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REPORT ON

WINTER AQUATICS SURVEYS - STEEPBANK RIVER, SHIPYARD LAKE, AND LEASES 19, 25 AND 29

Submitted to:

Suncor Energy Inc., Oil Sands
Fort McMurray, AB

DISTRIBUTION:

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ABSTRACT

A winter fisheries and water quality study was conducted for Suncor Energy Inc. as follow-up to the Steepbank Mine Environmental Impact Assessment (EIA). Sampling was conducted in waterbodies within the approved Steepbank Mine (Leases 19, 25 and 97) and in an adjacent lease (Lease 29). Water quality sampling, fish inventories and fish habitat assessments were done in Shipyard Lake, Saline Lake and Steepbank River. Additionally, fish habitat assessments were conducted for eight small unnamed Steepbank River tributaries and the upper reaches of Jackpine Creek. Most water quality parameters in the Steepbank River were within historical ranges. In Shipyard Lake, water quality varies considerably with season. Saline Lake contained very high ion, nutrient, metal, TSS and TDS concentrations. No fish were captured in Steepbank River or Shipyard Lake. Two of the pools sampled in the Steepbank River were of sufficient depth and adequate oxygen concentrations to provide overwintering habitat for fish. Conditions in Shipyard Lake, Saline Lake and an unnamed pond provided relatively poor overwintering habitat for fish. Shallow depths and low water flow at small Steepbank River tributaries and the upper reaches of Jackpine Creek would limit their use as fish overwintering habitats.

Key Words: Steepbank River, Saline Lake, Shipyard Lake, Jackpine Creek, water quality, overwintering, fisheries

ACKNOWLEDGEMENTS

This report was prepared for Suncor Energy Inc. (Suncor) by Golder Associates Ltd. (Golder). Martin Holysh was the Suncor project manager. Derek Melton was the Golder project manager and Marie Lagimodiere was the aquatics task leader.

Chris Bjornson led the field work and was assisted by Chris Briggs, Tony Calverley and Ken Allen. The report was prepared by Celine Larose and J.P. Bechtold. Dave Fernet, John Gulley and Marie Lagimodiere reviewed the report. Maureen Myers formatted the report.

EXECUTIVE SUMMARY

Suncor is currently conducting follow-up studies to the Steepbank Mine Environmental Impact Assessment (EIA) and preliminary studies for future expansion options. As part of this process, a winter environmental baseline program was conducted to provide current winter information on aquatic resources in areas of the Steepbank Mine (Leases 19, 25 and 97) and in an adjacent lease (Lease 29).

The winter aquatics program included water quality and fish overwintering surveys. Water quality sampling, fish inventories and fish habitat assessments were done in Shipyard and Saline Lakes as well as in the Steepbank River. Additionally, fish habitat assessments were done for eight small unnamed Steepbank River tributaries and the upper reaches of Jackpine Creek.

Most water quality parameters in the Steepbank River were within historical ranges. In Shipyard Lake, water quality varies considerably with season. Major ions, nutrients and most metal concentrations were higher in winter than previously observed in spring and summer. Saline Lake contained very high ion, nutrient, metal, TSS and TDS concentrations in addition to large amounts of biodegradable organic matter and high conductivity, alkalinity and total hardness measurements.

Shallow depths and low water flow at most of the sampling sites limit their use as fish overwintering habitats. One sampling site at Jackpine Creek could provide suitable habitat for overwintering for young-of-the-year fish species but is probably too shallow for large sportfish. Two of the pools sampled in the Steepbank River were of sufficient depth and had oxygen concentrations that were high enough to provide overwintering habitat. However, no fish were captured at these sites. Water pools sampled in Shipyard Lake, Saline Lake and an unnamed pond provide relatively poor overwintering habitats for most sportfish species.

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1.0 INTRODUCTION

Suncor Energy Inc. (Suncor) recently received approval from Alberta Environmental Protection (AEP) and Alberta Energy and Utilities Board (EUB) to develop the Steepbank Mine. The Steepbank Mine is an oil sands mine located within Leases 25, 19 and 97 on the east side of the Athabasca River, about 50 km north of Fort McMurray, Alberta. It is east of Suncor's existing mine facility on Lease 86/17, situated on the opposite side of the Athabasca River.

The Steepbank Mine Environmental Impact Assessment (EIA), conducted in 1996, included a comprehensive baseline study of the aquatic environment for the Athabasca and Steepbank Rivers (Golder 1996a), an analysis of aquatic issues (Golder 1996b, Golder 1996c) and supplementary aquatic studies (Golder 1996d, Golder 1996e). Suncor is currently conducting follow-up studies to the Steepbank Mine EIA to fill in data gaps and supplement existing information. As part of this process a winter environmental baseline program was initiated which included wildlife surveys and aquatic studies. This document reports on the aquatic studies.

The winter aquatics program included water quality and fish overwintering surveys for waterbodies in Lease 97, 19 and 25 and in a lease just north of the Steepbank Mine (Lease 29). The following waterbodies were surveyed: Steepbank River, eight small unnamed Steepbank River tributaries, Shipyard Lake, Saline Lake and Jackpine Creek.

1.1 Study Area

Suncor's approved Steepbank Mine includes areas within Leases 19, 25 and 97 on the east side of the Athabasca River (Figure 1-1). Waterbodies in the study area include the Athabasca River, some of its tributaries, such as Wood, Leggett and McLean Creeks, the Steepbank River and the eight tributaries that flow into it, Shipyard Lake and some unnamed ponds and wetlands. Waterbodies in the lease area north of the Steepbank Mine include Saline Lake, a small unnamed pond, and the upper reaches of Jackpine Creek.

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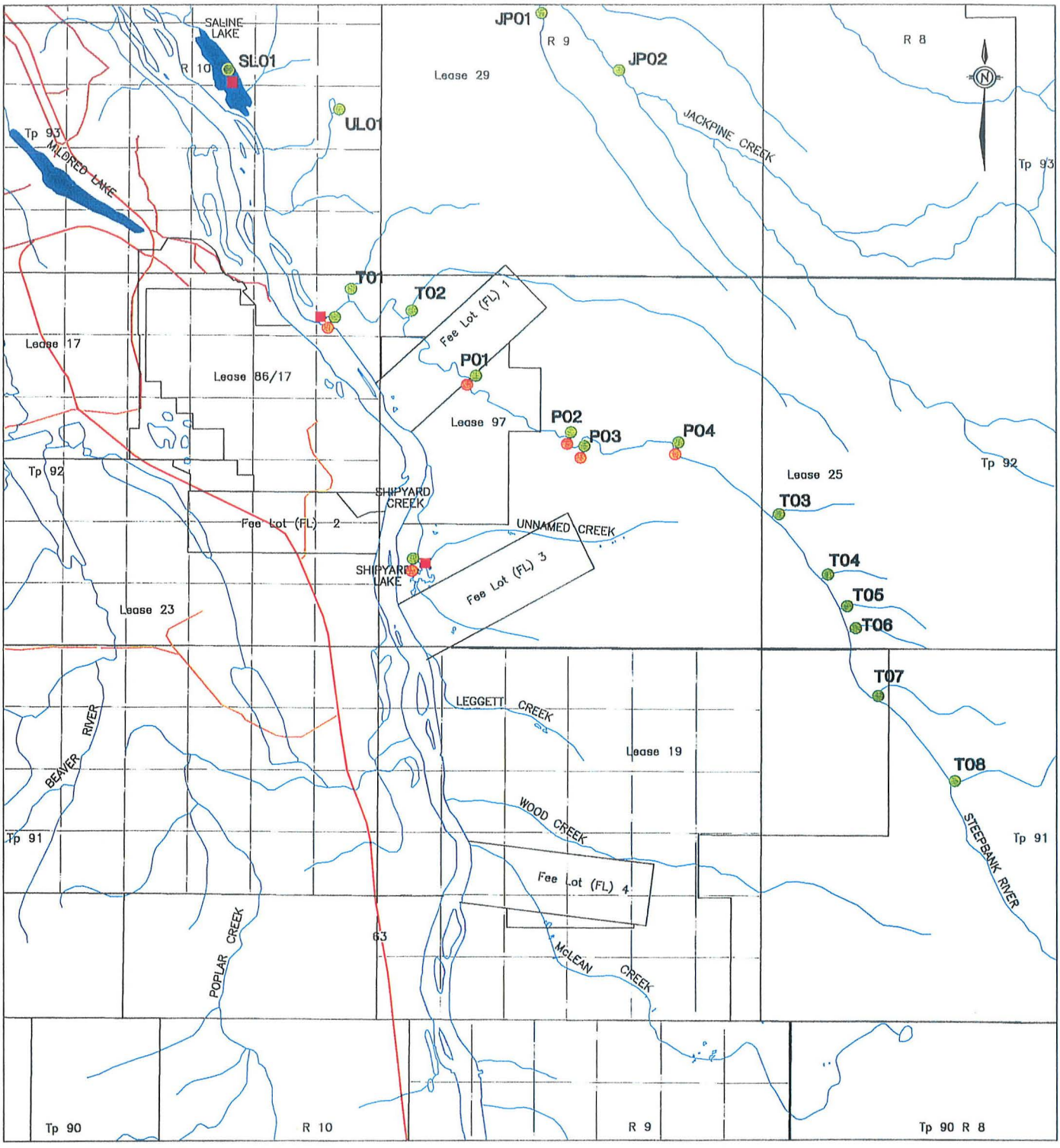

LEGEND

- WATER SAMPLING SITE
- FISH INVENTORY SITE
- FISH HABITAT SITE

0 1 2 3 4 5km

SCALE 1:150,000

SUNCOR ENERGY

Project Millennium
Taking Suncor into the 21st Century

LOCAL AQUATICS STUDY AREA AND SAMPLING SITES, WINTER BASELINE STUDY

REFERENCE

DIGITAL DATA SETS 74D AND 74E RESOURCE DATA DIVISION, ALBERTA ENVIRONMENTAL PROTECTION, 1997.
MINE PLAN SUPPLIED BY SUNCOR ENERGY, JAN 1998.
DATUM IS IN NAD83 UTM

10 Mar. 1998	Figure 1–1	DRAWN BY: RFM

1.2 Objectives

The objectives of this study were to provide current winter baseline information on the potential of different sections of waterbodies to provide overwintering habitat for fish and on the water quality of these waterbodies. The following activities were performed to fulfill these objectives:

- documentation of fish habitat and potential overwintering areas, water quality parameters and fish communities present in Shipyard Lake, Saline Lake and Steepbank River (Figure 1-1); and

- documentation of fish habitat and water quality (if flow was present) in eight small unnamed Steepbank River tributaries, the upper reaches of Jackpine Creek, Saline Creek and an unnamed pond located east of Saline Lake.

2.0 METHODS

Fish inventories, water quality sampling and habitat measurements were conducted in the winter from 25 to 28 February, 1997. Sampling sites are shown in Figure 1-1 and the type of sampling that was done at each site is shown in Table 2-1. A GeoExplorer Geographic Positioning System (GPS) unit was used to record the position of all sampling locations.

2.1 Water Quality

Field measurements were taken at 13 of the 20 sample sites (Table 2-1) and consisted of dissolved oxygen (DO), measured using a Hanna DO kit, pH (measured with an Omega pH meter), conductivity and temperature. A dissolved oxygen profile was also generated for Shipyard Lake. The remaining seven sample sites located at the mouth of small Steepbank River tributaries were dry (Table 2-1).

Water samples were collected from Saline Lake, the mouth of the Steepbank River and three locations in Shipyard Lake. As a quality control measure, two additional replicate samples were taken from the mouth of the Steepbank River. Multiple samples were collected to assess within-site variability. A field blank was also prepared while sampling at the mouth of the Steepbank River by filling a full set of sample bottles with laboratory-grade de-ionized water.

All eight samples were appropriately preserved following Golder Technical Procedure 8.3-1 (Appendix I) and shipped to Enviro-Test Laboratories (ETL) in Edmonton for analysis. Samples were analyzed for conventional parameters (including total dissolved solids, major ions and various nutrients), total and dissolved metals, polycyclic aromatic hydrocarbons (PAHs), alkylated PAHs, biological oxygen demand (BOD) and recoverable hydrocarbons.

2.2 Fish Habitat

Habitat measurements at each site consisted of ice thickness, water depth and water velocity. Velocity was measured with a Marsh-McBirney velocity meter and a top-setting wading rod. Fish habitat measurements in small tributaries to the Steepbank River consisted of determining if flow was present. Discharge measurements were made at the mouth of the Steepbank River and all tributaries that contained water following Golder Technical Procedure 8.24-0 (Appendix II).

