# Lake Wabamun Water Quality and Sediment Survey

Preliminary Report


## Summary

The 2002 Lake Wabamun Water Quality and Sediment Surveys were initiated based on public concerns regarding murky water in Lake Wabamun. The surveys were conducted between March and June 2002. During that time period, Alberta Environment (AENV) obtained a number of samples of drinking water, lake water and sediment samples from various locations across Lake Wabamun and TransAlta effluent.

While Alberta Environment is moving forward with a high degree of confidence to address the preliminary findings outlined in this report, more work is needed to confirm the results and findings that have been obtained to date. Final conclusions regarding water quality and specific sediment make-up in Lake Wabamun should not be drawn until AENV has completed its work and issues a final report in early 2003.

Alberta Environment continues to work closely with Alberta Health and Wellness and the local Health Authority to ensure that the health of lake users is not affected. No health advisories are in place for recreational use of the lake or consumption of fish.

In addition, Alberta Environment continues to work with TransAlta Utilities Corporation and other partners to investigate the incidence of fish mortality in the inlet canal of the TransAlta Power Plant.


## Findings

1) There is no evidence to suggest a widespread water quality problem in Lake Wabamun, however some water samples taken within 100 metres of the TransAlta Ash Lagoon discharge do exceed Alberta Surface Water Quality Guidelines for aluminium and do warrant further investigation.
2) The TransAlta Utilities ash lagoon discharge would appear to be a contributing source of the elevated heavy metals found in the lake sediments. Sediment concentrations above the Canadian Sediment Quality Guidelines for the Protection of Aquatic Life for chromium, arsenic and copper are primarily located within 100 metres of the ash lagoon discharge. Similar concentrations were also found in sediment within the ash lagoon. More work is required to understand the level of contribution and the significance of these levels.
3) Aluminium levels in the sediment in the vicinity of the ash lagoon outlet are generally higher than in other areas of the lake. More work is required to understand the level of contribution and the significance of these levels.
4) Ongoing monitoring of groundwater and drinking water in the area show no sign of metal contamination.
5) Concentrations of metals found in water and sediment do not appear to be the cause of the fish mortality. More work is required to understand what is causing the fish mortality.


ISBN No. 0-7785-2296-2 (Printed Edition)
ISBN No. 0-7785-2297-0 (On-Line Edition)
Pub No. I/919

August 7, 2002

## Next Steps

Alberta Environment will direct TransAlta Utilities to immediately:

1) Conduct a risk assessment/analysis that includes, but is not limited to:
   a) Providing more detailed information on the interactions between the ash lagoon and the lake. The information will include a water and material balance of the ash lagoons, retention times and flow regime within the lagoon and the lake,
   b) Determine the extent of the metals contamination adjacent to the ash lagoon,
   c) Determine the past and present relative contribution of TransAlta Utilities to the heavy metals concentrations found in the lake,
   d) Evaluate the risk to the ecosystem of the current levels of heavy metals found in the lake adjacent to the ash lagoon, and,
   e) Based on the level of risk to the ecosystem, provide a risk management plan.
2) Conduct monthly sampling, analysis and reporting of the ash lagoon effluent for a complete suite of heavy metals.
3) Develop and implement an action plan to resolve the fish mortality in the inlet canal of the TransAlta Power Plant.

Alberta Environment is conducting further sampling to determine how typical water and sediment samples taken so far compare to the rest of the lake and other lakes in Alberta. The terms of reference for this study are in Appendix 2. The in-depth survey report is expected to be released in early 2003.

Water quality monitoring and reporting continues on a regular basis beyond the scope of work discussed in this report. A 20-year review of water quality information on Wabamun Lake is currently underway.

Alberta Environment will continue to work with Alberta Sustainable Resource Development, Alberta Health and Wellness, the local Health Authority, Environment Canada, the Department of Fisheries and Oceans, the University of Alberta and TransAlta Utilities Corporation to investigate the incidence of fish mortality in the inlet canal of the TransAlta power plant.

## Sediment Sampling

Alberta Environment undertook a comprehensive investigation of heavy metals in the sediment of Lake Wabamun and the TransAlta Wabamun ash lagoon after samples collected in March and April 2002 by Alberta Environment showed chromium and arsenic concentrations above the Canadian Council of Ministers of the Environment (CCME) Interim Sediment Quality Guidelines (ISQG). The results of the samples are presented in Figures 1 and 4 and Tables 1 and 2.

Sediment samples were collected using a core sampler, which was pushed into the lake bottom to a depth of approximately 15 cm. The top 0-5 cm core was sliced off and placed into a sample pail and thoroughly mixed with five other cores collected from both sides of the boat (for a total of six cores) and put into a sealed 500 ml glass jar. The exact sample location was recorded using a range finder and Global Positioning System. Other pertinent field observations on core color, texture, amount of organic matter and presence of invertebrates and benthos were also recorded.

The parameters analyzed for the lake sediments samples included metals, total organic carbon, total carbon, pH and particle size. The samples from TransAlta Utilities Ash Lagoon sediments were analyzed for the same parameters, with the addition of volatile priority pollutants and extractable priority pollutants.

Additional sediment samples from Wabamun Lake were collected on June 18, 2002 to screen sediments for toxicity using a range of different aquatic test organisms. At each of the five sampling locations the top 5 cm of 9 to 20 individual Ekman dredges were placed in a plastic sample bag. This testing is currently in progress.

---

## Water Sampling

In March and April 2002, Alberta Environment collected water samples from Lake Wabamun and the TransAlta Utilities Wabamun Ash Lagoon Effluent. The initial lake samples were collected under winter ice conditions. An ice auger was used to drill holes through the ice. A sampling strainer was placed on the end of a sample line that was suspended below the bottom of the ice layer and approximately 15 cm off the lake bottom. The other end of the sample line was connected to a small portable, vacuum pump that was attached to a sample collection jar. Great care was taken to insure that no sediments were disturbed on the lake bottom and sediment was not introduced into the sample line. Lake water was analyzed for routine water chemistry, metals, total organic carbon, nutrients, total suspended solids, turbidity, and sulphide. Results are presented in Figure 2 and Table 3.

In May and June 2002, additional water samples were collected during spring and early summer conditions around Wabamun Lake. The water samples were collected from a boat at various sites using a Kemmerer water-sampling device that allowed lake water to be collected from three different depths of the lake. Water samples were taken near the bottom, mid way and at the surface for each sampling location. The individual grab samples from each depth at each sample site were combined into a sample bucket, thoroughly mixed and poured off into water sample bottles. Those samples requiring preservation were properly fixed with the appropriate preservative at the time of collection.

Industrial wastewater samples were collected at TransAlta Wabamun's Ash Lagoon Final Effluent, at the mouth of the inlet cooling water canal, at the railway bridge in the cooling water canal and at the outlet cooling water canal. The water sampling techniques used were the same as for the lake water samples with the exception of the ash lagoon effluent, which was collected using a single bucket grab sample. The parameters being analyzed included routine water chemistry, total suspended solids, chemical oxygen demand, metals, total phosphorus, iron, oil and grease, nutrients, total organic carbon, sulphide and ammonia. In addition volatile priority pollutants, extractable priority pollutants and polycyclic aromatic hydrocarbons were analyzed. Results are presented in Figure 3 and Table 4.

---

## Drinking Water Samples

In response to concerns about the quality of drinking water around Wabamun Lake, Alberta Environment conducted extra testing of both surface and groundwater. Sampling and analysis were done according to Standard Methods for the Examination of Water and Wastewater.

The Village of Wabamun raw water intake and treated water were sampled on March 21 2002. The Treated Water Survey consisted of a metals scan, routine water chemistry, and nutrients. The water survey was done on both raw water and final treated water. The samples were also analyzed for a full spectrum chemical analysis that included organic compounds of the following groups, extractable priority pollutants, volatile priority pollutants, and pesticides scan.

Alberta Environment also tested water at Seba Beach. The water in question is not used for human consumption, however untreated water is pumped from the lake directly into a cistern and then used for domestic use. All results are presented in Table 5.

## Groundwater Sampling

An Alberta Environment Groundwater Contaminant Specialist reviewed the 2002 TransAlta Groundwater Monitoring report and found that the program was sound and that monitoring has shown no concerns to date. However, because of continued concerns regarding groundwater quality, three private water wells in the Rich's Point area and one well on the Paul Band Reserve were sampled and tested for metals and routine water chemistry. Results are presented in Table 5.

---

## Fish Mortality Investigation

In October 2001, TransAlta Utilities reported the presence of dead whitefish on the cooling water inlet screens to their Wabamun Generating Station.

Since the initial report of fish kills, Alberta Environment has worked with Alberta Sustainable Resource Development, Federal Fisheries and Oceans, and Environment Canada to determine the cause of the fish mortality.

Alberta Environment commissioned the services of Dr Greg Goss, Ph.D., Assistant Professor from the University of Alberta to help investigate the cause of the fish mortality. Dr. Goss's report is included in Appendix 1.

---

## CCME Guidelines

The Canadian Sediment Quality Guidelines for the Protection of Aquatic Life provide scientific benchmarks, or reference points, for evaluating the potential for observing adverse biological effects in aquatic systems. The guidelines are derived from the available toxicological information according to the formal protocol established by the Canadian Council of Ministers of the Environment (CCME). More information about these guidelines, including specific concentration ranges, is included online at
http://www.ccme.ca/publications/pubs_updates.html?category_id=0#104

### Alberta Surface Water Guidelines

Alberta's Surface Water Quality Guidelines provide general guidance in evaluating surface water quality throughout Alberta for the protection of aquatic life, agricultural use, recreational use and aesthetics. More information about Alberta Environment Surface Water Quality Guidelines is available online at http://www3.gov.ab.ca/env/protenf/publications/SurfWtrQual-Nov99.pdf.

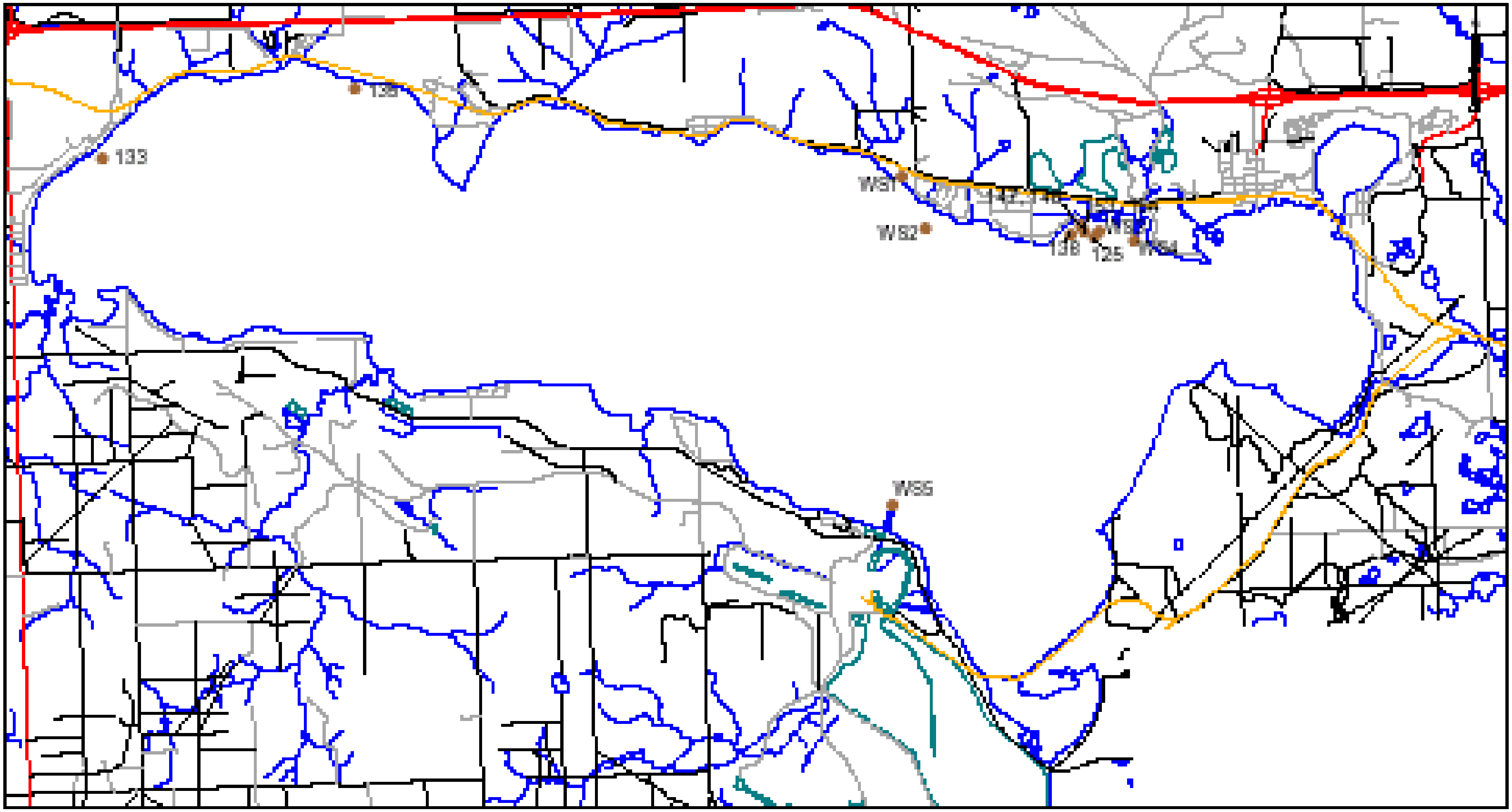
---

For more info, please contact:

Rick Ostertag
Acting Director Central Region
Alberta Environment
(780) 963-6131, ext. 277

Albert Poulette
Regional Compliance Manager
Alberta Environment
(780) 422-3035

Kim Hunt
Communications
Alberta Environment
(780) 427-2003




**LEGEND**

- Sediment Sampling Locations
- Primary Roads
- Secondary Roads
- Roads
- Trails and Other Access
- Lakes, Streams and Rivers
- Man Made Water Bodies

**REFERENCE**

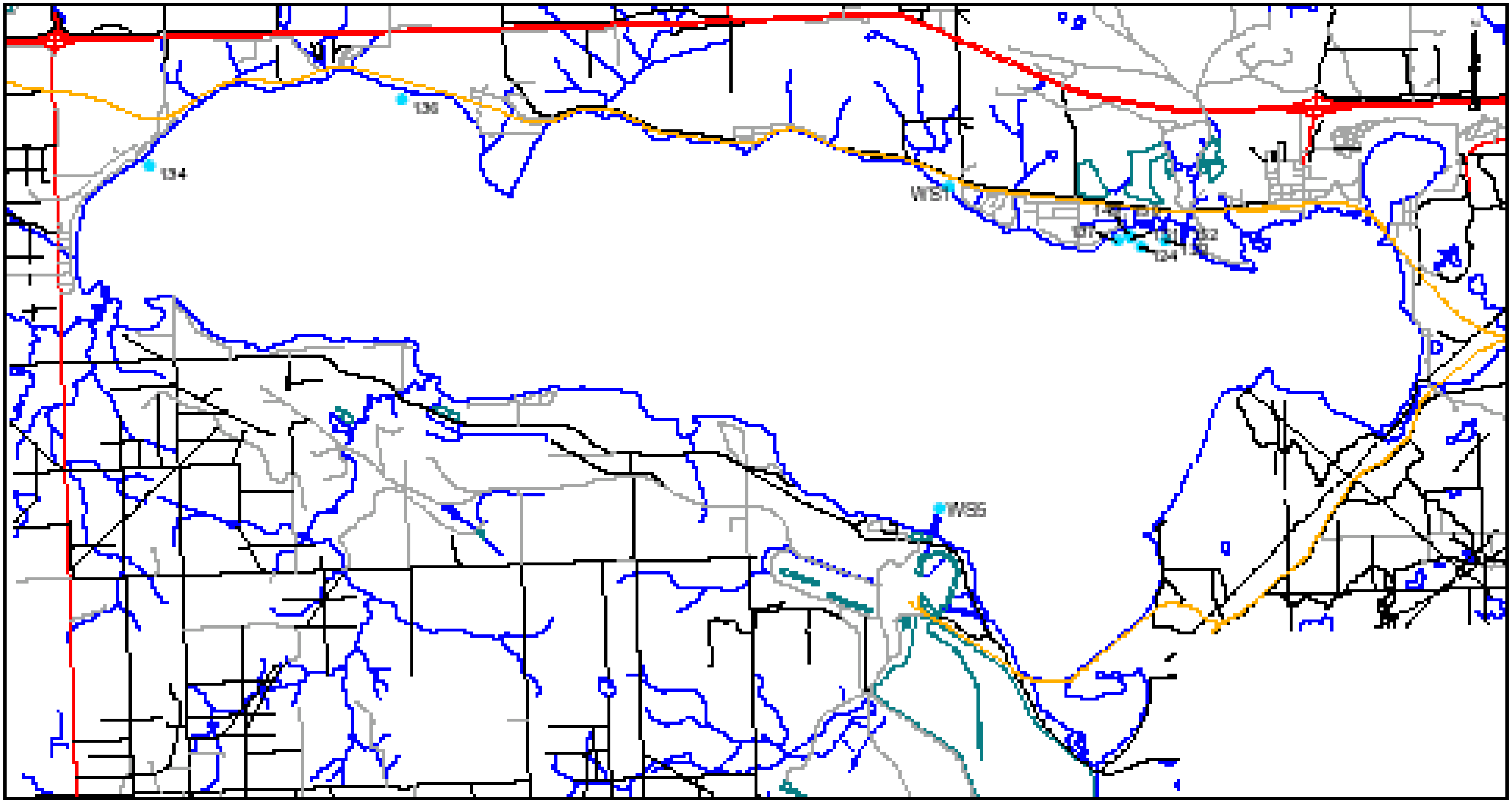
PROJECT

WABAMUN LAKE 2002
SAMPLING PROGRAM

TITLE

Wabamun Lake - Sediment Sampling Locations

FIGURE 1




**LEGEND**

| | |
|---|---|
| (cyan dot) | Water Sampling Locations |
| (red line) | Primary Roads |
| (orange line) | Secondary Roads |
| (black line) | Roads |
| (grey line) | Trails and Other Access |
| (blue line) | Lakes, Streams and Rivers |
| (teal line) | Man Made Water Bodies |

**REFERENCE**

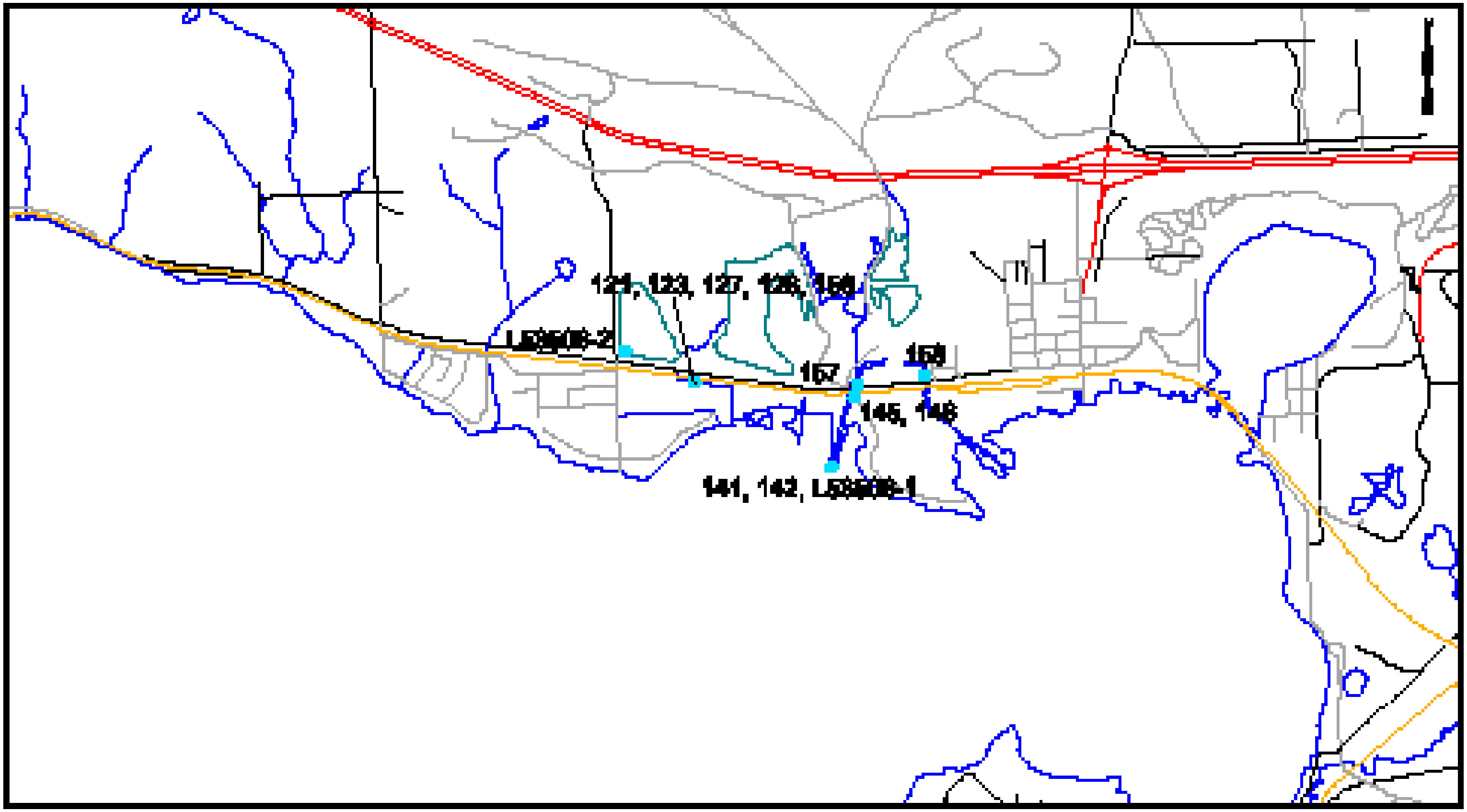
PROJECT

**WABAMUN LAKE 2002**
**SAMPLING PROGRAM**

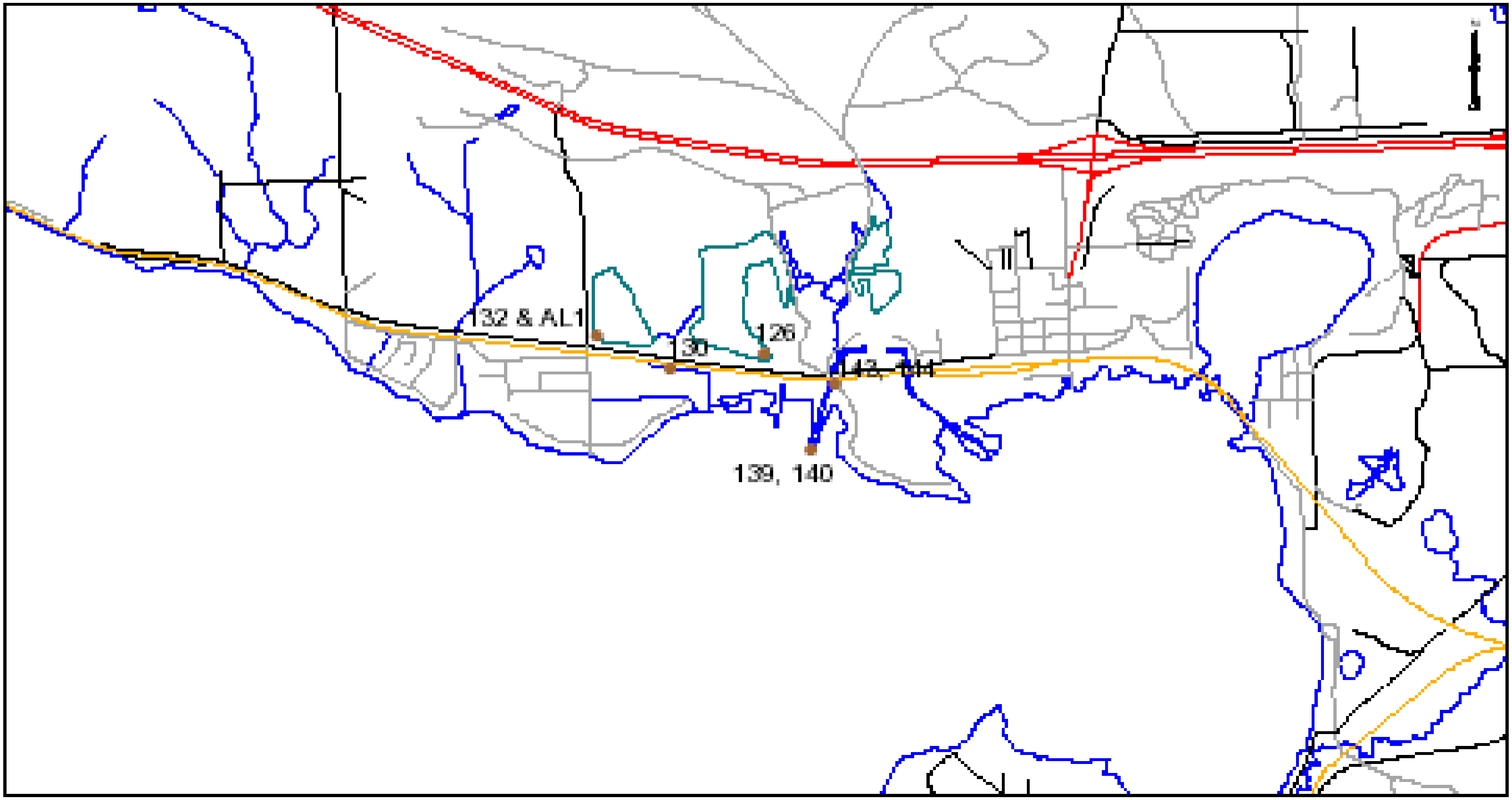
TITLE

**Wabamun Lake - Water Sampling Locations**

**FIGURE 2**



121, 123, 127, 128, 150
157
158
145, 146
141, 142




**LEGEND**

- TAU Sediment Sampling Locations
- Primary Roads
- Secondary Roads
- Roads
- Trails and Other Access
- Lakes, Streams and Rivers
- Man Made Water Bodies

