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BLUEBELL MINE - FORESHORE REMEDIATION OF GALENA BAY

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ABSTRACT

In 1997, Cominco Ltd.[1] initiated an environmental assessment and remedial program at its Bluebell Mine site which closed in 1972. An overview of the history of the mine and the complete project is provided in the companion paper titled *Bluebell Mine - Remediation of a Historic Mine Site.* This paper focuses on the management of tailing, concentrates (process fines) and mine water discharge (MWD) fines present on the foreshore of Galena Bay associated with the former concentrator operation. It explores the rationale and planning of the remedial work, and the challenges associated with completing the project.

The results of environmental assessments of the site determined that groundwater crossing the foreshore areas of Galena Bay was being impacted by process fines and MWD fines. The remedial plan called for the removal of these materials and subsequent reconstruction of a "self-cleaning" beach.

When planning the remedial action, many factors were considered, including: sediment chemistry; physical properties of the sediment; ecological health of Galena Bay; hydrodynamics of the bay; alternative excavation methods; containment of suspended sediments generated by the remedial work; and monitoring the effectiveness of the environmental control systems during excavation.

Protection of the aquatic environment was the most critical aspect of the remedial work. Containment of suspended sediments within the work area was achieved by the use of a dual floating silt barrier system. The systematic monitoring of water quality using field and laboratory methods was undertaken to track the performance of the control system. The sediment control system worked well but its performance could have been enhanced by moving the primary barrier further from the work area, improving the design of certain barrier components and having earlier routine underwater inspections.

INTRODUCTION

This paper focuses on remedial action that was undertaken in the foreshore area of Galena Bay at the Bluebell Mine site in Riondel, BC. In particular, the performance of the floating barrier system to contain suspended sediments generated during remedial excavation work below lake level is evaluated. A companion paper, titled *Bluebell Mine - Remediation of a Historic Mine Site* outlines the history of the

[1] In July 2001, Cominco Ltd. (Cominco) and Teck Corp. Ltd. merged to form Teck Cominco Metals Ltd (Teck Cominco).

Bluebell Mine and the site remediation in greater detail, and should be referenced for additional background information.

The approximate 75 ha Bluebell Mine site is located in the West Kootenay region of the province of British Columbia, between the Selkirk and Purcell mountain ranges. Kootenay Lake is present to the north, south and west of the site. The area of the site discussed by this paper is the north foreshore of Galena Bay. The mine generated approximately 3.9 million tons of tailing from the mine start up in 1952 until closure in 1972. Approximately half the tailing was discharged into Kootenay Lake at the south end of Galena Bay. Some of these process fines accumulated on the beach at the north end of Galena Bay. Mine water that was discharged into the east lobe of Galena Bay left behind a deposit of MWD fines.

An environmental site assessment commenced in 1997. Results indicate that total arsenic, cadmium, copper, lead and/or zinc concentrations in tailing exceeded the CSR[i] industrial land use (IL) standards and BC lake sediment guidelines[ii]. Acid Rock Drainage/Metal Leaching (ARD/ML) characterization work determined that tailing is capable of generating ARD/ML. However, the offshore tailing has little opportunity to oxidize due to low dissolved oxygen concentrations in the water cover. The ARD/ML characterization work determined that MWD fines are formed of carbonates and thus have no potential of generating ARD, although neutral pH leaching of zinc was occurring.

Groundwater entering Kootenay Bay from the west foreshore of Galena Bay was characterized as being impacted by ARD/ML from the overlying process fines [sulphate (max. 3,020 mg/L), cadmium (max. 0.158 mg/L), copper (max. 0.042 mg/L), lead (max. 0.254 mg/L) and zinc (max. 100 mg/L)]. Groundwater entering Kootenay Lake from the east foreshore of Galena Bay contained elevated zinc concentrations (max. 2.34 mg/L). Hammil Creek is located on the east side of the site. The quality of water in the creek decreased as it traversed the site (arsenic, cadmium and/or zinc concentrations exceeded the BC Surface Water Criteria[iii]). The quality of water in Galena Bay was excellent with little variation from a reference bay.