TABLE 2-1
SAMPLING STATIONS FOR WINTER AQUATICS BASELINE STUDY

Watercourse	Site	UTM E	UTM N	Site Locations	Fish Inventory	Habitat	Water Quality
Steepbank River	Mouth	471040	6319623	200 m upstream from confluence		x	F + L
	P01	474521	6318057	pool 7.8 km from mouth (2.0 m deep, Fall 1995)	SL	x	F
	P02	477159	6316492	pool 12.8 km from mouth (3.3 m deep, Fall 1995)	GN, MT, SL	x	F
	P03	479917	6316219	pool 16.6 km from mouth (2.5 m deep, Fall 1995)	GN, MT, SL	x	F
	P04	477509	6316129	pool 13.4 km from mouth (2.5 m deep, Fall 1995)		x	F
Tributaries of the Steepbank River	T01	471175	6320220	First trib u/s from mouth on N. side		x	No Water
	T02	473246	6319750	Second trib u/s from mouth on N. side		x	No Water
	T03	482011	6314785	Third trib u/s from mouth on N. side		x	No Water
	T04	482418	6314437	Fourth trib u/s from mouth on N. side		x	No Water
	T05	483747	6312675	Fifth trib u/s from mouth on N. side		x	No Water
	T06	484243	6312003	Sixth trib u/s from mouth on N. side		x	No Water
	T07	484501	6311302	Seventh trib u/s from mouth on N. side		x	No Water
	T08	485156	6309583	Eighth trib u/s from mouth on N. side		x	F
Shipyard Lake	AW020	473601	6312861	Same site sampled in 1996 (south)	GN, MT, SL	x	F + L
	AW021	473480	6313044	Same site sampled in 1996 (middle)		x	F + L
	AW022	473405	6312835	Same site sampled in 1996 (north)		x	F + L
Saline Lake	SL01	467863	6326884	South end of lake		x	F + L
Unnamed Pond	UL01	471214	6325173	Middle of lake		x	F
Jackpine Creek	JP01	476527	6327757	3 km south of Lease 29 boundary		x	F
	JP02	478358	632614	6 km south of Lease 29 boundary		x	F

Fish Capture Methods
GN = gill net
MT = minnow trap
SL = set line

Water Quality Samples
F = field parameters
L = samples collected for detailed laboratory analyses
u/s = upstream
trib = tributary

2.3 Fish Inventory

Fish inventories were conducted using gill nets, Gee minnow traps and set lines under the ice. Gill nets were set in areas where water depth was 1 m or greater. A 10-m gill net with a 5-cm stretch mesh was used in the Steepbank River. A 15-m gill net with a 6.25-cm stretch mesh was used in Shipyard Lake. Minnow traps and set lines were placed in the vicinity of the gill net.

Gill nets were set by first drilling a hole in the ice with a gas-powered ice auger and determining if there was sufficient water depth to set the net. Once a suitable location was found, a line of holes approximately 1 m apart the length of the net was drilled through the ice. The net was then set under the ice. Minnow traps and set lines were set through additional holes in the ice in the vicinity of the gill net. All fish inventories were conducted following Golder Technical Procedure 8.1-3 (Appendix III).

Steepbank River and Tributaries

Habitat maps created during 1995 baseline sampling for the Steepbank EIA (Golder 1996a) were used to select the most appropriate sampling location for the fish inventory work in the Steepbank River. These maps were used to locate one deep (>2.0 m) pool in each of three established study sections, (lower, middle and upper sites) where gillnets, set lines and minnow traps were set. Water quality samples were collected from the mouth of the Steepbank River. Tributaries of the Steepbank River to be sampled were identified from 1:50,000 topographic maps.

Shipyard Lake

Habitat maps of Shipyard Lake were used to determine the deepest location during the ice-free period, with the assumption that these would be the deepest locations in the winter and hence potential overwintering areas. Water samples were collected from the same three sampling stations as in the 1996 studies (Golder 1996d).

Saline Lake

No fisheries inventory of Saline Lake was conducted since water depths were too shallow to set gill nets.

3.0 RESULTS AND DISCUSSION

3.1 Water Quality

The following section summarizes the water quality sampling results. Site-specific data were compared with results from other sites and with historical records, if available. Similarities and notable differences are highlighted, but data interpretation is minimal.

Steepbank River

Historical records describing winter water quality at the mouth of the Steepbank River matched reasonably well with current data (NAQUADAT 1980-1989, Noton and Shaw 1989). Notable exceptions included higher levels of total aluminum and zinc for samples collected in this study, compared with earlier data (NAQUADAT 1980-1989, Noton and Shaw 1989 - see Table 3-1). Dissolved organic carbon (DOC) content and total molybdenum, vanadium and cobalt concentrations observed in the winter 1997 samples were lower than previously documented (NAQUADAT 1980-1989, Noton and Shaw 1989 - see Table 3-1). Aside from these differences, winter water quality observed at the mouth of the Steepbank River was similar to past findings.

Shipyard Lake

Chemical concentrations did not vary greatly among the three sample sites in Shipyard Lake (Table 3-2). There were a few exceptions: the sample from the south sample station (AW020) contained higher levels of chloride, dissolved iron and dissolved manganese than samples from the other sample sites (Table 3-2). Station AW020 also tended to be warmer and contained less total aluminum than the middle (AW021) and north (AW022) sites, which is likely an indication of groundwater entering the lake.

TABLE 3-1
WATER QUALITY FOR THE STEEPBANK RIVER
(Page 1 of 3)

Parameter	Units	Steepbank River								Field Blank
		Golder 1997					Historical*			
		Replicate number			Overall		Winter			
		1	2	3	mean	C.V.**	mean	range	n	
Field measurements										
Temperature	°C	-	-	-	**0.5**	-	0.1	-0.2 - 0.3	2	-
pH		-	-	-	**8.4**	-	-	-	-	-
Conductance (EC)	µS/cm	-	-	-	**548**	-	-	-	-	-
Dissolved Oxygen	mg/L	-	-	-	**13.7**	-	13.4	13.1 - 13.8	5	-
Conventional Parameters and Major Ions										
Bicarbonate (HCO_3)	mg/L	374	370	371	**372**	1%	389	357 - 422	3	**<5**
Calcium	mg/L	62	61	60	**61**	2%	67	62 - 76	3	**<0.5**
Carbonate (CO_3)	mg/L	<5	<5	<5	**<5**	-	-	-	-	**<5**
Chloride	mg/L	7.4	7.4	7.7	**7.5**	2%	6.8	6.5 - 7.8	5	**<0.5**
Color, True	T.C.U.	30	35	35	**33**	9%	60	42 - 95	3	**<3**
Conductance (EC)	uS/cm	588	586	588	**587**	0%	495	474 - 704	7	**5**
Dissolved Organic Carbon	mg/L	9	9	9	**9**	0%	13	11.5 - 13.1	5	**<1**
Hardness	mg/L	236	229	227	**231**	2%	259	243 - 289	3	**<1**
Magnesium	mg/L	19.4	18.7	18.7	**18.9**	2%	22	20 - 24	3	**<0.1**
pH in Water	pH	7.9	7.9	7.9	**7.9**	0%	7.9	7.4 - 8.3	7	**5.8**
Potassium	mg/L	2.0	2.1	2.0	**2.0**	3%	2.1	1.8 - 2.3	3	**<0.1**
Sodium	mg/L	40.0	41.0	40.0	**40.3**	1%	43	42 - 52	5	**<1**
Sulphate	mg/L	14.2	13.7	13.8	**13.9**	2%	12	10 - 15.8	5	**<0.5**
Sulphide	mg/L	<0.002	<0.002	<0.002	**<0.002**	-	< 0.01	-	2	**<0.002**
Total Alkalinity	mg/L	306	303	304	**304**	1%	319	293 - 347	3	**<5**
Total Dissolved Solids	mg/L	330	360	350	**347**	4%	351	327 - 383	3	**<10**
Total Organic Carbon	mg/L	13	12	15	**13**	11%	-	-	-	**1**
Total Suspended Solids	mg/L	3	2	4	**3**	33%	4	3 - 6	4	**2**
Nutrients										
Ammonia-N	mg/L	<0.05	<0.05	<0.05	**<0.05**	-	0.05	0.04 - 0.2	5	**0.2**
Nitrate+Nitrite-N	mg/L	0.33	0.32	0.45	**0.37**	20%	0.30	0.24 - 0.35	5	**<0.05**
Phosphorus, Total	mg/L	0.05	0.05	0.04	**0.05**	12%	0.07	0.04 - 0.08	5	**<0.01**
Phosphorus, Total Dissolved	mg/L	<0.02	<0.02	<0.02	**<0.02**	-	0.01	-	1	**<0.02**
Total Kjeldahl Nitrogen	mg/L	0.9	0.9	0.8	**0.9**	7%	0.7	0.6 - 1.6	5	**0.5**
Metals (total)										
Aluminum (Al)	mg/L	0.14	0.13	0.12	**0.13**	9%	0.05	0.01 - 0.08	3	**0.01**
Antimony (Sb)	mg/L	0.0005	<0.0004	<0.0004	**0.0004**	13%	-	-	-	**<0.0004**

TABLE 3-1
WATER QUALITY FOR THE STEEPBANK RIVER
(Page 2 of 3)

Parameter	Units	Steepbank River								Field Blank
		Golder 1997					Historical*			
		Replicate number			Overall		Winter			
		1	2	3	mean	C.V.**	mean	range	n	
Arsenic (As)	mg/L	0.0005	0.0004	<0.0004	**0.0004**	13%	0.0006	-	1	**<0.0004**
Barium (Ba)	mg/L	0.08	0.08	0.08	**0.08**	1%	0.07	-	1	**0.0004**
Beryllium (Be)	mg/L	<0.001	<0.001	<0.001	**<0.001**	-	< 0.001	-	1	**<0.001**
Boron (B)	mg/L	0.28	0.28	0.28	**0.28**	0%	-	-	-	**0.004**
Cadmium (Cd)	mg/L	<0.0002	<0.0002	<0.0002	**<0.0002**	-	0.002	-	1	**<0.0002**
Calcium (Ca)	mg/L	64	63	62	**63**	2%	-	-	-	**<0.05**
Chromium (Cr)	mg/L	<0.0004	<0.0004	0.0058	**0.0022**	142%	0.005	-	1	**<0.0004**
Cobalt (Co)	mg/L	<0.0005	<0.0005	<0.0005	**<0.0005**	-	0.001	-	1	**<0.0005**
Copper (Cu)	mg/L	0.0012	0.0016	0.0018	**0.0015**	20%	0.001	0.001 - 0.016	3	**0.004**
Iron (Fe)	mg/L	1.1	1.2	1.1	**1.1**	6%	0.8	0.7 - 0.9	3	**<0.01**
Lead (Pb)	mg/L	0.0103	0.0033	0.0009	**0.0048**	101%	0.008	0.005 - 0.011	2	**0.0006**
Lithium (Li)	mg/L	0.03	0.03	0.03	**0.03**	2%	-	-	-	**<0.003**
Magnesium (Mg)	mg/L	21.0	20.7	20.8	**20.8**	1%	-	-	-	**0.01**
Manganese (Mn)	mg/L	0.02	0.02	0.02	**0.02**	1%	0.028	0.018 - 0.034	3	**0.001**
Mercury, (Hg)	mg/L	<0.0002	<0.0002	<0.0002	**<0.0002**	-	0.0001	-	3	**<0.0002**
Molybdenum (Mo)	mg/L	0.0006	0.0005	0.0006	**0.0006**	10%	0.003	-	1	**<0.0001**
Nickel (Ni)	mg/L	0.001	0.002	0.002	**0.002**	10%	0.002	0.001 - 0.005	3	**0.001**
Potassium (K)	mg/L	2.0	2.0	2.0	**2.0**	2%	-	-	-	**0.1**
Selenium (Se)	mg/L	<0.0004	<0.0004	<0.0004	**<0.0004**	-	0.0001	-	1	**<0.0004**
Silicon (Si)	mg/L	6.2	6.1	6.0	**6.1**	1%	-	-	-	**0.1**
Silver (Ag)	mg/L	<0.001	<0.001	<0.001	**<0.001**	-	-	-	-	**<0.001**
Sodium (Na)	mg/L	45.7	45.6	45.3	**45.5**	0%	-	-	-	**0.4**
Strontium (Sr)	mg/L	0.29	0.29	0.29	**0.29**	1%	-	-	-	**0.0001**
Sulfur (S)	mg/L	6.2	7.4	6.6	**6.7**	9%	-	-	-	**<0.5**
Titanium (Ti)	mg/L	0.005	0.005	0.005	**0.005**	3%	-	-	-	**<0.0004**
Uranium (U)	mg/L	0.0002	0.0002	0.0002	**0.0002**	0%	-	-	-	**<0.0001**
Vanadium (V)	mg/L	0.0006	0.0005	0.0005	**0.0005**	11%	0.002	0.001 - 0.005	3	**<0.0002**
Zinc (Zn)	mg/L	0.03	1.53	0.16	**0.57**	145%	0.011	0.003 - 0.017	3	**0.02**
Metals (dissolved)										
Aluminum (Al)	mg/L	0.01	0.02	0.01	**0.01**	60%	-	-	-	**0.004**
Antimony (Sb)	mg/L	0.0005	<0.0004	<0.0004	**0.0004**	13%	-	-	-	**<0.0004**
Arsenic (As)	mg/L	<0.0004	<0.0004	<0.0004	**<0.0004**	-	-	-	-	**<0.0004**
Barium (Ba)	mg/L	0.07	0.07	0.07	**0.07**	0%	-	-	-	**0.0002**