**REFERENCE**

0.5 0 0.5 1 1.5 2

PROJECT

**WABAMUN LAKE 2002 SAMPLING PROGRAM**

TITLE

**TransAlta Site - Sediment Sampling Locations**

**FIGURE 4**

Table 1 – Wabamun Sediment Sampling Results

| Sample #<br>Date<br>Parameter | CCME<br>PAL<br>sediments<br>ISQG | CCME<br>PAL<br>sediments<br>PEL | WS1<br>18-Jun<br>mg/Kg | WS5<br>18-Jun<br>mg/Kg | 147<br>16-May<br>mg/Kg | 148<br>16-May<br>mg/Kg | 153<br>16-May<br>mg/Kg | 154<br>16-May<br>mg/Kg | 133<br>16-May<br>mg/Kg | 135<br>16-May<br>mg/Kg | 138<br>16-May<br>mg/Kg | 125<br>11-Apr<br>mg/Kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total As | 5.9 | 17 | 1 | **16.7** | **11.8** | **10.7** | **6.8** | **7.1** | 4.3 | 1.2 | 3.3 | |
| Total Hg | 0.17 | 0.486 | <0.05 | <0.05 | <0.05 | 0.05 | <0.05 | 0.08 | <0.05 | <0.05 | <0.05 | |
| Total Se | | | <0.2 | 0.4 | 1.6 | 2.1 | 0.7 | 1 | <0.1 | <0.1 | 0.3 | |
| Silver | | | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <0.1 |
| Aluminum | | | 20100 | 21900 | 13600 | 12000 | 10400 | 10000 | 4500 | 2600 | 5100 | 17000 |
| Arsenic | | | | | | | | | | | | **19.1** |
| Boron | | | | | 17 | 21 | 21 | 28 | <5 | <5 | 11 | 26 |
| Barium | | | 572 | 370 | 661 | 566 | 592 | 548 | 63 | 59 | 262 | 940 |
| Beryllium | | | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 0.7 |
| Bismuth | | | | | | | | | | | | <0.5 |
| Cadmium | 0.6 | 3.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 0.3 |
| Cobalt | | | 8 | 8 | 4 | 4 | 3 | 3 | 4 | 2 | 3 | 5.3 |
| Chromium | 37.3 | 90 | 23.5 | 25.6 | **50.9** | **44.7** | 25.8 | 29.2 | 9.9 | 5.2 | 7.7 | **136** |
| Copper | 35.7 | 197 | 20 | 20 | 25 | 22 | 18 | 18 | 2 | 2 | 8 | **66** |
| Molybdenum | | | 1 | 1 | 3 | 2 | 2 | 2 | 1 | <1 | <1 | 10.1 |
| Nickle | | | 21 | 21 | 14 | 8 | 12 | 6 | 9 | 5 | 3 | 33.6 |
| Lead | 35 | 91.3 | 9 | 9 | 10 | 9 | 7 | 7 | <5 | <5 | <5 | 11.2 |
| Tin | | | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 0.1 |
| Strontium | | | 49 | 56 | 587 | 536 | 607 | 573 | 14 | 16 | 356 | 616 |
| Titanium | | | 124 | 247 | | | | | | | | 63.2 |
| Thallium | | | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 0.24 |
| Uranium | | | | | <40 | <40 | <40 | <40 | <40 | <40 | <40 | 2.3 |
| Vanadium | | | 37 | 43 | 36 | 33 | 25 | 25 | 15 | 7 | 9 | 60.5 |
| Zinc | 123 | 315 | 100 | 90 | 50 | 50 | 40 | 40 | 30 | 20 | 30 | 78 |
| Calcium | | | 21900 | 24900 | 135000 | 142000 | 17700 | 174000 | 2100 | 4600 | 105000 | 132000 |
| Potassium | | | 6860 | 7060 | 1280 | 1290 | 1100 | 1310 | 830 | 510 | 690 | |
| Magnesium | | | 7600 | 8000 | 5200 | 5400 | 4900 | 5400 | 2500 | 2500 | 5000 | 5760 |
| Sodium | | | 1100 | 800 | 700 | 800 | 600 | 700 | 200 | 100 | 500 | 1080 |
| Iron | | | 20200 | 18600 | 9500 | 9300 | 7300 | 8100 | 6700 | 3700 | 5800 | 10700 |
| Manganese | | | 590 | 620 | 530 | 480 | 700 | 630 | 130 | 90 | 510 | 497 |
| iron Extract | | | | | | | | | | | | |
| EC | | | | | | | | | | | | |
| Tot. Inorganic | | | | | | 4.4 | | 4.96 | 0.08 | 0.43 | 3.51 | |
| Tot. Organic | | | | | | 2.8 | | 3.9 | <0.1 | 0.2 | 1.7 | |
| % sand | | | | | 15 | 11 | 14 | 7 | 99 | 97 | 44 | |
| % silt | | | | | 51 | 54 | 63 | 60 | 2 | 2 | 43 | |
| % clay | | | | | 35 | 35 | 24 | 33 | 1 | 1 | 13 | |

**LEGEND**

**Site Descriptions**

| | |
|---|---|
| WS1 | Wabamun Lake West of Ash Lagoon discharge |
| WS5 | Mouth of Sundance Water Treatment Plant Discharge |
| 147/148 | 50 meters East of the Ash Lagoon Discharge |
| 153/154 | 100 meters East of the Ash Lagoon Discharge |
| 133 | 200 meters West of Stream 16, 50 meters off north shore |
| 135 | 400 meters West of Fallis point, 50 meters off north shore |
| 138 | 250 meters West of Ash Lagoon Discharge |
| 125 | Wabamun Lake 100 meters East of Ash Lagoon Discharge |

**Acronyms**

| | |
|---|---|
| CCME | Canadian Council of Ministers of the Environment |
| PAL | Protection of Aquatic Life |
| PEL | Probable Effects Level |
| ISQG | Interim Sediment Quality Guideline |

**Parameters**

All parameters are in units of mg/Kg except the following:
pH - Unitless
Sand/silt/clay expressed as percentage

< denotes that the parameters was below the Detection Limit
Red indicates that the parameter exceeds limits or guidelines

Table 2 – TransAlta Wabamun Sediment Results

| Sample # Date Parameter | CCME PAL sediments ISQG | CCME PAL sediments PEL | Bottom 126 11-Apr Ash mg/Kg | 140 16-May Sediment mg/Kg | 139 16-May Sediment mg/Kg | 143 16-May Sediment mg/Kg | 144 16-May Sediment mg/Kg | 130 16-May Sediment mg/Kg | 131 16-May Sediment mg/Kg | 132 16-May Sediment mg/Kg |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Arsenic | 5.9 | 17 | 2.6 | 4 | 4.6 | 4.7 | 5.1 | 4.6 | 4.6 | **15** |
| Total Mercury | 0.17 | 0.486 | | 0.05 | 0.08 | <0.05 | <0.05 | 0.06 | <0.05 | 0.09 |
| Total Selenium | | | 4.9 | <0.1 | 0.2 | <0.1 | <0.1 | 0.2 | <0.1 | 1.5 |
| Silver | | | 0.1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Aluminum | | | 28900 | 9200 | 8500 | 7100 | 6900 | 13100 | 15600 | 12500 |
| Boron | | | 93 | <5 | 14 | 5 | 8 | 14 | 12 | 19 |
| Barium | | | 794 | 155 | 152 | 85 | 94 | 225 | 223 | 529 |
| Beryllium | | | 1.7 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Bismuth | | | <0.5 | | | | | | | |
| Cadmium | 0.6 | 3.5 | <0.1 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | | | 4.5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| Chromium | 37.3 | 90 | 10.1 | 13.5 | 22.6 | 10.9 | 12.5 | 20.8 | 13.9 | **85.8** |
| Copper | 35.7 | 197 | 7 | 18 | 18 | 7 | 8 | 12 | 13 | **39** |
| Molybdenum | | | 2.5 | <1 | <1 | <1 | <1 | <1 | <1 | 7 |
| Nickel | | | 11.2 | 15 | 18 | 13 | 13 | 13 | 11 | 31 |
| Lead | 35 | 91.3 | 2.4 | 32 | 7 | <5 | <5 | 9 | 9 | 9 |
| Tin | | | <0.1 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Strontium | | | 313 | 120 | 120 | 31 | 36 | 213 | 225 | 233 |
| Titanium | | | 476 | | | | | | | |
| Thallium | | | <0.05 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Uranium | | | 2.8 | <40 | <40 | <40 | <40 | <40 | <40 | <40 |
| Vanadium | | | 18.6 | 19 | 19 | 17 | 19 | 23 | 26 | 45 |
| Zinc | 123 | 315 | 26 | 60 | 50 | 40 | 40 | 40 | 40 | 40 |
| Calcium | | | 33400 | 38300 | 41200 | 10800 | 12200 | 32200 | 30200 | 50300 |
| Potassium | | | 420 | 1200 | 1330 | 970 | 1220 | 1550 | 1520 | 1220 |
| Magnesium | | | 2430 | 4300 | 4900 | 2300 | 2800 | 4400 | 4000 | 4400 |
| Sodium | | | 1040 | 300 | 300 | 200 | 300 | 400 | 400 | 500 |
| Iron | | | 9400 | 9800 | 9600 | 7300 | 7500 | 9900 | 10600 | 9100 |
| Manganese | | | 252 | 290 | 290 | 200 | 200 | 150 | 150 | 170 |
| pH | | | | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.2 | 8.1 |
| Total Carbon | | | | | 4.9 | | 0.6 | 4 | | 5.1 |
| Total Inorganic Carbon | | | | | 1.8 | | 0.69 | 1.6 | | 1.91 |
| Total Organic Carbon | | | | | 3.1 | | 0.1 | 2.4 | | 3.2 |
| % sand | | | | 63 | 65 | 86 | 83 | | 48 | 43 |
| %silt | | | | 23 | 23 | 7 | 10 | | 26 | 29 |
| % clay | | | | 14 | 12 | 8 | 7 | | 26 | 28 |

**LEGEND**

**Site Descriptions**

| | |
|---|---|
| 126 | Bottom ash sample |
| 140/139 | Mouth of inlet Canal |
| 130 | Ash Pond Effluent Discharge |
| 131/132 | Ash pond prior to discharge |

**Acronyms**

| | |
|---|---|
| CCME | Canadian Council of Ministers of the Environment |
| PAL | Protection of Aquatic Life |
| PEL | Probable Effects Level |
| ISQG | Interim Sediment Quality Guideline |

**Parameters**

All parameters are in units of mg/Kg except the following:
Sand/silt/clay expressed as percentage

< denotes that the parameters was below the Detection Limit
Red indicates that the parameter exceeds limits or guidelines