REMEDIAL DESIGN

Based on the location and level of contamination in the foreshore area of Galena Bay, source removal was selected as the remedial action. Studies of the lake environment determined that it would be necessary to recover process fines to a depth of 0.5 m below low water to prevent ARD/ML. Process fines to a depth of 5 m below low water would be capped to prevent their mobilization and redeposition on the beach during storm events. Once the tailing was removed, a stable engineered beach would be constructed that would resist becoming re-contaminated by offshore tailing during peak storm events.

Challenges associated with implementing the remedial design included:

1) accessing the tailing below the elevation of the lake;
2) constructing an engineered beach below the elevation of the lake;
3) preventing contamination of the lake by sediment and/or metal-containing water generated during the remedial work;
4) dewatering the recovered saturated tailing;
5) disposing of collected metal-containing water; and
6) obtaining all necessary approvals and permits in a nine-week period.

The last challenge was based on the necessity to complete the remedial work during the seasonal low lake level, which typically occurs in March and April. Additional constraints on the timing of the work were caused by the pending December 2001 closure of the Sullivan Mine in Kimberley, BC where it was planned to permanently manage the recovered process fines in an existing impoundment equipped with seepage collection and treatment facilities. The remedial plan was reviewed through the East Kootenay Mine Development Review Committee. Key participants were the BC Ministry of Energy and Mines, BC Ministry of Water, Land and Air Protection (MWLAP) and Environment Canada.

When evaluating remedial options, the primary criteria were to: 1) to select a method that would achieve the remedial goals in a timely, cost effective manner; and 2) minimize the transport of suspended sediments and metal containing water to Galena Bay.

The geography of Galena Bay and distribution of mine wastes affected the approach to remediation. Factors influencing the remedial options included:

- Galena Bay is approximately 250 m wide and 320 m in length with a steep drop-off and maximum depth of 45m.
- The base of the bay is covered with tailing.
- The bay is exposed to an approximate 17 km fetch of open water to the south, which allows waves to build to heights of 1.2 m (10 year return period) with the greatest wave heights occurring during south winds in the spring.

- The east and west lobes of Galena Bay are separated from each other by a bedrock outcrop that juts into the bay.
- The west lobe was easily accessible and capable of supporting heavy equipment. However, there was poor access to the east lobe.

Based on the above factors, four alternatives to remediation and beach reconstruction were considered: 1) build a temporary dam across the bay, dewater the contained area and work in a relatively dry environment; 2) build a temporary dyke across the bay and work in a saturated environment; 3) install sheet piling and work in a saturated environment; or 4) install floating silt barriers and work in a saturated environment. Analysis of these options indicated that the first two incurred higher engineering and schedule risks while the third was problematic due to the rocky nature of the lake bottom.

It was decided to implement sediment transport control using the following system:

- A floating wave break made from logs was deployed across Galena Bay.
- Primary control of suspended sediments in the near shore area was achieved by a 20 oz. PVC-coated floating siltation barrier (curtain) to which a hydrocarbon absorbent boom was attached. The curtain was comprised of a series of 15 m long by 6 m deep panels that were connected with rope and held to the bay bottom by a continuous chain.
- Secondary control of suspended sediments was achieved by a similar curtain which was 15 m deep and deployed across Galena Bay approximately 100 m from shore.

The approach to remediation was to recover all process fines and MWD fines to approximately 0.5 m below low water using excavators and trucks operating from "finger roads", and/or barge(s) as necessary. In some areas the wastes were removed to 2 m below low water to accommodate the engineered beach. The excavation proceeded from upslope areas towards the lake. Due to aforementioned constraints, the east lobe was remediated first and was accessed by a temporary road built around the bedrock outcrop in the centre of the beach. Excavated tailing was trucked to an infiltration pond where it was allowed to drain before being loaded onto highway trucks and transported to the Sullivan Mine. The MWD fines were blended with ARD/ML generating waste rock from another area of the site and placed in an open pit. The beach was reconstructed using the same work practices as the remedial excavation. A local gravel pit supplied general fill while an on site quarry and screening plant provided the appropriately sized beach capping material. Groundwater seepage and drainage from the infiltration pond were collected in interception trenches and pumped into the underground mine workings. Hammil Creek was diverted around the work area in a high density polyethylene pipe.