TABLE 3-1
WATER QUALITY FOR THE STEEPBANK RIVER
(Page 3 of 3)

Parameter	Units	Steepbank River								Field Blank
		Golder 1997					Historical*			
		Replicate number			Overall		Winter			
		1	2	3	mean	C.V.**	mean	range	n	
Beryllium (Be)	mg/L	<0.0005	<0.0005	<0.0005	**<0.0005**	-	-	-	-	**<0.0005**
Boron (B)	mg/L	0.25	0.27	0.27	**0.26**	4%	-	-	-	**0.003**
Cadmium (Cd)	mg/L	<0.0001	<0.0001	<0.0001	**<0.0001**	-	-	-	-	**<0.0001**
Chromium (Cr)	mg/L	<0.0004	<0.0004	<0.0004	**<0.0004**	-	-	-	-	**<0.0004**
Cobalt (Co)	mg/L	0.0001	0.0001	0.0001	**0.0001**	0%	-	-	-	**<0.0001**
Copper (Cu)	mg/L	0.0008	0.0011	0.0008	**0.0009**	19%	-	-	-	**0.003**
Iron (Fe)	mg/L	<0.01	<0.01	<0.01	**<0.01**	-	-	-	-	**<0.01**
Lead (Pb)	mg/L	0.0002	0.0002	0.0001	**0.0002**	42%	<0.002	-	1	**0.0002**
Lithium (Li)	mg/L	0.02	0.02	0.02	**0.02**	5%	-	-	-	**<0.003**
Manganese (Mn)	mg/L	0.0003	0.0008	0.0003	**0.0005**	62%	-	-	-	**0.0001**
Mercury, (Hg)	mg/L	<0.0002	<0.0002	<0.0002	**<0.0002**	-	-	-	-	**<0.0002**
Molybdenum (Mo)	mg/L	0.0005	0.0005	0.0005	**0.0005**	7%	-	-	-	**<0.00005**
Nickel (Ni)	mg/L	0.0006	0.0006	0.0006	**0.0006**	0%	-	-	-	**<0.0001**
Selenium (Se)	mg/L	<0.0004	<0.0004	<0.0004	**<0.0004**	-	-	-	-	**<0.0004**
Silicon (Si)	mg/L	4.9	5.07	5.1	**5.0**	2%	-	-	-	**0.05**
Silver (Ag)	mg/L	<0.0002	<0.0002	<0.0002	**<0.0002**	-	-	-	-	**<0.0002**
Strontium (Sr)	mg/L	0.24	0.24	0.24	**0.24**	0%	-	-	-	**0.0005**
Titanium (Ti)	mg/L	0.0004	0.0004	0.0005	**0.0004**	13%	-	-	-	**<0.0003**
Uranium (U)	mg/L	0.0002	0.0002	0.0002	**0.0002**	4%	-	-	-	**<0.00005**
Vanadium (V)	mg/L	<0.0001	<0.0001	<0.0001	**<0.0001**	-	-	-	-	**<0.0001**
Zinc (Zn)	mg/L	0.006	0.008	0.004	**0.006**	33%	-	-	-	**0.003**
Organic Compounds and Toxicity										
Hydrocarbons, Recoverable	mg/L	<1	<1	<1	**<1**	-	-	-	-	**<1**
Biochemical Oxygen Demand	mg/L	1	1	<1	**1**	0%	1.1	0.8 - 1.3	3	**<1**
PAHs and Alkylated PAHs	ug/L	< 0.02	< 0.02	< 0.02	**< 0.02**	-	-	-	-	**< 0.02**

* data from NAQUADAT (1980 - 1989), Noton and Shaw (1989)

** C.V. = coefficient of variation

TABLE 3-2
WATER QUALITY FOR SHIPYARD AND SALINE LAKES
(Page 1 of 3)

Parameter	Units	Shipyard Lake									Saline Lake
		Golder 1997					Historical*				
		Location			Overall		Spring		Summer		
		AW20	AW21	AW22	mean	C.V. **	mean	range	mean	range	
Field Measurements											
Temperature	°C	1.9	0.1	0.1	**0.7**	148%	-	-	-	-	**0.5**
pH		9.0	8.4	8.5	**8.6**	3%	-	-	-	-	**7.5**
Conductance (EC)	µS/cm	410	429	411	**417**	3%	-	-	-	-	**790**
Dissolved Oxygen	mg/L	3.4	1.8	2.4	**2.5**	32%	-	-	-	-	**9.6**
Conventional Parameters and Major Ions											
Bicarbonate (HCO_3)	mg/L	275	279	272	**275**	1%	132	129 - 134	165	165 - 166	**616**
Calcium	mg/L	61	61	61	**61**	1%	33	31 - 34	40	39 - 41	**140**
Carbonate (CO_3)	mg/L	< 5	< 5	< 5	**< 5**	-	-	-	-	-	**<5**
Chloride	mg/L	11.7	5.1	4.5	**7.1**	56%	5.9	5.8 - 6.2	4.5	3.7 - 4.9	**1230**
Color, True	T.C.U.	280	275	175	**243**	24%	-	-	-	-	**75**
Conductance (EC)	µS/cm	456	442	428	**442**	3%	239	227 - 248	273	269 - 275	**4570**
Dissolved Organic Carbon	mg/L	24	25	25	**25**	2%	-	-	-	-	**43**
Hardness	mg/L	211	210	207	**209**	1%	111	106 - 114	134	130 - 138	**481**
Magnesium	mg/L	14.0	13.7	13.6	**13.8**	2%	7.2	7 - 7.2	8.2	7.8 - 8.5	**31.9**
pH in Water	pH	6.9	7.0	7.1	**7.0**	1%	6.8	6.8 - 6.9	7.4	7.3 - 7.5	**7.4**
Potassium	mg/L	1.8	2.2	1.7	**1.9**	14%	-	-	0.8	0.7 - 0.9	**4.2**
Sodium	mg/L	15.0	11.0	10.0	**12.0**	22%	-	-	9.2	8.8 - 9.6	**762**
Sulphate	mg/L	4.7	4.6	4.5	**4.6**	2%	4.2	4 - 4.3	1.8	1.7 - 1.9	**37.8**
Sulphide	mg/L	0.091	0.081	0.109	**0.094**	15%	0.005	-	-	-	**0.029**
Total Alkalinity	mg/L	226	229	223	**226**	1%	108	106 - 110	135	135 - 136	**505**
Total Dissolved Solids	mg/L	300	280	290	**290**	3%	-	-	147	146 - 149	**2590**
Total Organic Carbon	mg/L	38	37	38	**38**	2%	18	18.2 - 18.4	24	23.5 - 24.3	**52**
Total Suspended Solids	mg/L	2	3	27	**11**	133%	157	150 - 165	182	175 - 190	**624**
Nutrients											
Ammonia-N	mg/L	0.6	0.8	0.9	**0.8**	21%	0.01	-	0.1	0.07 - 0.11	**6.0**
Nitrate+Nitrite-N	mg/L	<0.2	<0.2	<0.05	**<0.2**	-	0.01	-	0.02	0.016 - 0.026	**<0.2**
Phosphorus, Total	mg/L	0.07	0.20	0.25	**0.17**	54%	0.03	0.02 - 0.03	0.03	0.031 - 0.037	**1.04**
Phosphorus, Total Dissolved	mg/L	0.04	0.07	0.09	**0.07**	38%	0.019	0.017 - 0.021	0.01	0.012 - 0.017	**0.03**
Total Kjeldahl Nitrogen	mg/L	1.8	2.3	2.8	**2.3**	22%	0.7	0.7 - 0.8	0.6	0.5 - 0.8	**28.2**
Metals (total)											
Aluminum (Al)	mg/L	0.03	0.14	0.10	**0.09**	66%	0.02	-	0.05	0.05 - 0.06	**6.57**

TABLE 3-2
WATER QUALITY FOR SHIPYARD AND SALINE LAKES
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Parameter	Units	Shipyard Lake									Saline Lake
		Golder 1997					Historical*				
		Location			Overall		Spring		Summer		
		AW20	AW21	AW22	mean	C.V. **	mean	range	mean	range	
Antimony (Sb)	mg/L	<0.0004	<0.0004	<0.0004	**<0.0004**	-	-	-	0.0002	-	**<0.0004**
Arsenic (As)	mg/L	0.0008	0.0009	0.0010	**0.0009**	11%	0.0002	-	-	-	**0.0025**
Barium (Ba)	mg/L	0.05	0.07	0.05	**0.06**	18%	0.02	0.02 - 0.03	0.03	-	**0.24**
Beryllium (Be)	mg/L	<0.001	<0.001	<0.001	**<0.001**	-	-	-	-	-	**<0.001**
Boron (B)	mg/L	0.03	0.03	0.03	**0.03**	8%	0.04	0.03 - 0.05	0.04	0.02 - 0.06	**0.25**
Cadmium (Cd)	mg/L	<0.0002	0.0004	0.0005	**0.0005**	16%	-	-	-	-	**<0.0002**
Calcium (Ca)	mg/L	63	64	60	**62**	3%	34	31 - 37	-	-	**268**
Chromium (Cr)	mg/L	<0.0004	<0.0004	0.0077	**0.0028**	149%	0.0075	0.007 - 0.008	0.0100	0.004 - 0.017	**0.0082**
Cobalt (Co)	mg/L	0.0007	0.0007	0.0008	**0.0007**	8%	0.0006	0.0005 - 0.000	-	-	**0.0027**
Copper (Cu)	mg/L	0.0006	0.0012	0.0028	**0.0015**	74%	0.001	-	-	-	**0.0069**
Iron (Fe)	mg/L	9.6	9.8	7.7	**9.0**	13%	1.4	1.2 - 1.9	2.5	2.2 - 2.7	**5.5**
Lead (Pb)	mg/L	0.0008	0.0008	0.0030	**0.0015**	83%	0.0010	0.0008 - 0.001	-	-	**0.0031**
Lithium (Li)	mg/L	0.01	0.01	0.01	**0.01**	13%	0.01	0.005 - 0.006	0.01	0.007 - 0.008	**0.04**
Magnesium (Mg)	mg/L	15.4	15.1	13.5	**14.7**	7%	7.6	7.0 - 8.1	-	-	**37.2**
Manganese (Mn)	mg/L	0.45	0.41	0.54	**0.47**	14%	0.05	0.04 - 0.05	0.19	0.18 - 0.22	**0.85**
Mercury, (Hg)	mg/L	<0.0002	<0.0002	<0.0002	**<0.0002**	-	-	-	-	-	**<0.0002**
Molybdenum (Mo)	mg/L	<0.0001	<0.0001	0.0001	**0.0001**	0%	-	-	-	-	**0.0020**
Nickel (Ni)	mg/L	0.001	0.001	0.002	**0.002**	27%	0.010	0.009 - 0.012	0.011	0.008 - 0.014	**0.012**
Potassium (K)	mg/L	1.7	2.1	1.7	**1.9**	13%	1.8	-	-	-	**6.6**
Selenium (Se)	mg/L	<0.0004	<0.0004	<0.0004	**<0.0004**	-	-	-	-	-	**0.0011**
Silicon (Si)	mg/L	6.4	7.7	6.8	**6.9**	10%	3.0	2.8 - 3.1	-	-	**24.4**
Silver (Ag)	mg/L	<0.001	<0.001	<0.001	**<0.001**	-	0.0011	0.0005 - 0.002	-	-	**<0.001**
Sodium (Na)	mg/L	17.1	12.5	10.6	**13.4**	25%	8.5	8.2 - 9.0	-	-	**758**
Strontium (Sr)	mg/L	0.19	0.19	0.17	**0.18**	7%	0.08	0.082 - 0.085	0.116	0.115 - 0.118	**1.78**
Sulfur (S)	mg/L	2.6	2.6	2.6	**2.6**	0%	1.8	1.8 - 1.9	-	-	**34.4**
Titanium (Ti)	mg/L	0.0008	0.0027	0.0018	**0.0018**	54%	-	-	0.019	0.017 - 0.02	**0.082**
Uranium (U)	mg/L	<0.0001	<0.0001	<0.0001	**<0.0001**	-	0.0009	-	-	-	**0.0003**
Vanadium (V)	mg/L	0.0005	0.0009	0.0007	**0.0007**	29%	-	-	-	-	**0.026**
Zinc (Zn)	mg/L	0.03	0.01	0.03	**0.02**	56%	0.02	0.013 - 0.018	0.01	0.009 - 0.016	**0.06**
Metals (dissolved)											
Aluminum (Al)	mg/L	0.01	-	0.01	**0.01**	21%	-	-	-	-	**0.01**
Antimony (Sb)	mg/L	<0.0004	-	<0.0004	**<0.0004**	-	-	-	-	-	**<0.0004**