# Table 3 – Wabamun Lake Water Sampling Results

| Sample #<br>Date<br><br>Parameter | CCME<br>PAL<br>WATER<br>assumed hardness<br>100mg/l | WS1<br>18-Jun<br>water<br>mg/L | WS5<br>18-Jun<br>water<br>mg/L | 149<br>16-May<br>water<br>mg/L | 150<br>16-May<br>water<br>mg/L | 151<br>16-May<br>water<br>mg/L | 152<br>16-May<br>water<br>mg/L | 134<br>16-May<br>water<br>mg/L | 136<br>16-May<br>water<br>mg/L | 137<br>16-May<br>water<br>mg/L | 155<br>16-May<br>water<br>mg/L | 124<br>11-Apr<br>water<br>mg/L | 124-a<br>11-Apr<br>water<br>mg/L | 122<br>21-Mar<br>Lake NF<br>mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Antimony | | | | | | | | | | | | 0.0025 | 0.0014 | |
| Total Arsenic | 0.005 | 0.0025 | 0.0025 | 0.0035 | 0.0035 | 0.0029 | 0.0029 | 0.0027 | 0.0026 | 0.0028 | <0.0004 | **0.0093** | **0.0092** | |
| Total Mercury | 0.000013 / 0.000005 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | |
| Total Selenium | 0.001 | <0.0004 | 0.0004 | 0.0004 | <0.0004 | 0.0005 | <0.0004 | <0.0004 | <0.0004 | <0.0004 | <0.0004 | 0.0007 | 0.0006 | |
| Silver | 0.0001 | <0.005 | 0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.0004 | <0.0004 | |
| Aluminum | 0.1 | 0.05 | 0.06 | **0.14** | **0.16** | **0.27** | **0.28** | 0.02 | 0.03 | 0.09 | <0.01 | **0.36** | 0.07 | |
| Arsenic | | | | | | | | | | | | 0.009 | 0.009 | |
| Boron | | 0.85 | 0.86 | 0.92 | 0.98 | 0.86 | 0.91 | 0.9 | 0.87 | 0.87 | <0.05 | 1.75 | 1.8 | |
| Barium | | 0.12 | 0.124 | 0.12 | 0.134 | 0.124 | 0.137 | 0.126 | 0.127 | 0.127 | <0.003 | 0.157 | 0.154 | |
| Beryllium | | <0.002 | 0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.001 | 0.001 | |
| Bismuth | | | | | | | | | | | | <0.0001 | 0.0006 | |
| Cadmium | 0.000033 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.0002 | <0.0002 | |
| Cobalt | | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | 0.0003 | <0.0002 | |
| Chromium | 0.0089/0.001 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.0017 | <0.0008 | |
| Copper | 0.003 | 0.001 | 0.001 | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | <0.001 | **0.004** | 0.002 | |
| Molybdenum | | 0.005 | 0.006 | 0.008 | 0.007 | 0.006 | 0.006 | 0.005 | 0.005 | 0.006 | <0.005 | 0.0199 | 0.0198 | |
| Nickel | 0.065 | <0.002 | <0.002 | <0.002 | <0.002 | 0.002 | 0.002 | 0.002 | 0.002 | <0.002 | <0.002 | 0.001 | 0.0009 | |
| Lead | 0.004 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.0019 | 0.0002 | |
| Antimony | | | | | | | | | | | | <0.005 | <0.005 | |
| Selenium | | | | | | | | | | | | <0.0008 | <0.0008 | |
| Tin | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.0004 | <0.0004 | |
| Strontium | | 0.271 | 0.28 | 0.265 | 0.284 | 0.28 | 0.3 | 0.288 | 0.288 | 0.294 | <0.002 | 0.314 | 0.313 | |
| Titanium | | <0.001 | 0.001 | 0.005 | 0.004 | 0.008 | 0.008 | 0.001 | 0.001 | 0.002 | <0.001 | 0.023 | 0.005 | |
| Thallium | 0.0008 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.0001 | <0.0001 | |
| Uranium | | | | | | | | | | | | 0.0015 | 0.0016 | |
| Vanadium | | 0.001 | 0.001 | 0.004 | 0.004 | 0.003 | 0.003 | 0.001 | 0.001 | 0.002 | <0.001 | 0.0201 | 0.0197 | |
| Zinc | 0.03 | 0.003 | 0.004 | 0.006 | 0.003 | 0.019 | 0.007 | 0.014 | 0.01 | 0.007 | 0.006 | 0.017 | 0.007 | |
| Calcium | | 22.4 | 22.9 | 20.8 | 21.3 | 20.9 | 24.1 | 23.3 | 22.9 | 22.8 | <0.5 | 21.6 | 20.7 | 20.6 |
| Potassium | | 10.0 | 9.8 | 8.6 | 8.9 | 8.2 | 9.4 | 9.7 | 9.7 | 9.4 | <0.1 | 10.2 | 10.3 | 10.7 |
| Magnesium | | 16.6 | 16.6 | 14.7 | 15.1 | 14.2 | 16.7 | 17.1 | 16.9 | 16.5 | <0.1 | 15.1 | 15.6 | 15.2 |
| Sodium | | 65 | 63 | 60 | 60 | 55 | 62 | 62 | 64 | 62 | <1 | 82 | 85 | 82 |
| Iron | 0.3 | 0.027 | 0.029 | 0.09 | 0.06 | 0.107 | 0.142 | 0.022 | 0.024 | 0.037 | <0.005 | 0.235 | 0.014 | |
| Manganese | | 0.017 | 0.02 | 0.015 | 0.016 | 0.024 | 0.031 | 0.051 | 0.025 | 0.018 | <0.001 | 0.014 | 0.001 | |
| Iron Extract | 0.3 | 0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | 0.15 | 0.12 | 0.09 |
| Chloride | | 5 | 5 | 10 | 10 | 8 | 8 | 7 | 8 | 8 | <1 | 24 | 22 | 20 |
| Fluoride | | 0.41 | 0.39 | 0.39 | 0.4 | 0.39 | 0.4 | 0.39 | 0.4 | 0.4 | <0.05 | 0.51 | 0.51 | 0.52 |
| Nitrite/Nitrate | | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.1 | 0.2 | 0.1 |
| Nitrite | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 |
| Silica | | 1.9 | 2 | 2.3 | 2.4 | 1.5 | 1.5 | 3.7 | 3.7 | 1.6 | <0.1 | 12.3 | 12.1 | 10.7 |
| pH | | 8.6 | 8.5 | 8.5 | 8.5 | 8.5 | 8.4 | 8 | 8.2 | 8.4 | 6.2 | 8.7 | 8.7 | 8.6 |
| Conductivity | | 509 | 514 | 508 | 485 | 521 | 498 | 500 | 501 | 497 | 3.9 | 608 | 602 | 613 |
| Bicarbonate | | 230 | 249 | 233 | 233 | 250 | 252 | 259 | 261 | 253 | <5 | 221 | 216 | 251 |
| Carbonate | | 13 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 15 | 17 | 14 |
| Hydroxide | | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |

**LEGEND**

**Site Descriptions**

| | |
|---|---|
| WS1 | Wabamun Lake West of Ash Lagoon Discharge |
| WS5 | Mouth of Sundance Water Treatment Plant Discharge |
| 149/150 | 50 meters East of the Ash Lagoon Discharge |
| 151/152 | 100 meters East of the Ash Lagoon Discharge |
| 134 | 200 meters West of Stream 16, 50 meters off shore |
| 136 | 400 meters West of Fallis point, 50 meters off shore |
| 137 | 250 meters West of Ash Lagoon Discharge |
| 155 | Field Blank QA/QC |
| 124 | Ash Lagoon Discharge to Wabamun Lake Filtered |
| 124-a | Ash Lagoon Discharge to Wabamun Lake |
| 122 | Ash Lagoon Discharge to Wabamun Lake |

**Acronyms**

| | |
|---|---|
| CCME | Canadian Council of Ministers of the Environment |
| PAL | Protection of Aquatic Life |
| PEL | Probable Effects Level |

**Parameters**

All parameter units are in mg/L (ppm) except the following:
pH - Unitless
Conductivity - us/cm
Ion Balance - %
Turbidity - NTU's

< denotes that the parameters was below the Detection Limit
Red indicates that the parameter exceeds limits or guidelines

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alkalinity | | 210 | 211 | 199 | 199 | 211 | 211 | 212 | 214 | 212 | <5 | 205 | 204 | 229 |
| Ion Balance | | 106 | 106 | 105 | 105 | 103 | 105 | 103 | 102 | 103 | low | 102 | 99.6 | 94.2 |
| Tot. Diss. Solids | | 325 | 323 | 297 | 294 | 305 | 303 | 303 | 305 | 304 | <1 | 356 | 354 | 351 |
| Hardness | | 139 | 139 | 124 | 124 | 132 | 133 | 130 | 130 | 130 | <1 | 122 | 120 | 114 |
| Sulphate | | 68.8 | 69 | 55.3 | 53.1 | 55.8 | 52.5 | 52.8 | 52.5 | 53.4 | <0.5 | 73.1 | 76.6 | 64.6 |
| Sulphide | | 0.051 | 0.031 | 0.006 | <0.003 | 0.007 | 0.006 | <0.003 | | 0.004 | <0.003 | | | |
| Tot. Phosphorus | 0.05 | <0.02 | 0.02 | <0.02 | 0.03 | 0.04 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | 0.05 | | |
| Ammonia-N | pH-T-dependent | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | | |
| Tot. Kjeldahl Nitrogen | | 0.8 | 0.8 | | | | | | | | | 1.3 | | |
| Diss. Kjeldahl Nitrogen | | | | | | | | | | | | 1.3 | | |
| Nitrate | | | | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.1 | | |
| Chemical Oxygen Demand | | 30 | 30 | | | | | | | | | 20 | | |
| Diss. Organic Carbon | | 12 | 12 | 12 | 13 | 13 | 13 | 12 | 12 | 14 | <1 | | | |
| Tot. Organic Carbon | | 12 | 12 | 14 | 13 | 15 | 15 | 13 | 14 | 14 | <1 | | <1 | |
| Tot. Suspended Solids | | | | 6 | 6 | 20 | 15 | <3 | 4 | <3 | <3 | | | <3 |
| Turbidity | | | | 4.9 | 1.5 | 7.7 | 5.7 | 1.1 | 0.79 | 1.7 | 0.1 | | 0.2 | |

Table 4 – TransAlta Wabamun Water Sampling Results

| Sample # | CCME | 157 | 158 | 156 | 127 | 128 | 142 | 141 | 145 | 146 | 123 | 123 | 121 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | PEL | 5-Jun | 5-Jun | 5-Jun | 16-May | 16-May | 16-May | 16-May | 16-May | 16-May | 11-Apr | 11-Apr | 21-Mar |
| | WATER | Water | Water | Water | Water | Water | inlet Canal | inlet Canal | south RR | south RR | effluent | Effl. Filter | effluent |
| Parameter | assumed hardness=100 | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L |
| Total SB | | | | | | | | | | | 0.0021 | 0.0014 | |
| Total As | 0.005 | 0.0026 | 0.0028 | **0.0075** | **0.0067** | **0.0057** | 0.0028 | 0.0026 | 0.0026 | 0.0026 | **0.0095** | **0.0093** | **0.0104** |
| Total Hg | 0.000013 / 0.000005 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Total Se | 0.001 | <0.0004 | 0.0004 | 0.0006 | <0.0004 | 0.0006 | 0.0005 | <0.0004 | <0.0004 | <0.0004 | 0.0007 | 0.0006 | 0.0004 |
| Silver | 0.0001 | <0.005 | 0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.0004 | <0.0004 | 0.005 |
| Aluminum | 0.1 | 0.06 | 0.08 | **0.2** | **0.28** | **0.24** | 0.09 | 0.09 | **0.17** | **0.14** | **0.41** | 0.07 | **0.7** |
| Arsenic | | | | | | | | | | | 0.009 | 0.009 | |
| Boron | | 0.84 | 0.83 | 1.44 | 1.29 | 1.16 | 0.82 | 0.89 | 0.86 | 0.89 | 1.72 | 1.77 | 1.78 |
| Barium | | 0.124 | 0.127 | 0.182 | 0.155 | 0.121 | 0.113 | 0.124 | 0.116 | 0.124 | 0.168 | 0.194 | 0.169 |
| Beryllium | | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.001 | <0.001 | 0.002 |
| Bismuth | | | | | | | | | | | <0.0001 | <0.0001 | |
| Cadmium | 0.000033 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.0002 | <0.0002 | 0.001 |
| Cobalt | | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | 0.0003 | <0.0002 | 0.002 |
| Chromium | 0.0089/0.001 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.0013 | 0.001 | 0.005 |
| Copper | 0.003 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Molybdenum | | 0.005 | 0.006 | 0.021 | 0.016 | 0.014 | 0.006 | 0.005 | 0.006 | 0.005 | 0.02 | 0.0199 | 0.02 |
| Nickel | 0.065 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | 0.0011 | 0.0008 | 0.002 |
| Lead | 0.004 | <0.005 | <0.005 | <0.005 | 0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.0004 | <0.0001 | 0.005 |
| Antimony | | | | | | | | | | | <0.005 | <0.005 | |
| Selenium | | | | | | | | | | | <0.0008 | <0.0008 | |
| Tin | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.0004 | 0.0008 | 0.05 |
| Strontium | | 0.284 | 0.283 | 0.288 | 0.249 | 0.209 | 0.266 | 0.29 | 0.271 | 0.287 | 0.322 | 0.317 | 0.331 |
| Titanium | | <0.001 | 0.001 | <0.004 | 0.009 | 0.008 | 0.003 | 0.002 | 0.005 | 0.003 | 0.031 | <0.005 | 0.037 |
| Thallium | 0.0008 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.0001 | <0.0001 | <0.05 |
| Uranium | | | | | | | | | | | 0.0015 | 0.0015 | |
| Vanadium | | <0.001 | 0.002 | <0.016 | 0.013 | 0.012 | 0.002 | 0.002 | 0.002 | 0.002 | 0.0208 | 0.0199 | 0.02 |
| Zinc | 0.03 | 0.002 | 0.015 | <0.002 | 0.008 | 0.014 | 0.017 | 0.006 | 0.005 | 0.004 | 0.006 | 0.006 | 0.004 |
| Calcium | | 22.3 | 22.6 | 19.6 | 19 | 18.2 | 19.7 | 22.9 | 19.9 | 21.7 | 21.8 | 21.1 | 21.4 |
| Potassium | | 9.2 | 9.3 | 8.7 | 7.8 | 7.5 | 8.1 | 9.5 | 8.1 | 9.2 | 10.2 | 10.2 | 9.8 |
| Magnesium | | 16.6 | 16.6 | 12.9 | 11.8 | 11.1 | 14.4 | 16.7 | 14.1 | 15.6 | 15.5 | 15.6 | 15.2 |
| Sodium | | 62 | 62 | 68 | 60 | 60 | 55 | 62 | 54 | 59 | 82 | 85 | 82 |
| Iron | 0.3 | 0.023 | 0.028 | 0.051 | 0.105 | 0.106 | 0.043 | 0.041 | 0.069 | 0.067 | 0.282 | 0.01 | **0.324** |
| Manganese | | 0.024 | 0.027 | 0.003 | 0.012 | 0.011 | 0.015 | 0.017 | 0.018 | 0.02 | 0.016 | 0.002 | 0.016 |
| Iron extr. | 0.3 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | 0.16 | 0.13 | 0.19 |
| Chlorides | | 6 | 6 | 21 | 19 | 19 | 8 | 7 | 8 | 8 | 24 | 23 | 27 |
| Fluoride | | 0.37 | 0.38 | 0.44 | 0.41 | 0.4 | 0.39 | 0.4 | 0.39 | 0.39 | 0.51 | 0.051 | 0.53 |
| Nitrate/Nitrite | | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.1 | 0.2 | 0.1 |
| Nitrite | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 |
| Silica | | 1 | 1 | 8 | 7.3 | 7 | 1.7 | 1.7 | 1.6 | 1.6 | 12.5 | 12.4 | 12.2 |
| pH | | 8.4 | 8.4 | 8.7 | 8.7 | 8.8 | 8.5 | 8.4 | 8.5 | 8.4 | 8.7 | 8.8 | 8.8 |
| Conductivity | | 489 | 490 | 480 | 451 | 472 | 516 | 494 | 515 | 494 | 608 | 607 | 611 |
| Bicarbonate | | 246 | 247 | 187 | 163 | 169 | 248 | 248 | 247 | 246 | 220 | 214 | 207 |