Cominco retained several consultants to develop the remedial action plan and manage the project. These consultants and their contribution are as follows:

- Morrow Environmental Consultants Inc. - design and completion of terrestrial site assessment work, remedial action plan, confirmatory sampling, environmental monitoring, reporting and co-ordination of other consultants.
- Bel-MK Engineering Ltd. - contract management.
- EVS Environmental Consultants Ltd. - assessment of aquatic environment.
- Westmar Consultants Inc. - beach design.

Due to the time required to ship and analyze samples for quantitative analysis, control of lakewater quality was necessarily based on field measurements of turbidity. The environmental monitoring program, summarized below in Table 1, was designed by MECI and reviewed by provincial and federal regulators who required several minor modifications before providing the approval to proceed.

TABLE 1: Summary of Environmental Monitoring Program

Location	Parameter	Frequency	Comment
Galena Bay at the work face and inside and outside the silt barriers.	Turbidity, pH, temperature, conductivity and dissolved oxygen.	Morning and mid-day each work day	Turbidity monitoring and observations to assess conformance with BC MWLAP criteria.
Galena Bay at the work face; outside of primary containment; inside and outside the secondary containment; and south of the wave break.	Total and dissolved metals, hardness, alkalinity/acidity, anions, turbidity, total suspended solids, pH, temperature, conductivity and dissolved oxygen.	Weekly	Where lake depths exceed 3 m, samples were collected 1 m below surface and 1 m above the bottom.
Kootenay Lake in general.	Visual inspection of the area in and around the Bluebell peninsula.	Daily	Objective was to detect any evidence of a discharge to the lake.
Groundwater and Infiltration Pond Seepage and combined discharge to mine.	Total and dissolved metals, hardness, alkalinity/acidity, anions, pH, temperature and conductivity.	Weekly	Four stations were sampled each week.

When turbidity values varied from the BC MWLAP criteria, a mitigative action plan was promptly implemented. Action consisted of immediate notification of the BC MWLAP, repairs as necessary, altered work practices, increased frequency of monitoring/sampling, and/or cessation of work in the lake. The specific form of mitigative action was decided on in cooperation with the BC MWLAP.

PERFORMANCE OF FLOATING SILT BARRIER SYSTEM

The performance of the floating silt barrier system was qualitatively evaluated by visual observations and field measurements. A summary of the challenges encountered and the actions taken over the course of the project is provided below in Table 2. Graph 1 shows the maximum daily turbidity values recorded during the lake monitoring program.