TABLE 3-2
WATER QUALITY FOR SHIPYARD AND SALINE LAKES
(Page 3 of 3)

Parameter	Units	Shipyard Lake									Saline Lake
		Golder 1997					Historical*				
		Location			Overall		Spring		Summer		
		AW20	AW21	AW22	mean	C.V. **	mean	range	mean	range	
Arsenic (As)	mg/L	0.0005	-	0.0005	**0.0005**	0%	-	-	-	-	**<0.0004**
Barium (Ba)	mg/L	0.04	-	0.04	**0.04**	11%	-	-	-	-	**0.13**
Beryllium (Be)	mg/L	<0.0005	-	<0.0005	**<0.0005**	-	-	-	-	-	**<0.0005**
Boron (B)	mg/L	0.03	-	0.02	**0.02**	3%	-	-	-	-	**0.27**
Cadmium (Cd)	mg/L	0.0001	-	0.0001	**0.0001**	0%	-	-	-	-	**<0.0001**
Chromium (Cr)	mg/L	<0.0004	-	<0.0004	**<0.0004**	-	-	-	-	-	**<0.0004**
Cobalt (Co)	mg/L	0.0002	-	0.0002	**0.0002**	0%	-	-	-	-	**0.0003**
Copper (Cu)	mg/L	0.0007	-	0.0010	**0.0009**	25%	-	-	-	-	**0.0006**
Iron (Fe)	mg/L	4.8900	-	2.3900	**3.6400**	49%	-	-	-	-	**0.0600**
Lead (Pb)	mg/L	0.0004	-	0.0003	**0.0003**	13%	-	-	-	-	**0.0002**
Lithium (Li)	mg/L	0.01	-	0.01	**0.01**	7%	-	-	-	-	**0.04**
Manganese (Mn)	mg/L	0.27	-	0.00	**0.14**	139%	-	-	-	-	**0.60**
Mercury, (Hg)	mg/L	<0.0002	-	<0.0002	**<0.0002**	-	-	-	-	-	**<0.0002**
Molybdenum (Mo)	mg/L	<0.00005	-	0.0001	**0.0001**	53%	-	-	-	-	**<0.00005**
Nickel (Ni)	mg/L	0.0009	-	0.0009	**0.0009**	0%	-	-	-	-	**0.0029**
Selenium (Se)	mg/L	<0.0004	-	<0.0004	**<0.0004**	-	-	-	-	-	**0.0005**
Silicon (Si)	mg/L	5.4	-	6.4	**5.9**	11%	-	-	-	-	**10.9**
Silver (Ag)	mg/L	<0.0002	-	<0.0002	**<0.0002**	-	-	-	-	-	**<0.0002**
Strontium (Sr)	mg/L	0.16	-	0.18	**0.17**	6%	-	-	-	-	**1.25**
Titanium (Ti)	mg/L	0.0003	-	0.0004	**0.0004**	20%	-	-	-	-	**0.0018**
Uranium (U)	mg/L	<0.00005	-	<0.00005	**<0.00005**	-	-	-	-	-	**<0.00005**
Vanadium (V)	mg/L	<0.0001	-	<0.0001	**<0.0001**	-	-	-	-	-	**0.0002**
Zinc (Zn)	mg/L	0.004	-	0.006	**0.005**	28%	-	-	-	-	**<0.002**
Organic Compounds and Toxicity											
Hydrocarbons, Recoverable	mg/L	<1	<1	<1	**<1**	-	-	-	<1	-	**<1**
Biochemical Oxygen Demand	mg/L	12	13	14	**13**	8%	-	-	-	-	**108**

* data taken from Golder (1996d)

** C.V. = coefficient of variation

In contrast, total suspended solids (TSS), total lead, total phosphorus and total copper levels were highest at the north station, AW022 (Table 3-2). These results were likely due to sediments introduced to the water sample during sampling, since bottom sediments were inadvertently disturbed while collecting samples from AW022. Water quality at the mid-lake station (AW021) was either very similar to that at AW020, AW022 or both, aside from slightly higher total titanium levels observed at this site (Table 3-2).

No historical data are available to describe winter water quality in Shipyard Lake. Existing data are limited to spring and summer. Lake dynamics change dramatically from summer to winter. Ice cover, reduced water flows and limited photosynthetic activity triggered by reduced light penetration due to snow and ice, considerably alter water chemistry. Not surprisingly, winter water quality observed during this survey greatly differed from previous spring and summer data (Golder 1996d). For example, total dissolved solids (TDS), major ions, most nutrients and many metal levels were considerably higher in winter than in either spring or summer, while TSS concentrations were higher in spring and summer than in winter (Table 3-2).

Saline Lake

Only one water sample was collected from Saline Lake. Since no historical data are available for this lake, historical comparisons can not be made.

Saline Lake, as its name implies, contained very high levels of sodium, chloride and to a lesser extent, other major ions (Table 3-2). Hence the very high conductivity, TDS, hardness and alkalinity readings associated with this lake. It was also rich in biodegradable organic matter, as illustrated by high biochemical oxygen demand (BOD) values (Table 3-2). Total metals levels were generally higher in Saline Lake than Shipyard Lake. The same trend was found with some of the dissolved metals, including boron, silicon and barium (Table 3-2).

There is no continuous or direct outflow from Saline Lake. Water flowing into the lake from the surrounding area can usually only escape through evaporation or seepage into the groundwater. Therefore, aside from some minor downward migration, most chemicals carried into Saline Lake

remain in the lake. As a result, salt concentrations increase over time, eventually producing the water quality observed in this study.

Quality Control Results

Field Blank

Analytical results indicate that the field blank prepared at the Steepbank River maintained its integrity throughout the sampling procedure. It arrived at ETL relatively free of contaminants, as illustrated by the very low or non-detectable readings produced from most tests (Table 3-1).

However, ammonia and dissolved copper concentrations were slightly higher than expected. The field blank contained 0.2 mg/L of ammonia (reported as nitrogen) and 0.003 mg/L of copper; detection limits for these two elements were 0.05 and 0.0004 mg/L, respectively (Table 3-1). Although these results would generally indicate that samples have been contaminated with ammonia and copper during preparation, preservation or shipping, the three Steepbank River water samples were clearly not affected. They contained non-detectable levels of ammonia and lower levels of dissolved copper than the field blank (Table 3-1). In fact, dissolved copper readings in all of the water samples were below levels observed in the field blank. This suggests an analytical error produced the relatively high copper concentrations observed in the field blank, rather than sample contamination.

Ammonia concentrations in Saline Lake were sufficiently high (i.e., 6.0 mg/L nitrogen) that an additional 0.2 mg/L added through sample contamination would not have greatly altered the test results. Similarly, general trends observed in Shipyard Lake would remain virtually unchanged after accounting for the 0.2 mg/L of ammonia possibly added to each sample after they were collected. Concentration gradients across the lake would still have been minor, and winter conditions would have remained substantially different from those observed in spring and summer.

Replicate Samples

As previously indicated, three water samples were collected at the mouth of the Steepbank River. Analytical results indicate that the three samples were almost identical. Of the 81 parameters measured, only total chromium, zinc and lead concentrations varied significantly from sample to sample (Table 3-1). The cause of these results is unclear. Overall, the Steepbank River sample site appears to have been relatively homogeneous, with little variation in water quality observed within this area.

3.2 Fish Habitat

At each site where water was present, depth, velocity and ice thickness were measured. Whenever discharge was measured, the width of the stream was also measured. A summary of measurements made at each site is shown in Table 3-3.

Steepbank River

Only two of the four pools sampled in the Steepbank River (Pools 2 and 3) may be suitable for fish overwintering, with water depths of 0.97 m and 1.25 m, respectively (Table 3-3). The DO levels were suitable to sustain fish over winter (11.6 mg/L for both pools; Table 3-3). The water flows measured were low (0.02 and 0.07 m/s respectively) and the pools were approximately 4 m wide by 10 m long. The shallower depths and higher velocities in the other two pools (Table 3-3) would render them less suited for supporting fish through the winter months.

During previous habitat mapping exercises, these pools were identified as the deepest in the study area and hence, are most likely the best potential overwintering habitats available in the Steepbank River. Since no fish were captured in these areas, there is a possibility that the Steepbank River is not used as an overwintering habitat by fish. This would be consistent with historical fish fence information for the Steepbank River which indicated that large fish species vacate the river in the fall (Machniak and Bond 1979). A similar pattern was observed in the Muskeg River system in the fall during previous fish fence surveys (Golder 1996a).

TABLE 3-3
FIELD WATER QUALITY AND FISH HABITAT PARAMETERS
FROM THE SUNCOR STUDY AREA

Location	Steepbank River					Jackpine Creek	
Site	Mouth	Pool 1	Pool 2	Pool 3	Pool 4	JP01	JP02
pH	8.37	7.25	7.75	8.04	8.10	8.41	8.04
Conductivity (µS/cm)	548	490	430	460	460	540	399
Temperature (°C)	0.5	0.2	0.1	0.2	0.2	0.4	0.0
Dissolved Oxygen (mg/L)	13.7	11.2	11.6	11.6	13.6	10.7	3.2
Water Depth (m)	0.28	0.21	0.97	1.25	0.30	0.26	0.15
Ice Thickness (m)	0.80	0.66	0.80	1.00	0.60	0.44	0.49
Width (m)	10.30	N/A	N/A	N/A	N/A	5.20	2.80
Velocity (m/s)	0.16	0.37	0.02	0.07	0.25	0.02	0.07
Discharge (cms)	0.44	N/A	N/A	N/A	N/A	0.05	0.02

Location	Shipyard Lake			Saline Lake	Trib. 8
Site	AW020	AW021	AW022	SL01	
pH	8.95	8.42	8.45	7.49	7.79
Conductivity (µS)	410	429	411	790	790
Temperature (°C)	1.9	0.1	0.1	0.5	0.0
Dissolved Oxygen (mg/l)	3.4	1.8	2.4	4.2	9.6
Water Depth (m)	1.00	0.40	0.40	0.25	0.02
Ice Thickness (m)	0.70	0.70	0.70	0.85	0.32
Width (m)	N/A	N/A	N/A	N/A	1.64
Velocity (m/s)	0.00	0.00	0.00	0.00	0.01
Discharge (cms)	N/A	N/A	N/A	N/A	0.00

N/A= not available

Steepbank River Tributaries

Only one of the eight tributaries (Tributary 8) to the Steepbank River contained flowing water. However, the water depth measured (0.02 m) was likely insufficient to allow for fish overwintering. Running water was heard under the ice at Tributary 6, but no flow could be detected, so it was assumed that the water was flowing through the substrate. Tributary 5 did not contain any ice, indicating it was dry before winter. All five remaining tributaries all had ice cover, but were dry.

Jackpine Creek

Both of the sites on Jackpine Creek contained flowing water. Site 1 had little water flow (0.018 m^3/s; Table 3-3) as well as a low DO concentration (3.2 mg/L; Table 3-3) making this site likely unsuitable as a winter fish habitat. Site 2 also had a low water flow (0.05 m^3/s). Although the DO measured (10.7 mg/L) at this site would be adequate to sustain fish, such as young-of-the-year, the shallow water depth (0.26 m) would likely prevent large adult fish from overwintering in this area.