**LEGEND**

**Site Descriptions**

| | |
|---|---|
| 157 | Bridge Crossing Inlet Canal |
| 158 | Bridge Crossing Outlet Canal |
| 156 | Ash Pond Effluent Discharge |
| 127/128 | Ash Pond Effluent Discharge |
| 142/141 | Mouth of Inlet Canal |
| 145/146 | Inlet canal 42 m South of Rail Crossing |
| 123 | Ash Pond Effluent Discharge |
| 123 | Ash Pond Effluent Discharge Filtered |
| 121 | Ash Pond Lagoon Discharge |

**Acronyms**

| | |
|---|---|
| CCME | Canadian Council of Ministers of the Environment |
| PEL | Probable Effects Level |

**Parameters**

All parameter units are in mg/L (ppm) except the following:
pH - Unitless
Conductivity - us/cm
Ion Balance - %
Turbidity - NTU's

< denotes that the parameters was below the Detection Limit
Red indicates that the parameter exceeds limits or guidelines

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Carbonate | | <5 | <5 | 7 | 15 | 13 | <5 | <5 | <5 | <5 | 15 | 18 | 24 |
| Hydroxide | | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 5 |
| Alkalinity | | 205 | 206 | 165 | 158 | 161 | 209 | 208 | 208 | 207 | 205 | 205 | 209 |
| Ion Balance | | 109 | 107 | 107 | 102 | 101 | 103 | 105 | 105 | 105 | 103 | 98.4 | 95.5 |
| Tot. Diss. Sol. | | 297 | 296 | 296 | 272 | 273 | 302 | 298 | 303 | 299 | 357 | 353 | 346 |
| Hardness | | 129 | 128 | 104 | 98 | 97 | 128 | 129 | 130 | 129 | 123 | 121 | 110 |
| Sulphate | | 50.7 | 50.8 | 59.7 | 54.5 | 55.2 | 55.1 | 52.2 | 55 | 52.7 | 73.4 | 76 | 65.6 |
| Tot. Phos. | 0.05 | | | <0.02 | <0.02 | 0.03 | 0.03 | 0.07 | 0.03 | <0.02 | 0.05 | | 0.02 |
| Ammonia-N | pH-T-dependent | | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | | 0.05 |
| Tot. Kjeldahl N | | | | 0.7 | 0.6 | 0.7 | | | | | 1.1 | | 0.6 |
| Diss. TKN | | | | 0.5 | 0.5 | 0.7 | | | | | 1.1 | | 0.5 |
| NO3 | | | | <0.1 | <0.1 | <0.1 | <0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 |
| Oil & Grease | | | | <1 | 1 | 1 | | | | | <1 | | 1 |
| Diss. Org. C | | | | 20 | 20 | 20 | 13 | 12 | 13 | 12 | 20 | | 20 |
| TSS | | <3 | <3 | <3 | 8 | 6 | 9 | 6 | 10 | 11 | 5 | | 5 |
| TDS | | | | | | | | | | | 357 | | |
| Chromium Hex | | <0.001 | <0.001 | <0.001 | | | | | | | <0.001 | | |
| TOC | | | | 11 | 9 | 8 | 15 | 14 | 14 | 14 | | | |
| Sulphide | | | | 0.004 | <0.003 | <0.003 | 0.005 | <0.003 | 0.004 | 0.005 | | | |
| Turbidity | | | | | 2 | 4.9 | 3.6 | 1.9 | 5.1 | 2.8 | | | |

**LEGEND**

**Site Descriptions**

| | |
|---|---|
| 157 | Bridge Crossing Inlet Canal |
| 158 | Bridge Crossing Outlet Canal |
| 156 | Ash Pond Effluent Discharge |
| 127/128 | Ash Pond Effluent Discharge |
| 142/141 | Mouth of Inlet Canal |
| 145/146 | Inlet canal 42 m South of Rail Crossing |
| 123 | Ash Pond Effluent Discharge |
| 123 | Ash Pond Effluent Discharge Filtered |
| 121 | Ash Pond Lagoon Discharge |

**Acronyms**

| | |
|---|---|
| CCME | Canadian Council of Ministers of the Environment |
| PEL | Probable Effects Level |

**Parameters**

All parameter units are in mg/L (ppm) except the following:

pH - Unitless

Conductivity - us/cm

Ion Balance - %

Turbidity - NTU's

< denotes that the parameters was below the Detection Limit

Red indicates that the parameter exceeds limits or guidelines

Table 5 – Potable Water Sample Results

| | | L1 | ML2 | WB1 | SH1 | FB1 | K1 | B1 | 323 | 322 | 321 | 320 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | 10-Jun | 10-Jun | 10-Jun | 10-Jun | 10-Jun | 24-May | 10-May | 9-May | 9-May | 21-Mar | 21-Mar |
| Tot. Arsenic | | | | | | | 0.0025 | | | | | |
| Tot. Mercury | | | | | | | <0.0002 | | | | | |
| Tot. Selenium | | | | | | | 0.0004 | | | | | |
| Silver | | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Aluminum | | 0.08 | 0.11 | 0.01 | 0.01 | 0.01 | **0.62** | <0.01 | 0.02 | 0.2 | 0.01 | 0.1 |
| Arsenic | 0.025 imac | | | | | | | <0.0004 | 0.0028 | 0.0023 | 0.0032 | 0.0025 |
| Boron | 5.0 imac | 0.91 | 0.92 | 0.26 | 0.23 | 0.27 | 0.89 | 0.35 | 0.928 | 0.963 | 1.09 | 1.08 |
| Barium | 1.0 mac | 0.114 | 0.117 | 0.079 | 0.078 | 0.08 | 0.116 | 0.0687 | 0.125 | 0.117 | 0.13 | 0.125 |
| Beryllium | | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Bismuth | | | | | | | | 0.00009 | | | | |
| Cadmium | 0.005 mac | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.0001 | 0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | 0.0002 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Chromium | 0.05 mac | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.0006 | <0.0001 | <0.0004 | <0.0004 | <0.0004 |
| Copper | 1.0 ao | 0.052 | 0.001 | 0.016 | 0.003 | 0.003 | 0.023 | 0.0063 | 0.0178 | 0.0114 | 0.017 | 0.0119 |
| Hg | 0.001 mac | | | | | | | | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Molybdenum | | <0.005 | 0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.0021 | 0.0057 | 0.0058 | 0.0059 | 0.0058 |
| Nickel | | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | 0.0001 | 0.0001 | 0.0023 | 0.0002 | 0.0014 |
| Lead | 0.010 mac | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.0002 | 0.002 | 0.0008 | 0.001 | 0.0005 |
| Antimony | | | | | | | | <0.0008 | | | | |
| Selenium | 0.01 mac | | | | | | | 0.0004 | 0.0004 | <0.0004 | <0.0004 | <0.0004 |
| Tin | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.0002 | 0.0004 | <0.0002 | 0.0003 | <0.0002 |
| Strontium | | 0.286 | 0.286 | 0.064 | 0.063 | 0.059 | 0.263 | 0.0529 | 0.285 | 0.287 | 0.291 | 0.287 |
| Titanium | | 0.002 | 0.002 | 0.004 | 0.003 | 0.003 | 0.013 | 0.0125 | 0.0007 | <0.0003 | 0.0007 | 0.0004 |
| Thallium | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.00005 | 0.00005 | <0.00005 | <0.00005 | <0.00005 |
| Uranium | 0.1 mac | | | | | | | <0.0001 | 0.0006 | 0.0004 | 0.0006 | 0.0005 |
| Vanadium | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.0002 | 0.0014 | 0.0012 | 0.0015 | 0.0013 |
| Zinc | 5.0 ao | 0.005 | 0.002 | 0.067 | 0.041 | 0.054 | 0.027 | <0.002 | 0.013 | 0.004 | 0.015 | 0.006 |
| Calcium | | 22.5 | 22.6 | 3.4 | 3.4 | 3.3 | 19.4 | 3.2 | 24.8 | 25.3 | 25 | 24.9 |
| Potassium | | 9.4 | 9.4 | 0.9 | 0.9 | 0.9 | 8.1 | 0.9 | 9.9 | 10.1 | 10.9 | 11 |
| Magnesium | | 16.6 | 16.6 | 0.2 | 0.2 | 0.2 | 13.4 | 0.3 | 18.3 | 18.2 | 18.7 | 18.5 |
| Sodium | 200 ao | 65 | 64 | **352** | **353** | **357** | 58 | **322** | 65 | 68 | 72 | 72 |
| Iron | 0.3 ao | 0.075 | 0.042 | 0.026 | 0.027 | 0.022 | 0.288 | 0.021 | 0.012 | <0.005 | 0.007 | 0.005 |
| Manganese | 0.05 ao | 0.018 | 0.015 | 0.004 | 0.003 | 0.003 | 0.019 | 0.005 | 0.013 | 0.001 | 0.007 | 0.001 |
| Iron Extract | | | | | | | 0.18 | | | | | |
| Chloride | 250 ao | | 5 | 2 | 1 | 1 | 14 | 13 | 8 | 17 | 16 | 10 |
| Fluoride | 1.5 mac | | 0.41 | 1.22 | 1.16 | 1.17 | 0.38 | **1.63** | 0.37 | 0.36 | 0.43 | 0.44 |
| Nitrite & Nitrate | | | 0.1 | 0.1 | 0.1 | 0.1 | <0.1 | <0.1 | 0.1 | 0.1 | <0.1 | <0.1 |
| Nitrite | | | <0.05 | 0.05 | 0.05 | 0.05 | <0.05 | <0.1 | 0.06 | <0.05 | 0.05 | <0.05 |
| Silica | | | 2 | 13.4 | 10.7 | 12.9 | 2.7 | | 2.4 | 1.9 | 2.8 | 3 |

**LEGEND**

**Site Descriptions**

| | |
|---|---|
| ML1 | Priv. Res. SE-4-53-5-W5 Tap |
| ML2 | Priv. Res. SE-4-53-5-W5 Lake Water |
| WB1 | Priv.Res SW-3-53-4-W5 Ground Water |
| SH1 | Priv. Res.SW-3-53-4-W5 Ground Water |
| FB1 | Priv. Res. SW-3-53-4-W5 Ground Water Well |
| K1 | Priv. Res. SE-4-53-5-W5 Tap |
| B1 | Paul Band Ground Water Well |
| 323 | Vill. of Wabamun Raw Water supply |
| 322 | Vill. of Wabamun Treated Water supply |
| 321 | Vill. of Wabamun Raw Water supply |
| 320 | Vill. of Wabamun Treated Water supply |
| notes | ML2 and K1 not used for potable water |

**Acronyms**

| | |
|---|---|
| GCDWQ | Guidelines for Canadian Drinking Water Quality |
| MAC | Maximum Acceptable Concentration |
| IMAC | Interim Maximum Acceptable Concentration |
| AO | Aesthetic Objectives |

**Parameters**

parameters in mg/L except the following:

pH - Unitless

Conductivity - us/cm

Ion Balance - %

Turbidity - NTU's

< denotes value below detection limit

Red numbers indicate value above guideline value

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | | | 8.4 | 8.4 | 8.4 | 8.4 | 8.3 | 8.6 | 8.5 | 7.9 | 7.9 | 8.3 |
| Conductivity | | | 530 | 1400 | 1410 | 1420 | 518 | 1320 | 520 | 559 | 591 | 595 |
| Bicarbonate | | | 253 | 918 | 916 | 912 | 242 | 725 | 252 | 252 | 261 | 291 |
| Carbonate | | | <5 | 5 | 7 | 5 | 5 | 28 | 5 | 5 | 5 | <5 |
| Hydroxide | | | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Alkalinity | | | 212 | 759 | 762 | 753 | 198 | 640 | 214 | 207 | 214 | 239 |
| Ion Balance | | | 106 | 106 | 106 | 104 | 103 | 99.7 | 107 | 104 | 98.4 | 97.9 |
| Total Dissolved Solids | | | 302 | 826 | 842 | 836 | 298 | 775 | 307 | 318 | 346 | 340 |
| Hardness | | | 132 | 10 | 10 | 10 | 120 | 9 | 137 | 138 | 139 | 138 |
| Sulphate | 500 ao | | 53.1 | 0.5 | 7.5 | 4 | 50.7 | 51.3 | 52.5 | 55.4 | 75.4 | 60.4 |
| Total Phosphorus | | | | | | | <0.02 | | 0.04 | <0.02 | | |
| Dissolved Phosphorus | | | | | | | <0.02 | | | | | |
| Ammonia-N | | | | | | | 0.07 | | <0.05 | <0.05 | 0.05 | 0.05 |
| Total Kjeldahl Nitrogen | | | | | | | | | 0.7 | 0.9 | 0.5 | 0.8 |
| Chemical Oxygen Demand | | | 30 | 30 | 30 | 30 | | <10 | | | 30 | 30 |
| Dissolved Organic Carbon | | | 12 | 15 | 14 | 14 | 16 | 12 | 14 | 11 | | |
| Total Organic Carbon | | | 14 | 17 | 16 | 17 | 17 | | 16 | 12 | | |
| Colour | | | | | | | | | 10 | 5 | | |
| Turbidity | | | 1.3 | 0.32 | 0.39 | 0.1 | | 0.16 | 1 | 0.71 | 0.12 | 0.39 |