TABLE 2: Qualitative Summary of Floating Barrier Performance

Date	Event	Comment
March 20	Wave Break Deployed	Contractor dragged the log wave break into Galena Bay from the north beach causing turbidity levels to increase above background.
March 23	Barriers Deployed	The primary and secondary panels were deployed across the bay.
March 23 to March 31	Optimal Performance	The two barrier system operated as designed with a gradient in turbidity being visually apparent between the work face, the intermediate area and the area outside the secondary barrier.
March 31	Primary Barrier Damaged	A large storm event pushed the primary barrier onto the east beach. Work to free the barrier resulted in two panels being damaged on submerged debris.
March 31 to April 13	Primary Barrier Marginally Effective	The primary barrier was repaired and redeployed in 6-8 m of water. Additional barrier material was spliced onto the base of the existing panels. Monitoring data indicated that the primary barrier was not effectively containing suspended solids. The secondary barrier continued to perform well with up to two orders of magnitude difference in turbidity between the inside and outside of the barrier.
April 13	Secondary Barrier Fails Work Ceases	An underwater soil slump occurred at the work face where pit-run gravel was being placed. The slump passed under the primary barrier and tore the secondary barrier free from the shore. The secondary barrier was recovered using divers, repaired and re-deployed within 48 hours.
April 19	Work Resumes	Approval to resume work in the bay was granted by the BC MWLAP once the secondary barrier was fully functional.
April 16 to May 4	Efforts to Clear Secondary Barrier	Divers determined that up to 6 cm of sediment per day were accumulating on the base of the secondary barrier. Accordingly, continuous efforts were made to free the barrier using divers and boats.