Shipyard Lake

Water depths at the sampling sites in Shipyard Lake were between 0.4 m and 1.0 m (Table 3-3) and DO levels were relatively low (from 1.8 to 3.4 mg/L) (Table 3-3). Therefore, these areas have a low potential for fish overwintering. Several northern pike (*Esox lucius*) in spawning condition were captured in this lake in spring 1996 (Golder 1996e). Although this fish species can withstand low DO levels (Inskip 1982), it is unlikely that these fish are long-term residents of Shipyard Lake (Golder 1996e). The access to this waterbody is often sporadic, depending on beaver dams and water levels in the Athabasca River. The general characteristics of this lake (i.e., relatively shallow in most areas) indicate that it provides relatively poor overwintering habitat for most species.

Saline Lake

Field personnel observed a thick ice cover on Saline Lake (0.85 m; Table 3-3) and a strong sulphur odour coming from the water, indicating possible hypoxic conditions under the ice. The shallow depth at the sampling site (0.25 m), which is characteristic of habitats in this lake (Golder 1996a), and the low DO level (4.2 mg/L) make it a poor overwintering habitat for most sportfish species. Forage fish resistant to hypoxic conditions could possibly overwinter in this system.

Unnamed Pond

The unnamed pond located east of Saline Lake had an ice cover of 0.50 m and water depth of 0.4 m. Ice thickness and water depth were consistent throughout the pond. The shallow depth and low oxygen levels make the pond a poor overwintering habitat for most sport fish species.

The 1:50,000 topographic map of the area indicates that there is no defined outlet or inlet to the pond and no connection to other waterbodies.

3.3 Fish Inventory

Steepbank River

Gill nets and minnow traps were set in Pools 2 and 3 in the Steepbank River. A net was set in Pool 3 on two days. Other sites were too shallow to set a net or minnow trap. Set lines were placed in Pools 1, 2 and 3 in the Steepbank River. As a condition of the fish collection permit, gill nets set in the Steepbank River were not left overnight and were pulled before leaving the site at the end of the day, but were left in for at least 2.5 hours. Minnow traps and set lines were left overnight, except in Pool 3, where they were pulled after 2.5 hours. No fish were captured in any of the pools.

Shipyard Lake

Gill nets, set lines and minnow traps were set in Shipyard Lake (near site AW020, Table 2-1). The gill net in Shipyard Lake was set overnight and checked the next day. No fish were captured at this site.

Saline Lake

Water depths in Saline Lake were too shallow to allow fisheries inventory. As described in Section 3.2, overwintering habitat in this lake is poor.

4.0 CONCLUSIONS

4.1 Water Quality

Generally, water quality was consistent across Shipyard Lake and within the Steepbank River sample sites. There were several exceptions, as described in Section 3.1. Data collected from the mouth of the Steepbank River were consistent with historical winter water quality (NAQUADAT 1980-1989, Noton and Shaw 1989). Aside from differences in DOC and several total metal levels, all of the current information fell within established concentration ranges.

Only historical spring and summer data are available for Shipyard Lake (Golder 1996d). Water quality varies considerably from spring and summer to winter. Major ions, nutrients and most metal levels were higher in the winter samples than previously observed under spring and summer conditions.

Saline Lake's water chemistry may be considered unique. Saline Lake contained very high ion, nutrient, metal, TSS and TDS concentrations, in addition to large amounts of biodegradable organic matter and high conductivity, alkalinity and total hardness measurements. Without outflow, chemicals and other materials introduced into Saline Lake remain there and become concentrated due to evaporation, accumulating over time to produce the observed water quality.

4.2 Potential for Fish Overwintering

Shallow depths and low water flow at most of the stream sampling sites (Jackpine Creek's Site 1 and Tributary Eight) limit their use as overwintering habitats for fish. The area sampled in Jackpine Creek's Site 2 could provide areas to overwintering young-of-the-year fish but it is likely too shallow for large sportfish species.

Saline Lake and the unnamed pond would also be poor overwintering habitats due to shallow depths and low oxygen levels. Fish resistant to hypoxic conditions could possibly overwinter in the system.

During the spring sampling in 1996 (Golder 1996e) several northern pike in spawning condition were captured in Shipyard Lake. It was not known if the pike captured were part of a resident population or if the fish originated from the Athabasca River. Water pools sampled in Shipyard Lake provide relatively poor overwintering habitats for most sportfish species. Northern pike probably use the lake only for spawning, and possibly for rearing and summer feeding.

Two of the pools sampled in the Steepbank River could support large fish species over winter. However, no fish were captured during sampling and historical reports indicate that large numbers of fish vacate the Steepbank River in the fall (Machniak and Bond 1979).

5.0 CLOSURE

We trust that this report presents the information that you require. Should any portion of the report require clarification, please contact the undersigned.

GOLDER ASSOCIATES LTD.

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6.0 REFERENCES

Golder 1996a. Aquatic baseline report for the Athabasca, Steepbank and Muskeg Rivers in the vicinity of the Steepbank and Aurora Mines. Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Ltd., Fort McMurray, Alberta. 166 p.

Golder 1996b. Impact analysis of aquatic issues associated with the Steepbank Mine. Prepared for Suncor Inc., Oil Sands Group, Fort McMurray, Alberta. 126 p.

Golder 1996c. Athabasca River water release impact assessment. Prepared for Suncor Inc., Oil Sands Group, Fort McMurray, Alberta. 123 p.

Golder 1996d. Shipyard Lake environmental baseline study. Prepared for Suncor Inc., Oil Sands Group, Fort McMurray, Alberta. 22 p.

Golder 1996e. Addendum to Suncor Steepbank Mine environmental impact assessment: Spring 1996 Fisheries investigations. Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Ltd, Fort McMurray, Alberta. 14 p.

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Noton, L.R. and R.D. Shaw. 1989. Winter water quality in the Athabasca River system, 1988 and 1989. Environmental Quality Monitoring Branch, Environmental Assessment Division, Environmental Protection Services, Alberta Environment, Edmonton, AB. WQL-60. 200 p.

APPENDIX I

GOLDER TECHNICAL PROCEDURE 8.3-1

SURFACE WATER SAMPLING METHODS

1. PURPOSE

This document describes the sampling protocols used by Golder Associates to collect surface water samples. It contains sampling instructions and information concerning appropriate containers, preservation and handling of water quality samples.

2. APPLICABILITY

This technical procedure is applicable to any persons involved in the collection of surface water samples. It is applicable to all geographic areas.

3. DEFINITIONS

3.1 Analytical Request Form

Standard form provided by analytical laboratories. This form is filled out by the person collecting samples and is used to indicate how each sample is to be analyzed. This form is often combined with the Chain-of-Custody Form in a single document.

3.2 Chain-of-Custody Form

Standard form used to track the movement of sample containers from the time they leave the field until they arrive at the specified laboratory. The Chain-of-Custody form provides a clear record of sample transport and handling, thereby reducing the risk of sample loss during transport. This form may be combined with the Analytical Request Form in a single document.

3.3 Chemical Analysis

Analytical procedure used to measure the *amount* of a certain compound, or group of compounds, present in a sample.

3.4 Preservatives

Preservatives are used to maintain sample integrity from the time a sample is collected until it is analyzed. Sample preservation may involve adding acid or other fixatives to collected waters or simply keeping them refrigerated. Sample-specific requirements are outlined in this document (Table 1); preservatives, when required, are provided by the analytical laboratory.

3.5 Quality Assurance/Quality Control (QA/QC)

Quality Assurance refers to a detailed protocol used to produce high quality products, while Quality Control refers to the process by which this protocol is tested to ensure that final products are of the specified quality. With reference to water sampling, QA protocol includes the use trained personnel, proper sampling methods, clean containers and equipment, proper sample preservation and transportation and detailed documentation of the entire process; field, travel and other assorted test blanks are used for Quality Control testing.

3.6 Sample Types

3.6.1 Grab Samples

Sample containing water collected during a single sampling event (i.e., water taken from a given place at a given time).

3.6.2 Composite Samples

Sample containing a mixture of water collected from multiple locations or from different times at the same location.

3.6.3 Equipment Blanks

Equipment blanks are used to detect contamination from sampling equipment. They are prepared by rinsing precleaned equipment with deionized water and collecting the rinsate into an appropriate container.

3.6.4 Field Blanks

Field blanks are used to detect contamination during sample collection and transport. They are prepared during a sampling event by filling the appropriate container with deionized water. Field blanks are usually used in situations where there is reason to suspect that contamination will occur during sample collection and transport.

3.6.5 Travel Blanks

Travel blanks detect sample contamination during transport. Travel blanks consist of pre-filled bottles provided by the analytical lab. They accompany empty sample bottles to the field site, where they are left intact and unopened inside the shipping cooler. The unopened travel blanks are then returned to the analytical lab to be analyzed along with collected samples.

3.6.6 Field Spikes

Field spikes are used to measure the performance of the complete analytical system, including sample handling, preservation and storage, as well as interference from the sample matrix. To generate a field spike, field personnel fill the usual sampling container with sample, leaving a small amount of space at the top. They then add a specified amount of the chemical or compound of interest to the bottle and submit it with the rest of the samples. In general, field spikes are not recommended due to the logistical difficulties of transporting concentrated solutions in the field. If there is reason to doubt the performance of the sampling system, then a separate study involving field spikes should be carried out.

3.6.7 Standard Reference Samples

Standard reference samples, or blind QA samples, are samples of known concentration that are submitted to the analytical lab as a normal sample. The lab is not informed about the identity of the sample until after all analyses are complete.

3.6.8 Replicate Samples

Replicate samples are used to evaluate within-site variation. Replicate samples are collected by filling multiple containers at a single site. They are labelled and preserved individually and are submitted separately to the analytical laboratory. Check the SWI for the number of replicate samples required per sampling site.

3.6.9 Split Samples

Split samples are used to check analytical variation. A single sample (e.g. grab) is collected and is split into two sample containers. These are labelled and preserved individually and are submitted separately to the analytical laboratory.

3.7 Specific Work Instructions (SWI)

Detailed instructions in a standardized format provided to field personnel. The SWI describe all aspects of the work to be conducted, including personnel allocation, procedures to be used, time allocation and any additional information deemed necessary by the project or task manager.

3.8 Toxicity Analysis

Analytical procedure specifically designed to examine how the health of living organisms may be affected by exposure to a given substance or sample. Toxicity tests can be based on either: acute exposures (short-term exposures lasting only a small portion of the animals life cycle, e.g. 96 hours for rainbow trout); or, chronic exposures (longer-term exposures meant to represent a significant portion of the animal's life cycle, or a particularly sensitive portion of the animal's life cycle, e.g. 28 days for *Daphnia magna*). Responses measured in toxicity tests can be lethal (e.g. mortality), or sublethal (e.g., reduced growth or reproduction). Unlike other procedures, toxicity testing evaluates the sample as a whole, rather than describing its chemical make-up.

4. REFERENCES AND SUGGESTED READING

4.1 Sampling Methodology

Environment Canada. 1993. Quality Assurance in Water Quality Monitoring. Ecosystem Sciences and Evaluation Directorate Conservation and Protection. Ottawa, Ontario, Canada.

Clesceri, L.S., A.E. Greenberg and R.R. Trussell. 1989. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C., U.S.A.

4.2 Laboratory Capabilities and Pricing

- Chemex Labs (Alberta) Inc. 1995. Service Description and Price List
- Enviro-Test Labs. 1996. Service Description and Price List
- HydroQual Laboratories Ltd. 1996. Statement of Qualifications

5. DISCUSSION

5.1 General Safety

Refer to Golder Associates Ltd. Health and Safety Manual.

5.2 Sampling Procedures

Samples are collected as representative pieces of a larger puzzle. Ideally, they should describe all of the characteristics of the larger body from which they originate, which, by its very definition, is too large to analyze directly. As a result, it is very important to follow a well-organized sampling plan and to preserve sample integrity throughout the collection and transportation process.

5.2.1 General Practices

Usually, analytical laboratories will provide pre-cleaned sample containers, shipping containers, required forms for sample submission and specific sample shipping instructions. It is important to check with the lab that these arrangements have been made. Similarly, field crews should familiarize themselves with the SWI before initiating a sampling program. By reviewing the instructions, personnel can ensure that they have all of the equipment they require to fulfill the objectives of the sampling program. Field crews will also then be aware of the types of samples they are being asked to collect, be they grab samples, composite samples or QA/QC test blanks. Finally, sample crews should organize themselves such that samples will be collected and shipped during the early part of the work week (Monday to Wednesday) to help avoid delays caused by weekend shipping.

Sampling Locations

General sampling locations are described in SWI. However, field crews will have a certain degree of freedom in choosing the exact locations from which to take the samples. When selecting these sites, personnel should consider the layout of the local environment, project objectives and personal safety. They should then choose areas that are both easily accessible and representative of the target waterbody or waterbodies.