**LEGEND**

**Site Descriptions**

| | |
|---|---|
| ML1 | Priv. Res. SE-4-53-5-W5 Tap |
| ML2 | Priv. Res. SE-4-53-5-W5 Lake Water |
| WB1 | Priv.Res SW-3-53-4-W5 Ground Water |
| SH1 | Priv. Res.SW-3-53-4-W5 Ground Water |
| FB1 | Priv. Res. SW-3-53-4-W5 Ground Water Well |
| K1 | Priv. Res. SE-4-53-5-W5 Tap |
| B1 | Paul Band Ground Water Well |
| 323 | Vill. of Wabamun Raw Water supply |
| 322 | Vill. of Wabamun Treated Water supply |
| 321 | Vill. of Wabamun Raw Water supply |
| 320 | Vill. of Wabamun Treated Water supply |
| notes | ML2 and K1 not used for potable water |

**Acronyms**

| | |
|---|---|
| GCDWQ | Guidelines for Canadian Drinking Water Quality |
| MAC | Maximum Acceptable Concentration |
| IMAC | Interim Maximum Acceptable Concentration |
| AO | Aesthetic Objectives |

**Parameters**

parameters in mg/L except the following:

pH - Unitless

Conductivity - us/cm

Ion Balance - %

Turbidity - NTU's

< denotes value below detection limit

Red numbers indicate value above guideline value

# Appendix 1

**A report prepared for Alberta Environment**

**Prepared by Greg G. Goss, Ph.D.**
**Associate Professor**
**Dept of Biological Sciences**
**University of Alberta**

Final Report

# Status of Lake Wabamun fishes regarding fish kills occurring at the TransAlta Wabamun power generating station.

A report prepared for Alberta Environment

Prepared by Greg G. Goss, Ph.D.
Associate Professor
Dept of Biological Sciences
University of Alberta
Edmonton Alberta
T5G 2E7
Email: greg.goss@ualberta.ca
Tel: 780-492-2381
FAX: 780-492-9234

Distribution:

July 30, 2002

## Table of Contents

Table of Figures

## General Summary

This report summarizes the general findings to date regarding the problem of fish appearing on the inlet screens at the TransAlta Wabamun power generating plant. Despite a great deal of study employing rigorous scientific procedures and analyses, a direct cause for the appearance of fish on the inlet screens has not as yet been determined.

We are, however, able to positively state the following:

**1)** Metal toxicity does not appear to be related to fish kills at the TransAlta Wabamun power generating plant.

**2)** Fish appearing on the inlet screens at Lake Wabamun TransAlta have been exhaustively exercised prior to turning up on screens. However, Northern Pike released back to inlet channel indicates that return passage back to the lake is likely not a problem for this species. These mark and release tests were not performed for whitefish and it still remain a possibility that this species cannot get out of the inlet canal.

## Assessment of the problem-Current Hypothesis and Views

Low levels of metals found in the water and the sediment of the lake are not the proximal cause of the fish appearing on the screen (see below for explanation). We have eliminated the most likely causes and now must search for a less discrete and more complex mechanism. We have been made aware of specific indicators of serious ecological problems on the lake. Specifically, a reduced fitness in the fishes indicated by a drop in condition factors in the fish caught combined with a reduced zooplankton level in the lake indicated a reduced primary productivity in the lake. We do not have data regarding invertebrate productivity in the lake at this time. The lake has recently been severely impacted by dropping lake levels. At this point, one hypothesis is that a drop in water levels in the lake may likely be the cause of a reduced primary productivity in the lake. Combined with other unknown events, it is my opinion that fishes may be migrating to new habitats for spawning as a result of the deteriorating conditions in the lake. Since the only outlet from the lake is via the inlet canal of the TransAlta powerplant, fish may be migrating into the canal seeking a new environment. Suggestions to eliminate this problem may include a fish exclusion program for the inlet canal. However, a fish exclusion program may simply move the problem to another site. I feel that with a drop in temperature in October, we may see a repeat of the problems that surfaced in October 2001. A contingency plan for such a scenario should be readied and in place should the problems arise once again.

Recommendations:

**Recommendation #1)**

A complete investigation of the elevated metals in the sediments are Lake Wabamun and surrounding lakes should be undertaken. While in general, these levels were low and given the hydrogeology of the lake, relatively non-toxic, the appearance of higher than normal levels of metals in the sediments and water column in the 200FAR site west of the inlet canal cannot be discounted.

**Recommendation #2)**

While plans should be drawn up for a fish exclusionary device for the inlet canal, this may only divert the problem 500 metres away from the plant. Ultimately, a reason for the fish wishing to enter the inlet canal (leave the lake?) will have to be understood and rectified.

**Recommendation #3)**

I recommend that a “library” of key indicator fish species (8-10 pike, whitefish, walleye) be kept. Additionally, invertebrate, water and sediment samples be collected and processed properly for each year from a selected set of sites (6-10) around the lake. Finally, copies of theses and studies on the lake should be catalogued and maintained as a central resource for this lake. This would allow for historical data to be accessible regarding metals, organics, populations, species richness etc. With this data accessible, it can serve as a database should future problems arise and should allow for more rapid assessment of problems, should they occur.

**Recommendation #4)**

Should the problems re-occur in the fall of 2002 (likely associated with a drop in water temperature), I recommend that a mark and release study be immediately initiated with lake whitefish to determine if they are able to swim out of the inlet channel. Since whitefish are much more sensitive to handling stress, I would expect a greater mortality associated with this study than was found for Northern Pike.

**Recommendation #5)**

I recommend that a survey of the invertebrate population be instigated. This may either be by a new study or through gathering data already collected. This study is imperative if we are to able to accurately assess the condition of the lake and how it is faring during re-instatement of historical water levels through the contribution of the Sundance water treatment plant.

General Introduction and Information provided prior to May 01, 2002

In numerous personal and telephone meetings (January to April) with representatives of Alberta Environment (Stephen Spencer and Ryan Levitt), I was made aware of problems occurring out at the TransAlta Wabamun power generating station. I was informed of daily fish kills occurring at the inlet screen of the Powerplant. The fish killed were primarily lake whitefish during this time and ranged in numbers from <10 to >100 on some days. Information presented at that time indicated that the fish kills started on October 26 and continued with regular numbers of fish appearing on the screens through to the spring.

Initially, we discussed the possibility that gas bubble disease may be resulting from specific operations at the plant. It was presented to me that a recirculating system was in place at the plant to put warmer water back into the inlet canal to prevent ice buildup. It was suggested that the fish kills might be caused by gas bubble disease resulting from mixing cool and warm water. However, two pieces of evidence were later present suggesting that gas bubble disease were not the proximal cause of fish mortality in the fish appearing on the screen. First, histological analysis by fish pathologist Bev Larson suggested there was no evidence of gas bubble disease found in the fish. Secondly, TransAlta agreed to remove the recirculating water returning to the inlet canal in February. Cessation of these operations did not result in any apparent reduction in fish mortality suggesting that gas bubble disease and plant operation relating to the practice of recirculating the water was not the cause of the fish mortality. At this time, no apparent cause of mortality could be determined and a more thorough investigation was initiated.

In early April, Northern Pike started to appear on the inlet screens in ever increasing numbers. TransAlta initiated a round the clock rescue program when it was determined that most of the Pike who were found on the inlet screens were not dead but simply exhausted and washed up on the inlet screens.

At this point I was asked to provide independent scientific analysis of the fish metabolic status (see below) and analysis for the possibility that sublethal metal toxicity (see below) resulted in fish appearing on the inlet screens. Additionally, I was asked to provide independent input and scientific assessment of the data provided during the subsequent investigation.

## INVESTIGATIONS

### Metals in fish tissues

#### *Introduction*

Metals are known toxicant in fishes, with their primary mode of toxicity at the gills. Evidence found in the literature demonstrates that toxicity in freshwater fish produces gross morphological damage to gills resulting in impaired gas exchange at the gills and eventually leading to suffocation. However, at more environmentally relevant concentrations of metals, the toxic mechanisms are usually through disruption of ion transport. Metals, including cadmium, copper, silver, zinc and others, tend to bind to the gill at very specific receptor sites. It appears that at concentrations at and below the 96-hour LC50s, metals tend to interfere with the ability of the organism to regulate ion transport across the gill (e.g., McDonald et al., 1989; Wood, 1992; Wood et al., 1996 and 1999). The physiological mechanisms of toxicity for most metals can generally be divided into two categories: monovalent metals ($Ag^{+}$, $Cu^{+}$) affecting $Na^{+}$ (and $Cl^{-}$) transport, and divalent metals (i.e. $Cd^{2+}$, $Zn^{2+}$) disrupting $Ca^{2+}$ metabolism. In turn, the relative toxicity of each of these metals is impacted greatly impacted by the water chemistry of the specific environment. Specifically, with regard to Lake Wabamun, high water pH and increase water hardness act to reduce or negate the impact of most metals on the fishes. Given that metals had been found in the water column during an investigation by Alberta Environment in March-April of 2002, I was asked to perform an independent analysis of metals in the gills of whitefish found both in the lake and fish that turned up on the inlet screens of the powerplant.

#### *Sample Preparation*

The gill samples were received frozen. They were thawed and sub-samples of filaments were removed for digestion in ultrapure nitric acid followed by heating to 80 degrees centrigrade. Samples were left overnight and allowed to settle. Supernatent was removed and diluted in ultrapure water before analysis by a graphite furnace atomic absorption spectroscopy (Varian, 10 µl injection volumes). Samples were run in random order against fresh standards prepared from certified samples. Results are reported as both nmol metal/g wet tissue and µg metal/g wet tissue.

#### *Statistical Analysis*

All results were test using a non-parametric Kruskal-Wallis test for significance. A value of $P<0.05$ was considered significant.

*Results*

Aluminium (Figure 1), Copper (Figure 2) and Cadmium (Figure 3) were measured in the gills of fish collected by electrofishing in Lake Wabamun and fish that turned up on the screen house at the Lake Wabamun powerplant. Additionally, we tested 6 rainbow trout obtained from the University of Alberta holding facility. These rainbow trout were used as an indicator of background metals levels under conditions that are know to be non-toxic for a sensitive species. Results of the metals analysis indicated that for all three metals measured, there were no significant differences between the treatment groups. In all cases, the levels of metals were found to be extremely low and well below levels that would be inducing toxicity in rainbow trout. No specific LC50's (an indicator of toxicity) could be found in the literature for Lake whitefish. However, given these low levels and with comparison to other fish species, I do not believe these levels would negatively impact the whitefish.

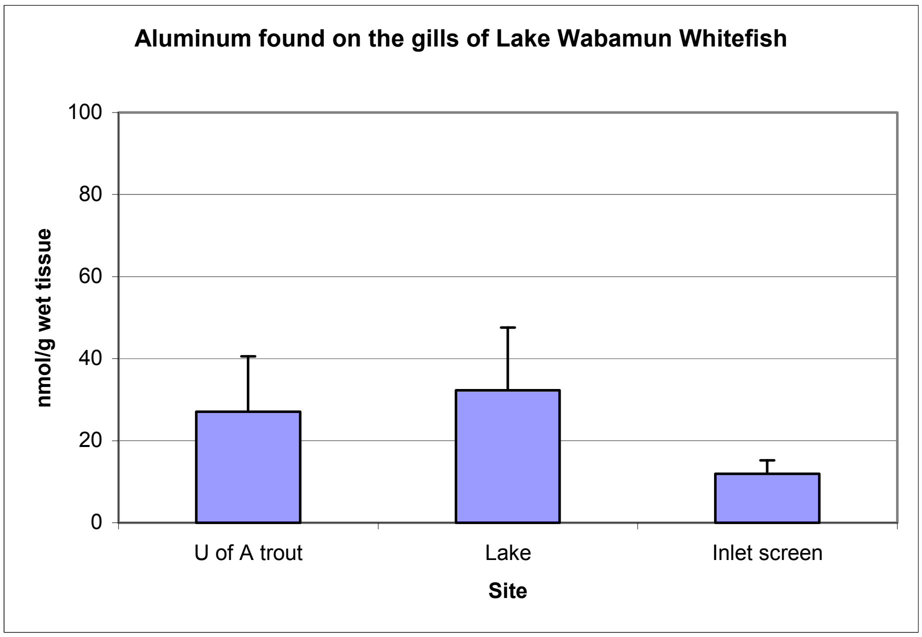



**Figure 1- Analysis of Aluminum on the gills of fish Collected at Lake Wabamun fish were collected from screen house and by electrofishing. N= 6 for each sample**