May 4	Base of Secondary Barrier Cut Work Ceases	Two of the secondary barrier panels were cut at the "mud line" as efforts to free the panels were unsuccessful and the rising lake level had caused a 25 m section of the barrier to sink.
May 15 to May 23	Beach Construction Continues	As the coarse gravel beach cover was placed, the amount of silt and sand eroding from the work area decreased, causing a reduction in turbidity.
May 23 to May 31	Clarification of Work Area	The work area was allowed to clarify for 8 days until turbidity values between the primary and secondary barriers were in the natural background range and the BC MWLAP had granted their approval to remove the secondary barrier. The primary barrier remained in place until July 12 to control sediment that would be washed from the "self cleaning" beach by the rising lake.

The effectiveness of the floating barrier system was evaluated quantitatively by the collection and analysis of lake water samples during 12 separate sampling events. As expected, higher turbidity values were accompanied by higher metal concentrations. However, the floating silt barriers were generally very effective in minimizing the transport of contaminants further out in Galena Bay. The effectiveness of the floating barrier system in preserving lake water quality is indicated by Graph 2, which presents data collected during the May 4, 2001 sampling event. The sampling occurred the day that the secondary barrier was cut and thus characterizes a period of compromised sediment containment.

EVALUATION OF THE SEDIMENT CONTROL PROGRAM

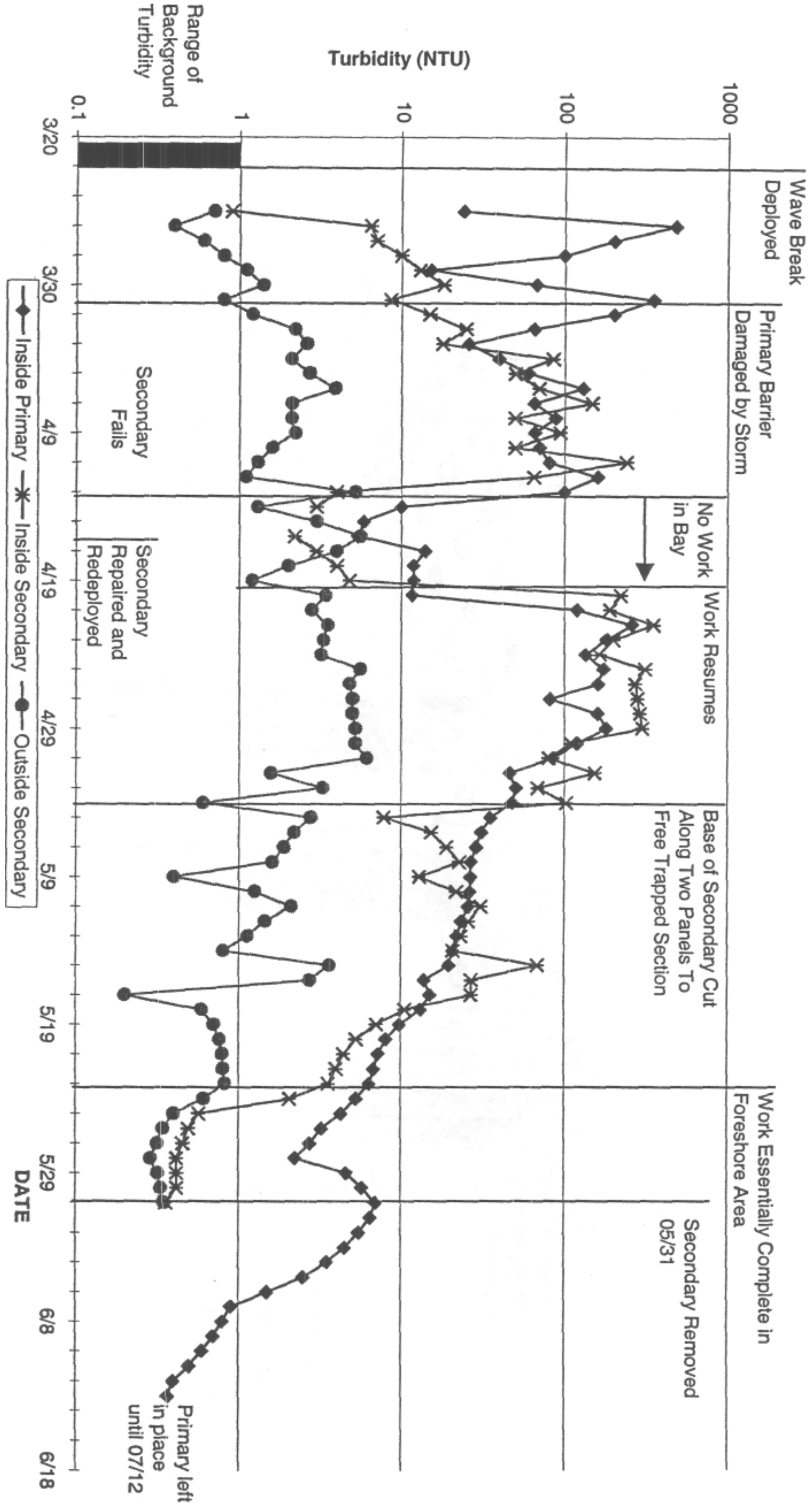
The use of floating silt barriers to contain sediment within the work area was appropriate given that there were two steep rocky shores to which the barriers could be anchored, and the barrier system minimized the disruption of tailing on the floor of the bay. The key observations and lessons learned during the remedial action are summarized below:

- Open communication with regulatory agencies in the forum provided by the Kootenay Mine Development Review Committee resulted in a positive, co-operative working relationship.
- Intercepting groundwater seepage and diverting Hammil Creek prevented an unnecessary flux of water and sediment into the contained area.
- Working from "top down" minimized the amount of time that the contractor was working below low water and allowed tailing further offshore to be used as a temporary coffer dam behind which sediment could settle before approaching the barriers.
- Pit-run fill material with a lower percentage of silt would have reduced the sediment loading to the curtain.
- The primary containment barrier was deployed too close to shore. This exposed the barrier to increased stress from wind, waves and activity in the work area. In hindsight, the primary barrier should have been deployed further from the work area.
- The barrier material was very robust. However, the design of the other barrier components could be improved to function better in a lake environment. Specifically, the barrier panels could have been better designed to allow them to be raised and lowered. The seal between the panels could have been improved by the use of "tongue in groove" construction, and the seal between the barrier and the shoreline could have been improved by the use of a heavier anchor chain.
- Earlier routine underwater inspections may have identified problems in time for mitigative action to be taken.

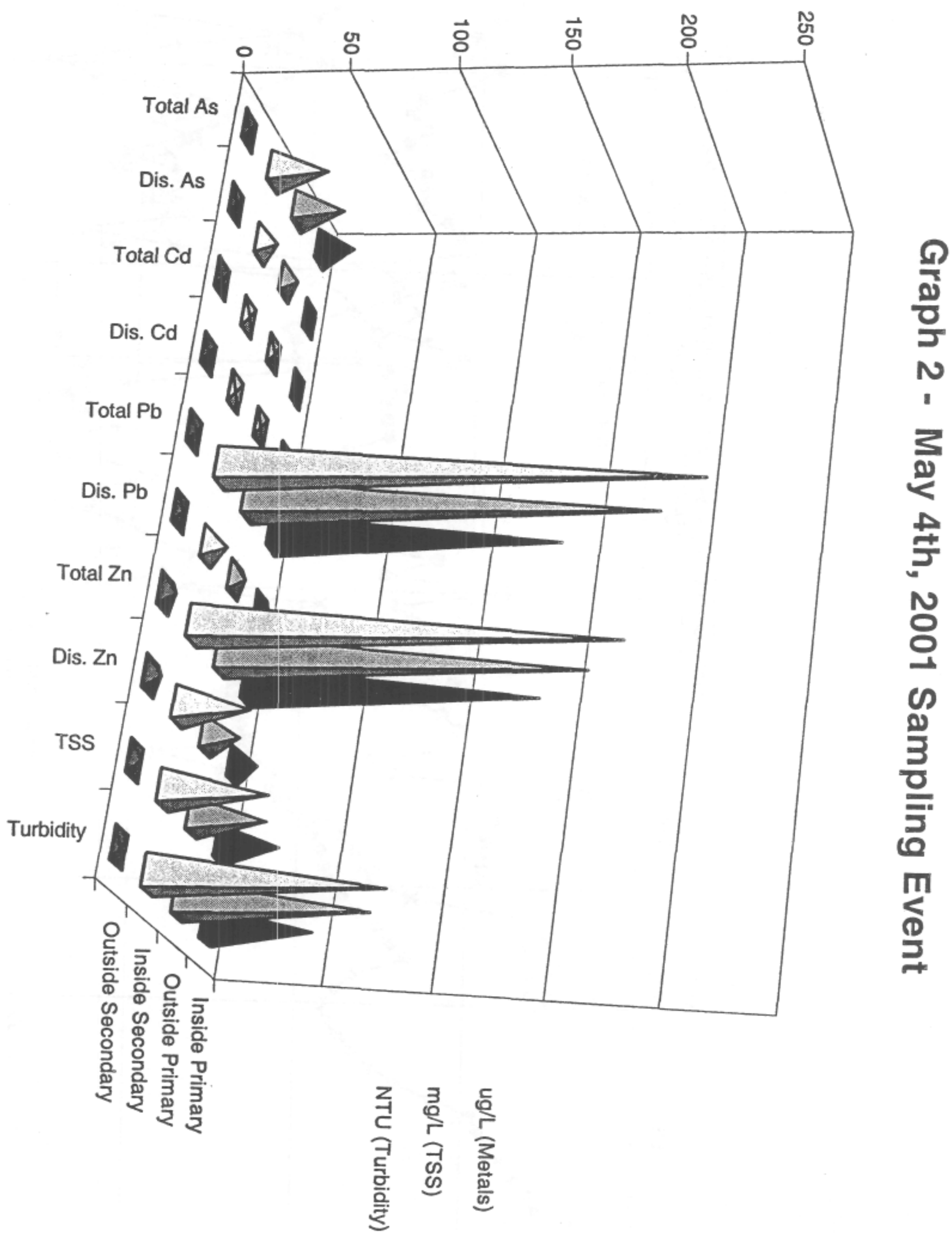
i Waste Management Act, *Contaminated Sites Regulation* (CSR), [includes amendments up to BC Reg. 244/99, dated 1999 07 19], BC Reg. 375/96, deposited 1996 12 16,0.C. 1480/96, effective 1997 04 01.

ii Water Management Branch, Environment and Resource Management Department, MWLAP, A Compendium of Working Water Quality Guidelines for BC: 1998 Edition (Compendium), updated 2001 Ol 17.

iii Waste Management Act, Draft Criteria for Managing Contaminated Sediment in British Columbia (Draft CMCSBC), 19990331.



Graph 1 - Maximum Galena Bay Turbidity Values


Graph 2 - May 4th, 2001 Sampling Event
0
50
100
150
200
250
Total As
Dis. As
Total Cd
Dis. Cd
Total Pb
Dis. Pb
Total Zn
Dis. Zn
TSS
Turbidity
Inside Primary
Outside Primary
Inside Secondary
Outside Secondary
ug/L (Metals)
mg/L (TSS)
NTU (Turbidity)