Once sampling sites have been identified, they must be accurately described relative to permanent landmarks, such as groundwater wells, outfalls or distinctive landscape features; measuring the distance from permanent landmarks to each site with an appropriate compass heading is recommended. Ideally, one should try to use the Global Positioning System (GPS), but locations can also be recorded as the perpendicular distance from the shoreline and the distance upstream or downstream of a permanent landmark.

Sample Collection

- Start sampling at the least contaminated site (i.e., the reference site) and move from there to the more contaminated areas.

- If sampling equipment must be used, then it must be cleaned before and after use. This may involve rinsing with ambient water, cleaning with soap and water, acid washing, rinsing with organic solvents or pure water, or a combination of these. Refer to the SWI for details.

- Each sample bottle must be labelled at the time of collection with either waterproof, permanent marker or using pre-printed waterproof labels. See section 5.3.2 for details of label format.

- When sampling, it is important to rinse sample containers 3 times before actually taking a sample. Rinse each bottle by partially filling it with ambient water, loosely attaching the cap and shaking the bottle; drain the water and repeat the process. As a general rule, rinse plastic bottles unless instructed otherwise by the analytical laboratory. Bottles that already contain the appropriate preservatives and containers for the following analyses should *not* be rinsed prior to taking the sample:
  - volatile organic compounds (VOCs), including total volatile hydrocarbons (TVH), total extractable hydrocarbons (TEH), BTEX (benzene, toluene, ethylbenzene and xylene) and total petroleum hydrocarbons (TPH; includes TVH, TEH and BTEX); and
  - bacteriological testing (e.g., fecal coliforms).

- Carefully fill sample containers, without splashing, leaving only enough space for preservatives (if required - see Table 1). Be sure to keep hands and fingers downstream of bottle opening and sample upstream of bridges, boats and yourself to prevent sample contamination. If no preservatives need to be added, completely fill the bottles and cap tightly. There should be as little air in the containers as possible, as it can affect sample integrity.

- Whenever possible, fill sample containers directly from the source, without using an intermediate container to transfer the sample. This avoids potential sample contamination due to carry-over from one sample to the next. Also, take care to avoid contaminating sample waters through contact with rubber, oil, gasoline and other machinery fluids, metal-based paints, cigarette ash, paper tissues and other such material.

- Sample bottles should then be stored appropriately (Table 1). In most cases, this will involve keeping the sample cool (4°C) and dark. Samples should never be allowed to freeze and should be shipped as soon as possible to the appropriate analytical lab, in coolers with reusable ice packs. If possible, avoid using bags of ice purchased from convenience stores; the water that leaks out of these bags as the ice melts may ruin sample labels.

- Chain-of-Custody and Analytical Request forms must accompany all samples (one set of forms per sample shipment). Prior to shipping, the person submitting the sample should inform the analytical lab by telephone or fax that the samples will be arriving. As well, he or she should check back later to confirm arrival of the samples and to explain analysis requests if needed.

5.2.2 Sampling for Metals

When collecting samples for a metals analysis, it is important that sample waters do not come into contact with any metal products. Samples for metals analysis also have other stringent collection and preservation requirements (Table 1). For example, waters collected for dissolved metal analysis have to be field-filtered using a 0.45 µm polycarbonate or cellulose acetate filter and then preserved with acid. Field crews need to be aware of these restrictions to ensure that samples are taken correctly and that they maintain their integrity until they can be analyzed. Special sampling and preservation instructions should be included in the SWI.

5.2.3 Sampling for Organic Chemicals

In addition to the general principles outlined above, there are specific protocols associated with sampling for organic measurements. As described above, sample bottles should *not* be rinsed prior to taking samples for certain organics analyses. It is also very important to completely fill each bottle, as certain organics will volatilize into the overlying air space and will be lost after opening the bottle. Finally, proper containers must be used when sampling for organics, since some bottles will release or absorb organic compounds when filled with water. Generally, glass containers are used, but certain tests may require other materials; be sure to obtain the appropriate sample bottles from the analytical laboratory and refer to the SWI.

5.3 Sample Documentation

The importance of proper sample documentation cannot be overemphasized. Lack of careful documentation can lead to misunderstandings and questionable test results. Components of proper documentation of field activities are described below.

5.3.1 Field Notebooks

Field notebooks must be kept, describing all field activities. Format of field notes and information to be recorded should follow Golder Associates' specific guidelines. During the field survey, field notes must be maintained in a permanent, safe location at the field site where samples are collected. If possible, new entries in the field note book should be photocopied at the end of each field day and copies should be stored in a safe place.

5.3.2 Sample Labels

Sample labels must contain the following information:

- Sample identifier (name of site or sample code);
- Date (written as day/month/year; month abbreviated as three letters) and time (24 hour clock) of collection;
- Initials of collector; and
- Analysis requested (this is usually done by the analytical laboratory in the form of a code on the sample bottle).

Fill out labels at the time of collection using waterproof ink and affix a label to each sample container. Plastic bottles may be labelled by writing directly on the bottle using a waterproof marker; however, this approach is not recommended if samples are transported over long distances (friction may rub label off) or if bags of ice are used to keep the samples cool (water may damage label information).

5.3.3 Custody Seals

If required for a project, numbered seals should be used to detect unauthorized tampering with samples in transit. Attach the seal in a way that it is necessary to break it to open the cooler containing the samples. The number on the custody seal should be recorded in the field note book and on the Chain-of-Custody and Analytical Request forms

5.3.4 Chain-of-Custody Forms and Analytical Request Forms

Chain-of-Custody and Analytical Request forms must accompany all samples submitted for analysis. These forms are usually combined as a single document. An example of Golder Associates' combined Chain-of-Custody and Analytical Request Form is provided in Appendix 1.

The combined form must be filled out completely and the white and yellow copies should be sent along with the samples being submitted. Field personnel should retain the pink copy after it is signed by the shipper. Depending on the shipping container, these forms can either be enclosed inside the sealed container or attached firmly to the outside of the container. In either case, it is advisable to enclose the forms within a waterproof plastic bag to guard against damage. It is important that each person having custody or control of the samples identify themselves on this form. This means that the person collecting the sample, any intermediate persons involved in packaging, storing or transporting the sample and the person accepting the sample on behalf of the analytical lab must all be identified.

5.4 Sample QA/QC

The main goal of sample QA/QC is to monitor for various sources of contamination during sample collection, transport and analysis. This process will involve the use of field, travel and other test blanks. QA/QC programs are designed on a project-specific basis. Details of individual QA/QC programs are described in the SWI.

6. EQUIPMENT AND MATERIALS

6.1 Sampling

The following is a list of sampling equipment generally recommended for surface water sampling:

- Pre-cleaned sample bottles and required preservatives (usually supplied by the analytical laboratory)
- Coolers and reusable ice packs
- Waterproof labels and permanent markers
- Sampling equipment (e.g. Kemmerer or Van Dorn bottles)

6.2 Site Location and Sample Documentation

For proper sample site identification and sample documentation, field crews may need:

- Bound, water-proof field logbooks
- Maps
- Air photos
- Indelible ink pens and pencils
- Long tape measure
- Survey flagging tape
- Compass
- GPS unit
- Combined Analytical Request and Chain-of-Custody forms

6.3 Health and Safety

The following health and safety equipment is recommended for surface water sampling:

- Waders and waterproof gloves
- Heavy socks, warm pants, rain gear and other articles of clothing suitable for prolonged water work
- Extra set of clothes
- First aid kit
- Approved personal floatation device for deep water or boat work

TABLE 1

SUMMARY OF SAMPLE COLLECTION, PRESERVATION AND STORAGE REQUIREMENTS

PARAMETER	BOTTLE TYPE	ETL[1] LABEL	SAMPLE PRESERVATION	PRESERVATIVE CODE (ETL)[1]	HOLDING TIME	COMMENTS
Conventional Chemistry						
pH to TDS + DOC	500 mL plastic	"routine"	in the dark at 4°C	-	**48 hrs.**	Note short holding time
TOC	100 mL amber glass	unlabelled	1 mL H_2SO_4	Fluorescent Red	5 days	Do not triple rinse
Major Ions						
Calcium to Sulphate	in "routine" bottle	n/a	-	-	-	
Sulphide	100 mL plastic	"Sulphide"	1 mL NaOH+ 2 mL zinc acetate	Orange	5 days	
Nutrients						
Ammonia, TKN & Total P	500 mL plastic	"nutrients"	2 mL H_2SO_4	Purple	10 days	Indicate on label that sample is preserved
Nitrate + Nitrite & Dissolved P	in "routine" bottle	n/a	-	-	-	
Bacterial						
Biochemical Oxygen Demand	1 L plastic	unlabelled	in the dark at 4°C	-	**48 hrs.**	Note short holding time
Coliforms	300 mL sterilized glass	unlabelled	in the dark at 4°C	-	**48 hrs.**	Note short holding time
Toxicity						
Daphnia magna 48 h. Static Acute	1 L clear glass / plastic	unlabelled	in the dark at 4°C	-	5 days	
Rainbow trout 24 and 96h Static Acute	20 L collapsible carboy	unlabelled	in the dark at 4°C	-	5 days	
Algal Growth 72h Inhibition/Stimulation	1 L clear glass / plastic	unlabelled	in the dark at 4°C	-	3 days	
Ceriodaphnia dubia 7d Growth and Reproduction	20 L collapsible carboy	unlabelled	in the dark at 4°C	-	3 days	
Fathead Minnow 7d Survival/Growth	20 L collapsible carboy	unlabelled	in the dark at 4°C	-	3 days	
Bacterial Luminescence (Microtox IC50 and IC20)	1 L clear glass	unlabelled	in the dark at 4°C	-	48 hrs.	Note short holding time
Other						
Total Recoverable Hydrocarbons	1 L amber glass	"oil & grease"	2 mL H_2SO_4	Purple	5 days	Do not triple rinse
Naphthenic acids	1 L amber glass	unlabelled	0.5g ascorbic acid + 2 NaOH pellets		10 days	Do not triple rinse; preservative in bottle
Total Phenolics	100 mL amber glass	unlabelled	1 mL H_2SO_4	Fluorescent Red	**24 hrs.**	Note short holding time Do not triple rinse
Chlorophyll *a*	500 mL plastic	"nutrient"	in the dark at 4°C	-	**48 hrs.**	Note short holding time Indicate on label that sample is unpreserved
Total Metals						
Aluminum to Zinc + Sb, As & Se	500 mL plastic	"metals"	2 mL NO_3	Blue	6 months	
Mercury (Hg)	250 mL plastic	"mercury"	2 mL NO_3 + dichromate	Yellow	30 days	
Dissolved metals						
Aluminum to Zinc + Sb, As & Se	500 mL plastic	"metals"	filter, 2 mL NO_3	Blue	6 months	See dissolved metals sampling protocol
Mercury (Hg)	250 mL plastic	"mercury"	filter, 2 mL NO3 + dichromate	Yellow	30 days	See dissolved metals sampling protocol
PAHs						
Naphthalene....	2 L clear glass	unlabelled	in the dark at 4°C	-	14 days	Bottle may be 4 L Do not triple rinse
Phenolics						
Phenol....	in PAH bottle	unlabelled	-	-	-	
Volatile Organics						
Acetone...	40 mL amber glass	unlabelled	Na2S2O3, 2 crystals, dark, 4°C	-	14 days	Do not triple rinse; preservative in bottle

NOTE: 1ETL = Enviro-Test Laboratories

APPENDIX 1

GOLDER ASSOCIATES' COMBINED CHAIN-OF-CUSTODY

AND ANALYTICAL REQUEST FORM

GOLDER ASSOCIATES LTD. Page ___ of ___

CHAIN-OF-CUSTODY RECORD

AND ANALYTICAL REQUEST FORM

Field Sampler: (Signature) _____ Shipment Date: _____

Phone No. _____ Carrier: _____

Waybill No.: _____

Ship To: Send Results To:

Project Name: _____ Project No. _____

P.O. No.: _____

Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Relinquished from lab by: (Signature)	Received by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): _____ Standard Turnaround Time: _____

PLEASE RETURN WHITE COPY TO GOLDER ASSOCIATES LTD.

GOLDER ASSOCIATES LTD.
CHAIN-OF-CUSTODY RECORD
AND ANALYTICAL REQUEST FORM

Field Sampler: (Signature) _____

Phone No._____

Shipment Date:_____

Carrier: _____

Waybill No.: _____

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): _____

Standard Turnaround Time: _____

PLEASE RETURN WHITE COPY TO GOLDER ASSOCIATES LTD.