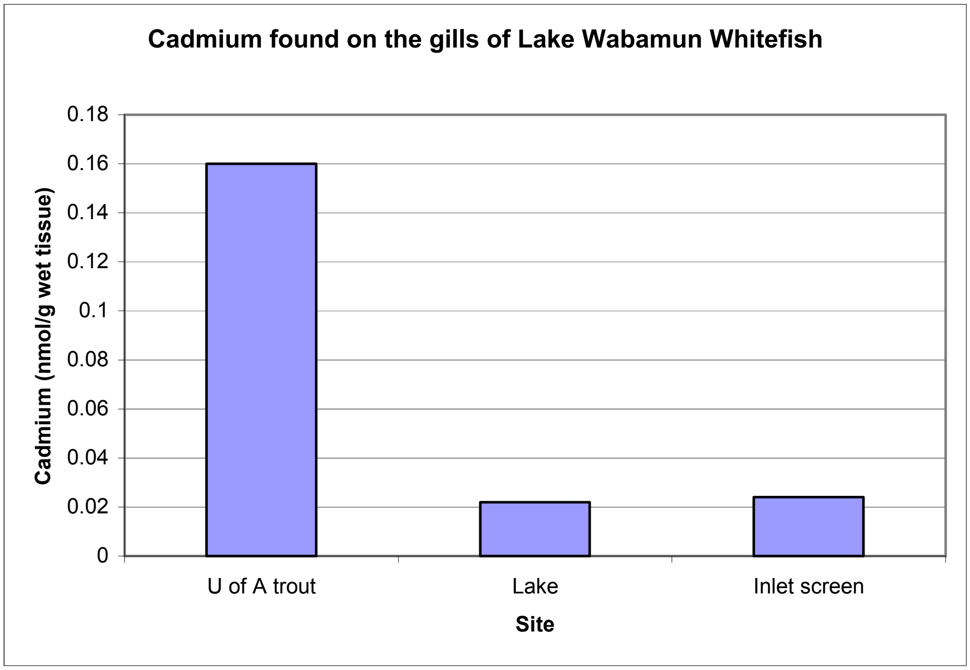



**Figure 2- Analysis of Cadmium on the gills of fish Collected at Lake Wabamun fish were collected from screen house and by electrofishing. N= 6 for each sample**

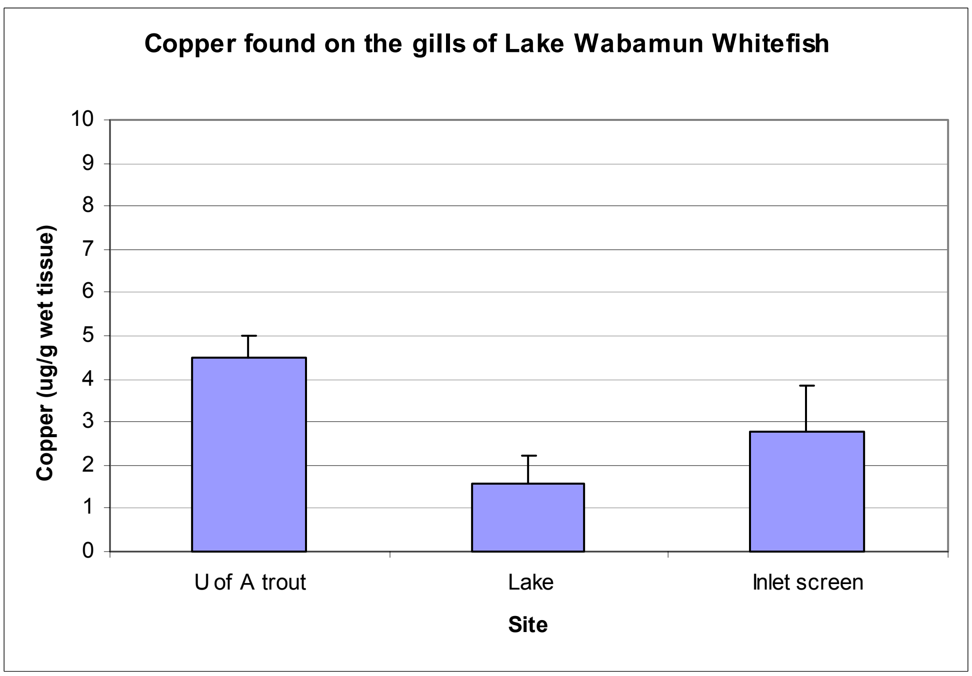



**Figure 3- Analysis of Copper on the gills of fish Collected at Lake Wabamun fish were collected from screen house and by electrofishing. N= 6 for each sample**

### *Discussion*

The lack of any appreciable accumulations of metals on the gills of whitefish suggest that metals are not the cause of toxicity in the fishes appearing on the inlet screens at the Lake Wabamun powerplant. These values are very low and would not be associated with fish toxicity. The values reported are very much in line with those reported by Golder and Associates (employed by Transalta) in their 2001 analysis of whitefish obtained from Lake Wabamun. The water quality in Lake Wabamun includes a very high ph (usually pH> 8.0) and a fairly high level of hardness in the water. These two environmental features will act to significantly reduce any impact of metals by reducing their toxicity. The toxic species of most metals is the free ionic form (e.g. Al3+, Cu2+) and these act by entering and preventing normal Na+ and Ca++ transport functions by the fish gill. However, at high pH and elevated hardness, these metals exist mostly as complexes of hydroxyls (e.g. Al(OH)3 and Cu(OH)2 which are non-toxic forms of the metals. It is my conclusion that the very low levels of metals present on the gills of Lake whitefish do not present a problem to the fish in that lake.

### Metals in Water column and sediments in Lake Wabamun

As part of the initial investigation, it was found by members of Alberta environment that there were elevated levels of metals found in the water and sediments in the region of the powerplant. Specifically, in areas near the outfall from the settling ponds, elevated levels of metals (Aluminium and Arsenic) were found in the water column while both Alberta Environment and Golder Associates also reported elevated levels in the sediment in this region. Aluminium is present as the third most abundant element in the earth's crust and therefore, measuring elevated levels of this metal should be interpreted with caution. There is a great deal of variability and naturally occurring aluminium is present everywhere. However elevated levels of other metals including Arsenic should be more thoroughly investigated. While the specific water chemistry in the lake renders these metals non-toxic, they are still present and will eventually find their way into the food chain as insects take up the metals, followed by consumption by fishes. The presence of elevated levels of Boron in these sediment samples suggested a human source rather than a natural one. Elevated levels of Boron, while non-toxic, are known indicators of coal mining effluents. It is likely that a long-term build-up in metals released from the outfall from the ash lagoon, even in low and non-toxic quantities, is causing an elevated level of certain metals in these areas. A more complete investigation of these problems is warranted. However, I have no reason to believe that these issues are at all related to the fish kills occurring at the plant. I think these two issues are entirely separate.

## Muscle and liver glycogen analysis, muscle lactate analysis

***Introduction.***

In fish, the maximal sustainable swimming speed is termed Ucrit. This value is obtained experimentally in fish by sequentially increasing swimming speed until the fish can no longer keep up and exhaustion is noted (Wilson and Egginton, 1994). Ucrit is a parameter that is affected greatly in each fish as there is both individual variability as well as other parameters that go into the critical swimming speed determined for each species of fish. In general, the parameters that most affect swimming speed are size (larger fish have higher swimming speeds), temperature (a decrease in temperature is directly related to a drop in Ucrit for most species) and fish health (Wilson and Egginton, 1994). For example, the presence of toxicants in fish is known to significantly reduce Ucrit in salmonids.

Glycogen is the primary energy store found in muscles and the liver. It is a large molecule made up of linked glucose molecules. During longer periods of exercise below Ucrit, metabolic fuel (ATP) demand is increased and glycogen is broken down into glucose by a process called glycolysis. ATP can be produced aerobically (using $O_2$) or anaerobically (without $O_2$) In general, animals do not use anaerobic glycolysis to any great extent as long as O2 supply meets the demand. Only at higher levels of exercise, such as short bursts of exercise above 100% Ucrit, the demand for metabolic fuel outstrips the capacity of the fish to deliver fuel and anaerobic glycolysis begins to increase supply of ATP to the cells. Above Ucrit, there is an increase in lactic acid production and this type of exercise is not sustainable for more than a few minutes. In general, fish can maintain values below 70% of Ucrit indefinitely, as long as adequate food and $O_2$ supply is maintained. Neither exercise below 70% Ucrit will not lower tissue glycogen levels nor will tissue lactate be elevated. At speeds greater the 70% Ucrit but below Ucrit, the fish can maintain these speeds over extended periods of time. However, these speeds are not sustainable indefinitely if food supply for replacement of metabolic fuel is lacking. Under these conditions, tissue glycogen stores will be depleted and the fish will eventually exhaust. However, since the exercise is below Ucrit and all exercise is aerobic, there will be no elevation in tissue lactate noted. At exercise levels above 100% Ucrit, noticeable increases in muscle lactate will be present in conjunction with a depletion of glycogen reserves in both the liver and the muscle tissue. We investigated whether muscle and liver glycogen reserves were lowered in fish obtained from the screens to determine if the fishes were exhaustively exercised prior to turning up on the screens at the Wabamun powerplant. Increases in tissue lactate will only be found if fish are held in an anaerobic state for extended periods of time. This may occur if fish are exercising above Ucrit or if fish are out of water for long periods of time ( >2 minutes) while on the inlet screen. At these times, the ability of the gill to uptake oxygen does not meet metabolic demand and anaerobic glycolysis will be initiated to meet these ATP demands. An elevation in tissue lactate would be noted in fish removed from water for extended periods of time.

***Samples:***

6 Lake Whitefish Collected at each of two sites:

a) Wabamun Power Plant Inlet Screens

b) Lake Wabamun (electrofishing)

***Methods:***

Sample for muscle and liver glycogen and muscle lactate were collected from 6 fish on the inlet screens. Fish tissues were processed as soon as possible after being found on the inlet screen. Similarly, 6 fish were collected on Lake Wabamun by electrofishing and fish were prepared for analysis as rapidly as possible  The collection of fish from both the inlet screens and by electrofishing was performed by employees of Golder Associates as directed. Liver and muscle samples were removed from the fish and rapidly frozen. The  tissue were then delivered to the University of Alberta for analysis and kept at –80 $^{o}$C until measurement could be completed.

For measurement of glycogen, samples (100-250 mg) were placed directly in 30% KOH and boiled to completely digest the tissue. Glycogen was then isolated by the method of Hassid and Abraham (1957) and measured as free glucose (Sigma glucose kit) after digestion with amylglucosidase. For measurement of tissue Lactate, tissue (~ 100-250 µg) were ground into a fine powder under liquid nitrogen using a mortar and pestle, then 6 volumes (x weight) of 8% perchloric acid was added and the slurry was homogenized with a tissue homogenizer. Samples were then centrifuged and the deproteinized supernatant analyzed by standard techniques (Sigma lactate kit). Samples are expressed as mM lactate/L.

***Statistical Analysis***

All results are tested for significant differences from each other using a two-tailed Student's t-test. A value of $P<0.05$ was used as the fiducial limit of significance.

*Results*

In fish collected by electrofishing, the liver glycogen content was found to be normal in these fishes, ~ 150 µg/gm wet tissue weight (Figure 4) compared to those measured in many other species. These levels are comparable to those found in many other fish species under normal non-exercising conditions (trout, Milligan et al, 2000). In fish collected from the inlet screens at Wabamun screen house, the levels of liver glycogen were very low, averaging ~ 50 µg/gm wet tissue weight (Figure 4). The values measured are significantly lower than those measured from fish electrofished in the lake. These levels are indicative of extreme exhaustive swimming for extended periods of time (>15 minutes of exhaustive exercise**).**

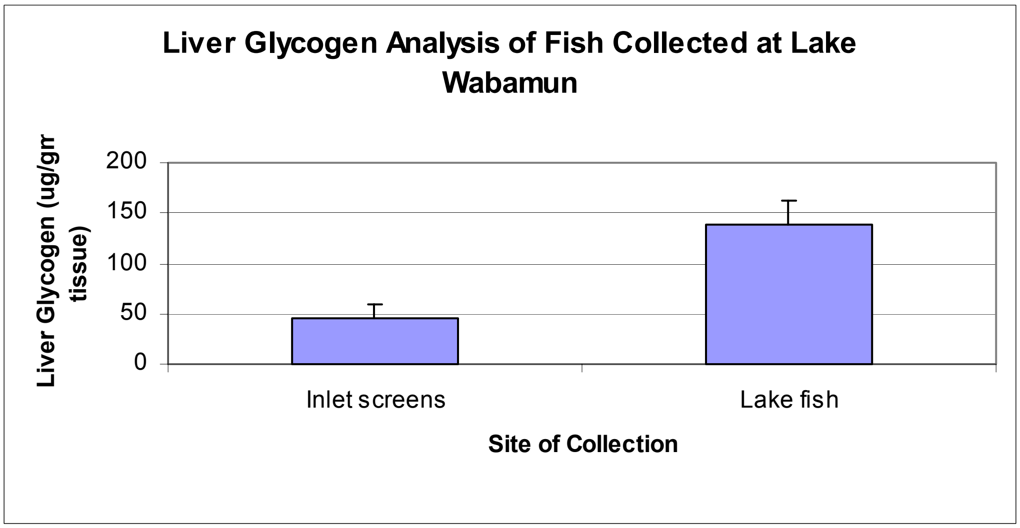



**Figure 1-Liver Glycogen Analysis of Fish Collected at Lake Wabamun fish were collected from screen house and by electrofishing. N= 6 for each sample**

Muscle glycogen content was also found to be normal in fishes electrofished from the lake at ~ 300 µg/gm wet tissue weight (Figure 5). These values are similar to those measured in other species. However, in fish collected from the inlet screens at Wabamun screen house, the levels of muscle glycogen were very low, averaging ~ 100 µg/gm wet tissue weight (Figure 5). The values measured are significantly lower than those measured from fish electrofished in the lake indicating similar results to those of Figure 4, (above) and suggesting exhaustive swimming for extended periods of time (>15 minutes of exhaustive exercise**)** prior to collection**.**

