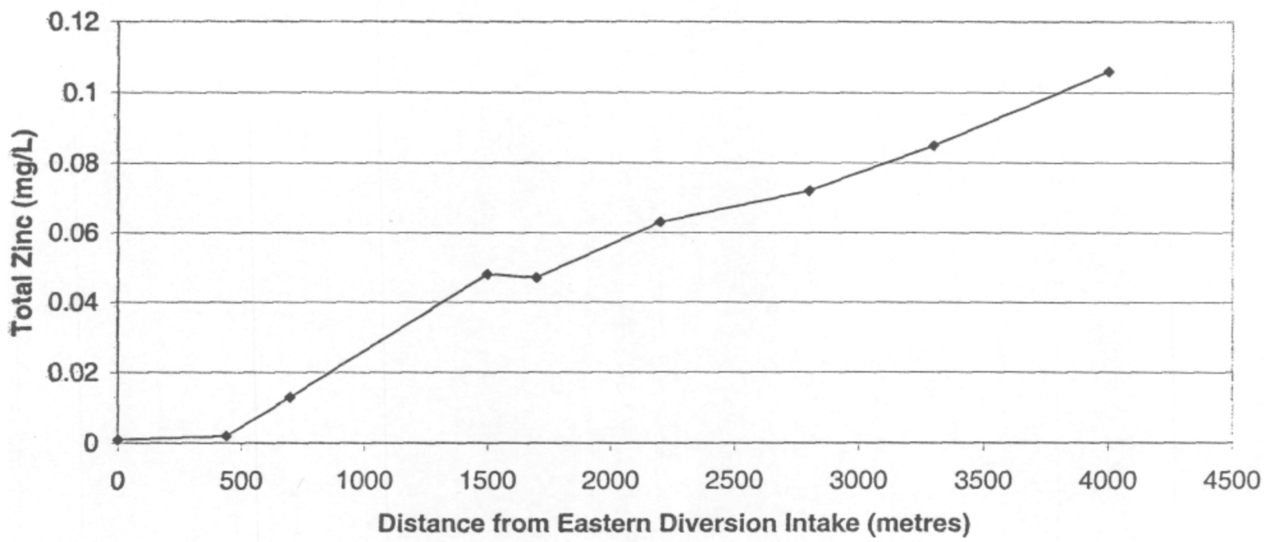

Figure 3. Zinc Concentrations at WQ-25