APPENDIX II

GOLDER TECHNICAL PROCEDURE 8.24-0

DISCHARGE MEASUREMENTS METHODS

1. PURPOSE

This document describes the method for measuring stream velocities to obtain an estimate of discharge through a channel cross-section.

2. APPLICABILITY

Three variations of the procedure include measurements made in shallow, deep, and ice covered streams. These procedures are applicable to most streams and rivers (see section 5.2 Site Selection).

3. DEFINITIONS

The terms 'flow' and 'discharge' are used interchangeably throughout the text and refer to the volume of water passing by a fixed point per unit time. The units of measurement are typically either cubic metres per second (cms or m^3/s), or cubic feet per second (cfs or $ft.^3/s$).

4. REFERENCES AND SUGGESTED READING

Mosley, M.P. and A.I. McKerchar; Maidment, D.R. (editor-in-chief) 1993. Chapter 8: Handbook of Hydrology. McGraw-Hill. 39 Pages.

Water Survey of Canada. 1978-1993. Chapters 2 and 4 Hydrometric Field and Related Manuals. Golder Calgary Hydrology Library. Three-ring binder.

5. DISCUSSION

5.1 General Safety

Refer to Golder Associates Ltd. Health and Safety Manual for details of safety procedures. Beware of stream and flow conditions that are unsafe for wading. A guideline for determining if a stream can be waded safely is to avoid entering a stream where the product of the velocity (m/s) and the depth (m) is greater than unity. For example:

if: depth = 1.0m, and
velocity = 1.5 m/s, then
depth × velocity = 1.5.

Therefore, these represent conditions that are unsafe for wading. This is only a guideline and other considerations should be made. Ice on the channel invert or algae covered rocks will affect the safety of wading. Consider using safety rope if conditions are marginal, but not threatening (e.g., downstream ice cover, waterfalls, etc.). In the winter, beware of unsafe ice conditions. Always test the ice thickness

before you move onto it and every few feet as you progress. Ice thickness can change abruptly in an active channel.

For more information refer to the Golder Associates Ltd. Health and Safety Manual for details of safety procedures, and the Water Survey of Canada References in the hydrology library.

5.2 Site Selection

The site (transect) for a stream discharge measurement should be selected based on the following characteristics:

- straight reach of channel
- uniform channel shape, bed profile and flow characteristics
- free from any debris, large boulders, and other obstructions
- u/s bridge is a good site
- no undercut banks or backwater effects
- suitable depth (greater than 0.2 m) and velocity (less than 2 m/s)
- mainly channelized flow with little opportunity for flow on a floodplain even during extreme events

A transect chosen in the middle of a long straight reach is desirable since it typically has these flow and geometric characteristics.

5.3 Shallow Water Discharge Measurement (suitable for wading)

The following is a step by step guide to completing stream discharge measurements (using a Price AA velocity meter) for small to medium sized streams that can be waded.

The recommended procedure for measuring flow in a shallow stream which can be waded is as follows:

a) Select a site in accordance with the guidelines listed in Section 5.2.

b) Fix a tape measure or tagline to either the left or right bank so that the zero mark is at the shoreline. If it is not possible to zero the tagline at the waters edge, record the point on the tagline which corresponds with the water's edge. Fix the tagline to natural objects or use short sections of small-diameter re-bar driven into the stream bank.

c) Affix the tape or tagline to the opposite bank. Ensure the tape is perpendicular to the direction of flow.

d) Record the locations of the shorelines on the discharge sheet (see Exhibit A).

e) The points on the tagline at which depth and velocity measurements are taken are called stations or verticals. A minimum of 20 "wet" stations, not including the waters edge stations, are preferred for medium sized streams and 30 stations for large rivers. To determine the measurement stations, divide the channel width from waters edge to waters edge by 20 or 30. A 10m wide channel would

have sample points approximately every 0.5m). If the wetted width is less than 4m place a measurement station every 0.2m but no closer. If the flow rate across the channel is not uniform, the section with the higher flow volume should have a greater number of stations. The flow through any single cell (area between two verticals) should not be greater than 10% of the total discharge.

Locate the first and last verticals as close to the banks as possible to reduce the errors introduced in the area calculations. Locate the remaining 18 verticals in such a way as to characterize any significant gradients in velocity or depth along the cross-section.

f) At each station measure and record the total water depth.

g) Measure the mean column velocity. If the water is less than 0.75m deep, use the current velocity meter to measure the velocity at 60% of the total depth (this is 0.6 × depth, as measured from the water surface). If the water is greater than or equal to 0.75m deep, then measure and record the velocity at both 20% and 80% of the total on the discharge sheet.

h) The current velocity is measured by maintaining the velocity meter at the correct depth in the water column with the wading rod set so that the base rests on the substrate. The top-setting wading rod can be used to automatically set the meter at 60%, 20% or 80% of depth, as required, by using the scale on the handle. Once the total depth is known the moveable rod can be adjusted to position the meter at the required depth. The handle scale is read by lining up the stamped numbers on the sliding rod with those on the handle. The scale on the handle refers to the centimetre portion of the depth (i.e. 1-9 cm) and the scale on the sliding rod represents the decimetre portion (i.e. the number 1 stamped on the rod equals 10 cm). For a reading at 60% the scales should be set to read the measured total depth. To make a reading at 20% set the scales to twice the depth measured depth. For 80% the scales should read 0.5 times the measured depth (see diagram in Exhibit B). For example:

If the total measured depth equals 36 cm (total depth less than 75 cm) then:
- to make a reading at the 60% depth, set the sliding rod scale at 3 equal to the handle scale at 6
- if the total depth was 92 cm (greater than 75 cm), measurements would be made at the 20% and 80% depths
- for the 20% depth measurement, set the sliding rod scale at 18 equal to the handle scale at 4 ($2 \times 92 = 184$)
- for the 80% depth measurement, set the sliding rod scale at 4 equal to the handle scale at 6 ($\frac{1}{2} \times 92 = 46$)

i) Hold the wading rod so that the meter is parallel to the direction of flow and is pointing upstream. If the direction of flow is unclear, rotate the rod slightly to find the angle at which the maximum velocity is observed. If an angular difference between the direction of flow and a perpendicular to the cross-section is perceived, note the angle in degrees (∅) beside the measured velocity on the discharge sheet. When estimating angles, consider that the angle between the "12" and the "1" (or any other two adjacent numbers) on a typical clock face is 30 degrees.

j) Start the stopwatch exactly when the coloured cup passes the wading rod yolk or, if using a headset, exactly on the audible click. To record only full rotations, the stopwatch should be stopped when the cups are in the same position as when the stopwatch was started (i.e. when the coloured cup passes the yolk or on the audible click).

k) Count revolutions for a minimum of 40 seconds.

l) After 40 seconds, stop the stopwatch at the first number of full revolutions which corresponds to one of the revolution numbers listed across the top of the calibration sheet that is included with the meter Use the calibration sheet specifically for the suspension method being employed (i.e. rod suspension). Using the columns on the calibration sheet, match the number of revolutions to the time required (seconds) to determine the velocity. Record the velocity on the discharge sheet.

m) Record the distance from the waters edge, the total depth and each velocity measurement (i.e. the velocity at either 60% of depth or 20 and 80% of depth) on the same line of the discharge record sheet for each vertical.

n) The actual velocity can also be calculated, instead of copied from the calibration sheet, using the conversion equation that is presented at the top of the calibration sheet. In this case, record the number of revolutions and the time required. The meter number (stamped onto the side of the frame) should also be recorded because the conversion equations are different for each meter.

o) The stream discharge can then be calculated using a spreadsheet program by entering the recorded stations, depths and velocities. An Excel spreadsheet for this purpose is located in the directory - *G:/Aquatics/Dischrge.xls*. The discharge can also be calculated in the field with the aid of a calculator using the appropriate formula. The discharge is calculated individually for each water column and then summed to provide the total discharge.

p) Operation of the Marsh-McBirney electromagnetic velocity meter is not covered here. The use of this instrument avoids the need for steps 5.10 to 5.12. In place of these steps record the digital velocity reading measured by the instrument on the discharge sheet. There is a copy of the operation manual for this meter inside the meter carrying case.

5.4 Deep Water Discharge Measurement

When the stream is too deep to be waded, and if the flow velocities do not exceed 2 m/s, a boat and weighted instrument (equipped with a hand bomb can be used to measure stream flow. The recommended procedure follows:

a) Assemble the bomb (Exhibit C) and hanger arm by inserting the hanger arm into the slot in the top of the bomb and fixing it in position with the long screw inserted on the side of the bomb

b) Attach the flow meter to the hanger arm by sliding the slot in the meter over the hanger arm and fixing the meter in place using the screw on the side of the meter

c) Assemble the fins by interlocking the slots and swiveling the holding pin into position

d) Attach the fins to the rear of the meter and fix in place with the screw on top of the meter frame

e) Attach the hand cable to the hanger arm using the clevis/cotter pin provided

f) If poor water clarity prevents visual observation of the submerged meter attach the wire and headset assembly (the headset battery is replaceable and is located inside the headset). This is done by fixing

the forked connector to one of the posts on the meter housing. The top post will produce one audible click per rotation of the cups and is used in slow and moderately fast flowing water. The bottom post produces one click per every five rotations and is for use in very fast water. The ring connector is then fixed to the back of the meter using the screw holding the fins in place.

g) Measure water depth by lowering the bomb to the bottom of the stream and reading the depth off of the calibrated cable.

h) Calculate the position of the bomb which is needed to conduct the 20% and 80% of depth velocity measurements. The depth marks on the cable refer to the distance to the bottom of the bomb, not to the meter.

i) Measure the distance from the bottom of the bomb to the middle of the meter cups

j) Calculate the distances below the surface at which the meter must be to conduct the 0.2 depth and 0.8 depth measurements

k) To measure the 0.8 depth, hold the cable with the mark at the waters surface which corresponding to [depth × 0.8 + (distance from bottom of bomb to meter)

l) To measure the 0.2 depth, use the formula: depth × 0.2 + (distance from bottom of bomb to meter)

5.5 Ice Covered Stream Discharge Measurement

Stream discharge measurements under ice are similar in most respects to those carried out in open water conditions. The difference is that the effective depth at each station is measured from the bottom surface of the ice to the substrate. If the water level in the hole drilled through the ice is above the bottom of the ice, effective depth is measured by subtracting the distance from the bottom of the ice to the water surface from the total depth measured on the wading rod. Ice thickness and the distance from the bottom of the ice to water surface are measured with the ice thickness gauge which consists of a meter stick attached to a perpendicular bracket which can be hooked under the ice. For effective depths greater than 0.75m the velocity is measured at 20% and 80% of the depth. For depths less than 0.75m, the velocity is measured at 50% of the distance between the bottom surface of the ice and the stream substrate and multiplied by a coefficient of 0.88 to obtain the average velocity. Alternatively, for depths less than 0.75 m, the velocity can be measured at 60% of the effective depth and multiplied by a coefficient of 0.92.

The depth and velocity measurements are made through holes cut in the ice at the prescribed distances (stations). However, locating the waters edge under the ice can be difficult. One method is to drill through the ice near the anticipated location of the shoreline but further from shore so that the hole will not be dry (i.e. frozen to the bottom). Using a shoulder length glove or a short length of pole, from the hole drilled near the shoreline locate the point where the stream is frozen all the way down to the substrate and determine the appropriate stationing from the waters edge.

5.6 Stream Discharge Formula

The formula for calculating discharge at each cross section is as follows:

Discharge = point velocity (m/s) • 1/2 {distance between previous and next stations} (m) • depth (m) • Cos ∅ (deg.)

5.7 Maintenance

Velocity meters are expensive pieces of high precision equipment. Therefore, It is important that the equipment is handled carefully and maintained each time it is used. Maintenance procedures are described in Exhibit D.