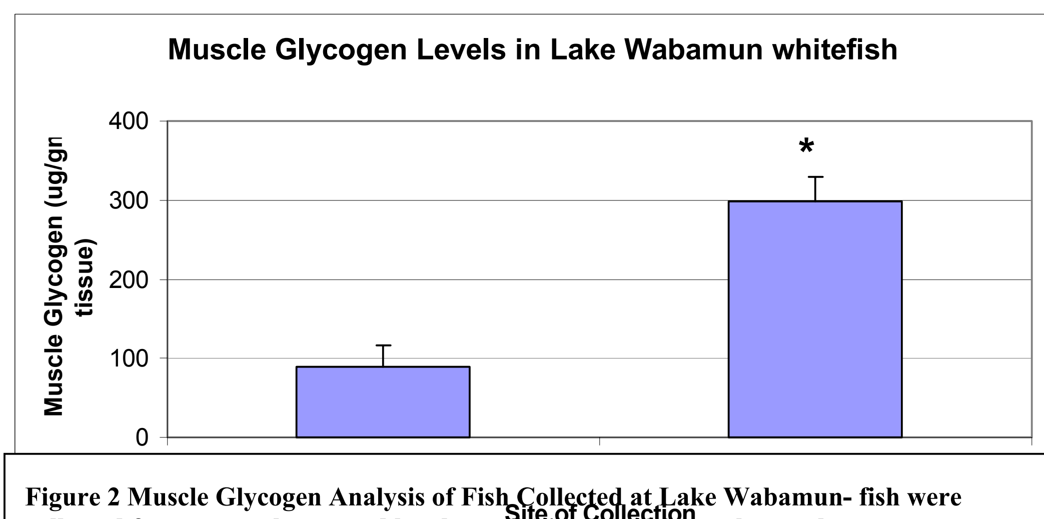



**Figure 2 Muscle Glycogen Analysis of Fish Collected at Lake Wabamun- fish were collected from screen house and by electrofishing. N= 6 for each sample**

Muscle lactate was found to be low in both fish collected by electrofishing and in fish collected on the inlet screens at the Wabamun powerplant (Figure 6). Values of muscle lactate are usually in the range of 2-5 mmol/L are typical of resting fish or fish exercised below their swimming speed (Ucrit) (Taylor et al, 1996). These values were not found to be statistically different from each other. Additionally, these data also suggest that the fish collected at the screens were collected rapidly enough so that the fish did not experience significant hypoxia prior to collection.

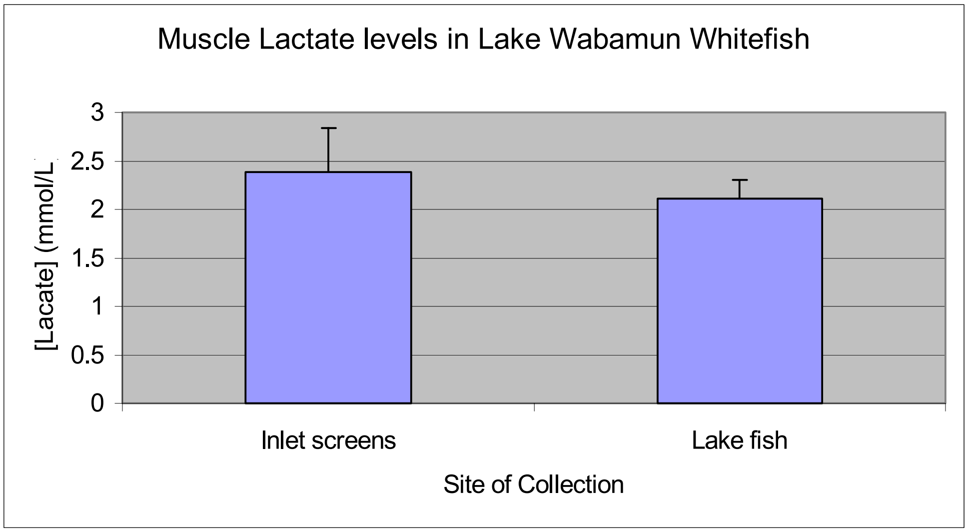



**Figure 3: Muscle Lactate of Fish Collected at Lake Wabamun- fish were collected from Inlet screen house and by electrofishing in the lake as described. N= 6 for each sample**

***Discussion***

The data collected indicate that fish collected at the Wabamun screen house have been exercised exhaustively over longer periods of time. The tissue lactate levels measured previously demonstrated a slight but not great increase in tissue lactate levels found in fish collected at the screen house. The small increase in lactate was more indicative of a short-term aerial exposure rather than exercise above their critical swimming speeds (Ucrit). However, we have found that tissue glycogen (both liver and white muscle) was significantly depressed in fish found on the Wabamun screen house when compared to those found by electrofishing in the lake. Taken together, these data indicate that the fish are swimming at fairly high levels that cannot be sustained over longer periods of time given the fishes overall fitness. This likely resulted in exhaustion and ended with the fish turning up on the screens.

Overall Discussion

It is known that most fish species demonstrate a reduction in Ucrit with a drop in water temperature. This is due primarily to the reduction in efficiency of many enzymes at lower temperatures. The appearance of whitefish on the screens at the Wabamun power plant (late October) coincides with two major events in the lake. The first is the spawning time for whitefish and the second is a decrease in water temperature.

Whitefish normally are fall spawners and spawn in bays in the lake. If there is a drop in the condition of the lake and fish are migrating looking for adequate spawning habitat, then the only outlet from the lake is the inlet canal leading to the powerplant. At the same time, it is know that a drop in water temperature is associated with a significant reduction in swimming performance. It is likely that the colder temperature results in a reduced swimming performance and weak fishes may be turning up on the inlet screens.

These two factors may combine under these circumstances to put the whitefish in the inlet channel while the drop in temperature may be related to a decrease swimming performance. We know from analysis of stomach contents of the whitefish found on the inlet screens (reported by TransAlta) that there is little food present in stomachs of the fish caught on the screens. This may indicated a reduced food resource present in the lake itself. Additional data provided by Alberta environment including historically low yields for whitefish, additionally, the condition factor (length: girth ratio) for whitefish caught in the lake is significantly reduced in recent years. There is also a general reduction in zooplankton biomass found in the lake in recent years point. These indicators point to significant long-term ecological problems with the lake and I believe this is a major contributing factor leading to the Wabamun TransAlta powerplant fish deaths. The factors resulting in this reduced fitness of the fish are as yet unknown and should be further investigated. Cyclic variations in lake ecological parameters such as zooplankton, fish fitness and invertebrate populations are known to occur. However, this lake is also impacted heavily by many anthropomorphic factors including historically low water levels, increased recreational use and housing development and the continued impact of heavy industry. Any or all these factors may contribute to reduce the overall fitness of the lake to sustain historical fish numbers. With a poor condition factor in the lake whitefish, they are likely simply seeking new and better habitats. By entering the inlet channel, the fish are naïve to the presence of the inlet screens and are caught on the screens. Mark re-capture experiments with Pike suggest that one aware, the pike can leave the inlet canal and re-enter the lake.

## Information transfer

While many studies have been performed on the lake and we are aware of much of the lake and it characteristics through these previous studies, it was difficult at times to get information from various groups. It would have been nice to have rapid access to a library of information regarding the lake. Lake Wabamun is one of the more heavily impacted lakes in Alberta. Access to historical catch records, invertebrate productivity, water chemistry, etc was difficult or impossible to obtain. While requested, I have never received information regarding the invertebrate productivity or community structure in the lake. A simple change in the invertebrate species distribution from a preferred food species to another may be a reason for the appearance of whitefish in the inlet canal. With this lake being so important economically, socially and politically, I think there should be a regular searchable library of documentation to both allow for historical records to be accessed and to prevent repetition of future studies.

## References Cited

**Hassid, WZ and Abraham, S** (1957) Chemical procedures for analysis of polysaccharides. Methods in Enzymology, New York, Academic Press 3: 34-37.

**Kieffer, JD, Alsop, D, and Wood CM** (1998) A respirometric analysis of fuel use during aerobic swimming at different temperatures in rainbow trout (*Oncorhynchus mykiss*) Journal of Experimental Biology 201: 3123-3133.

**Milligan CL, Hooke, CB and Johnston, C**. (2000) Sustained swimming speed at low velocity following a bout of exhaustive exercise enhances metabolic recovery in rainbow trout. Journal of Experimental Biology, 203: 921-926.

**Taylor, SE, Egginton, S, and Taylor, EW** (1996) Seasonal temperature acclimatization of rainbow trout: cardiovascular and morphometric influences on maximal sustainable exercise level. Journal of Experimental Biology 199: 835-845.

**Wilson, RW and Egginton S** (1994) Assessment of maximum sustainable swimming performance in rainbow trout (*Oncorhynchus mykiss*) 192: 299-305.

# Appendix 2

## Outline of Further Water Quality and Sediment Quality Sampling Programs On Wabamun Lake Alberta Environment

# Outline of Further Alberta Environment Water Quality and Sediment Quality Sampling Programs On Wabamun Lake

## 1. Sediment Chemistry

Sediment sampling has been carried out by various researchers in Wabamun Lake to determine contaminant levels (metals and trace organic compounds). The interpretation of the data requires a better understanding of the various types of sediments across the lake; data from other lakes in the province are needed to place Wabamun Lake results into context.

### *1.1 Sediment Survey*

To characterize the distribution of sediments across the lake with respect to particle size (% sand, clay, loam), total organic content (TOC). This information is critical because it will allow standardizing contaminant levels.

Sampling based on grid in deeper areas, transects in littoral zone and near point sources.

- Ekman dredges, top 4 cm.
- QA/QC: triplicates at three sites.

### *1.2 Sediment Chemistry Wabamun Lake*

To characterize the distribution of contaminants (metals and trace organics) in Wabamun Lake sediments.

- Grid sampling (random stratified); some transects near point sources and littoral zone.
- Composite Ekman dredges, top 4cm
- Metal Analysis (29 metals ICP-MS+ CV-AAS Hg) at selected sites
- Priority Pollutants (EPP, VPP, PAH) at selected sites
- QA/QC: triplicates at three sites.

### *1.3 Sediment Chemistry in Other Lakes*

Following lakes would provide a general indication of contaminant levels in other Alberta lakes that have similar features to Wabamun Lake: Pigeon, Gull, Sylvan, Isle, St Anne, Wizard, Bonnie and Amisk.

- Three composite samples from the profundal area of each lake
- Composite Ekman dredges, top 4cm
- TOC and particle size distribution.
- Metal Analysis (29 metals ICP-MS+ CV-AAS Hg)
- Priority Pollutants (EPP, VPP, PAH)
- QA/QC: one set of triplicate samples at one lake

### *1.4 Sediment Chemistry In Other Lakes Based On 1990's Freeze-Dried Samples*

Archived, freeze-dried sediments are available for about 25 Alberta lakes. A metals analysis of these sediments would provide a broader perspective of variability in metal levels in surficial (top 5 cm) sediments in Alberta lakes.

- These archived sediments are not suitable for the analysis of Hg, As, Se or trace organic compounds.
- Particle size and TOC data are available.

## 2. Disinfection By-Product (DBP) Survey

The water treatment process at the Wabamun Water Treatment Plant comprises chlorination and ozonation. These processes generate by-products such as trihalomethanes (THMs). THMs, more specifically chloroform, have been detected in the outlet canal where treated water is discharged. Ozonation by-products have not been analyzed in the canal at this time. Precursors of ozonation and chlorination by-products are TOC and bromide. There is a need to document DBP and their precursors in the lake.

- THMs, Halo-aceto-nitriles. halo-ketones, chloropicrin, halogenated VOCs, chloramines, bromate, chlorite/chlorate, Halo-acetic acids, aldehydes, and chlorinated phenols
- Sampling carried out this week (8 samples, 7 sites).

## 3. Spatial Variability In Lake Water Quality

The current water quality monitoring program is suitable to track whole lake changes in water quality, but it does not depict possible differences in east and west basin water quality or provide information on water quality in various bays and along the littoral zone.

- Grid pattern sampling
- Temperature, pH, conductivity and DO (surface, middle, bottom) to document horizontal and vertical variability
- Euphotic composites: TP, chl-a, sulphate
- Euphotic composites: major ions (selected sites)
- Bottom samples for metals (29), sulphide, ultra-trace Hg (selected sites)
- Surface grab samples for pesticide scan (selected sites)
- QA/QC:
    - All chemistry except Hg: triplicates at three sites; three field blanks over sampling period.
    - Hg: On three different days: Three field blanks poured off in field<br>Three open trip blanks<br>Three closed trip blanks<br>Triplicates at three sites

## 4. Sediment Toxicity Testing

Sediment Health Assessments are currently being carried out on six samples taken from Wabamun Lake to determine if toxicity is an issue. Formal toxicity testing, following Environment Canada protocols, will be required to confirm the presence of toxicity in the sediments. Toxicity Identification Evaluation (TIE) may be needed to identify the toxic compound(s) in the sediments.

***Depending on outcome of initial testing, further work may be required.***

## 5. Invertebrate Impact Assessment Study

Aquatic invertebrate distribution (numbers and species composition) can serve as an indicator of the degree of impact on aquatic biota. Depending on the outcome of the sediment toxicity testing such impact assessment may be required.

- Ideally, samples from a control site (un-impacted), in the greatest impact zone, and at increasing distances from the impact source (e.g.," near- field": 50 m and "far field": 100 to 200 m from impact source) are needed.
- Replicate samples are needed from each site to capture local spatial variability (estimated 10).