6. EQUIPMENT AND MATERIALS

6.1 Velocity Measuring Equipment

Price 622AA velocity meter or March-McBirney meter
Spare Batteries
Stopwatch - for Price meter only
Headset - for Price meter only
Wading rod wire - for Price meter only
Automatic depth calculating (top-setting) wading rod

DEEP WATER MEASUREMENTS
15 lb. weight and cable

6.2 Record-keeping and Site Locating/Marking

Tape measure or tagline long enough to cross channel
2 re-bar posts hammered into the shore for positioning the tagline
Hammer to install re-bar
Holder to attach tape measure to re-bar (not required for tagline)
Field Book
Pencil/pen
Discharge sheet
Calculator

6.3 Health and Safety Equipment

Personal Flotation Device
Safety Rope

6.4 Personal Gear

Hip Waders/Chest Waders
Bug Repellent

6.5 Boat and Associated Equipment (for Deep Water Only)

Boat and accessories
- min 2-person flat bottom boat with cable rung at front
- power boat for large rivers
- one PFD per person
- sounding device (e.g. a whistle)
- bailing bucket
- paddles/oars and extra paddles

6.6 Ice Gear

- ice drill and bits
- rod with hook
- safety rope

EXHIBIT A - Discharge Sheet

DISCHARGE DATA

STREAM: ______ PROJECT #: ______

TRANSECT: ______ LOCATION: ______

DATE: ______

Description	STATION (m)	DEPTH (m)	VELOCITY (m/s) 0.2d	VELOCITY (m/s) 0.8d	VELOCITY (m/s) 0.6d	Angle of Flow (degrees)	DISCHARGE (cms)
Left Edge	1.7	0					0.000
	1.8	0.1			0.350		0.005
	2	0.5			0.450		0.056
	2.3	0.8	0.600	0.230			0.116
	2.7	0.82	0.670	0.300			0.139
	3	0.65			0.500		0.081
	3.2	0.4			0.200		0.016
	3.4	0.1			0.200		0.003
Right Edge	3.5	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
	0	0					0.000
				TOTAL DISCHARGE			0.417

EXHIBIT B - Top Setting Wading Rod - Diagram

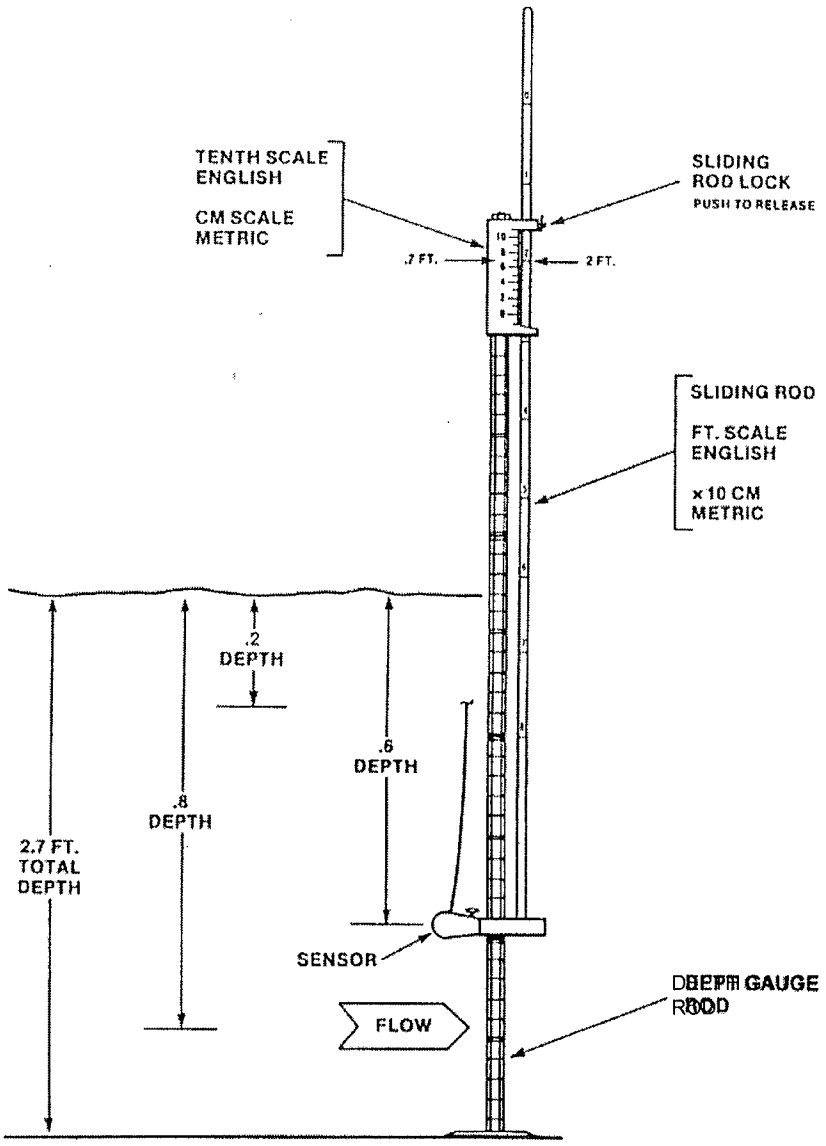

Figure 10—Top-Setting Wading Rod

EXHIBIT C - Deep Water Discharge Measurement - Hand Bomb

SUSPENSION CABLE

The suspension cable allows the sensor to be lowered into the flow from boats or bridges. The sensor is mounted to the suspension cable by inserting the shaft of the sensor mount into the hole at the back of the sensor. Hand tighten the thumb-screw on the sensor (See FIGURE 9).

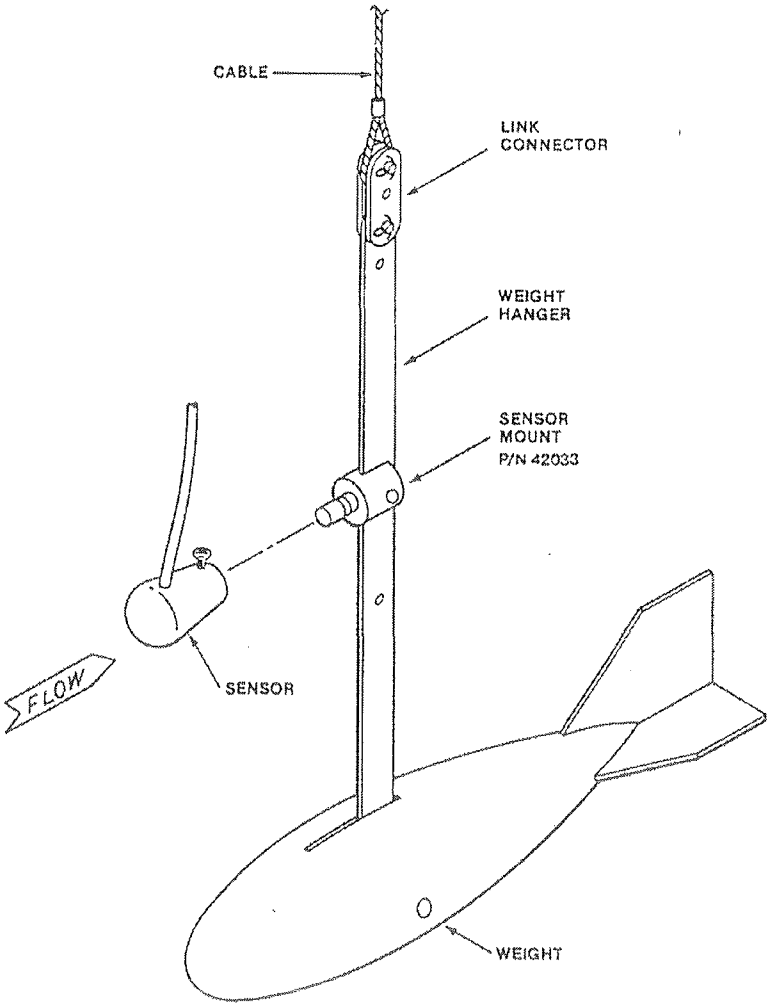

Figure 9—Suspension Cable

EXHIBIT D - Maintaining the PRICE AA Current Meter

The efficiency and life of a current meter depends largely on the thoroughness with which the operator cleans and lubricates various parts of the instrument.

Many meter users appear to be of the impression that, if a little oil is used in the head and also applied to the pivot, would be all there is to it to maintain the instrument in an efficient condition. Nothing is further from the truth. Water may be trapped in the head and also in the pivot bearing on the underside of the bucket wheel. Oil squirted onto wet parts will retain water in contact with the finely machined surfaces and will carry grit and silt to the bearings, thus aggravating wear and corrosion.

To clean and lubricate the Price type current meter is a most simple matter and its application only takes a few minutes and should not be postponed or neglected.

A simple and efficient manner to clean and maintain an instrument in good working order is as follows (refer for Figure 60):

1. Unscrew and remove headcap. Wipe dry and clean lower face.

2. Slacken set screw in lower limb of yoke and remove pivot.

3. Clean current meter in clear water as soon as possible, blow out water trapped in head and bearing chamber and allow to dry overnight. Never place a wet current meter in its carrying case.

4. Lubricate current meter at the start of each day. Lubricate pivot, pivot bearing and upper bearing in head. Do not over lubricate as oil tends to congeal in cold water.

5. The pivot and pivot bearing of the meter must be protected to insure proper results when using this instrument. A knurled nut is provided beneath the bucket wheel to raise it and provides clearance between the pivot and pivot bearing when instrument is in transit. The knurled nut has a left hand thread, rotate the nut in the direction in which the bucket wheel would turn when in use until you keel resistance and the bucket wheel no longer rotates freely. The upper end of the under side of the head cap and a separation exists between pivot and pivot bearing. Reverse the above to bring the pivot and pivot bearing into contact again when preparing to use the meter.

6. The oil used for lubricating should be light and of a non-corrosive nature. Rislone motor oil is obtainable most anywhere and is very satisfactory and highly recommended.

7. When damage to a current meter should occur during use and results obtained appear questionable, it is advisable to have such meter re-calibrated in its "DAMAGED" condition in order to have stress measuring results corrected.

8. For further information in regard to current meters or calibration requirements please contact the following:

National Water Research Institute
Research and Applications Branch
National Calibration Service
Hydraulics Studies
867 Lakeshore Road, P.O. Box 5050
Burlington, Ontario L7R 4A6

Attn: Clarence Bil
Tel. No. (416) 336-4521
Fax No. 9416) 336-4989

When in use, current meters should be partially disassembled, cleaned, and oiled daily; and after the completion of each transect if measurements are taken in water with large amounts of suspended sediment. Surfaces to be cleaned and oiled are the pivot and pivot bearing, pentagear teeth and cross-shaft bushings, and the thrust bearing that holds the rotor shaft in position inside the contact chamber.

After cleaning or just before using the next time, the meter should be "spin-tested." Hold the instrument level and out of the wind, and give it a moderate spin. A Price-AA, PAA, or Gurley meter in good shape should spin for a least 2 minutes (new ones will go nearly 2 minutes). Pygmy meters should spin at least a minute, and preferably a minute and a half. If the meter spins for less than the requisite time, check for corroded surfaces, poorly lubricated bearings, organic "gunk" lodged in the pivot bearing, burred pivot, or a bent rotor shaft.

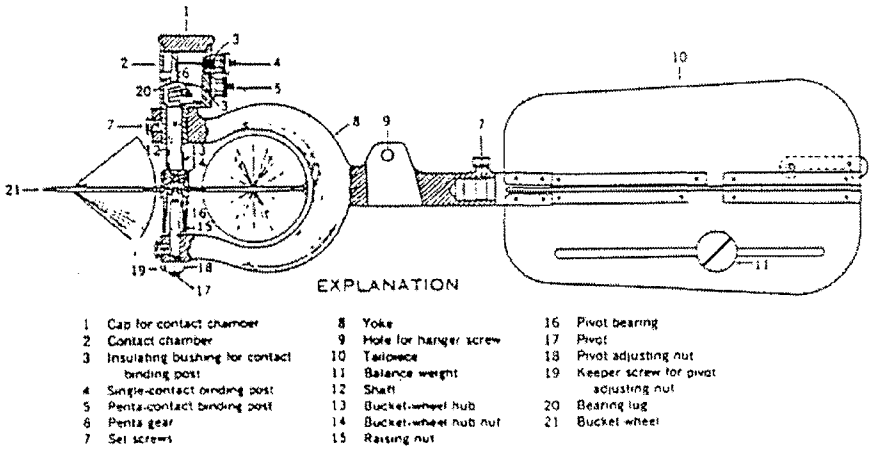

Figure 60. Assembly drawing of a Price AA current meter. Two components most vulnerable to damage are the bucket-wheel (21) and the pivot its contact point with the pivot bearing (16).

APPENDIX III

GOLDER TECHNICAL PROCEDURE 8.1-3

FISH INVENTORY METHODS

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1. PURPOSE

This technical procedure presents the techniques and methodologies used for standard fisheries sampling during fish inventory studies for the purposes of determining species presence, distribution, relative abundance, basic population characteristics and for conducting population estimates. Decisions regarding the type of sampling gear to use, the specific techniques to be employed and the timing of sampling will be determined prior to the commencement of the field study by the project team or project manager. However, due to the nature of fisheries work, some decisions regarding sampling specifics will depend upon conditions in the field. The methods for general fisheries inventory work are covered in this technical procedure. Other technical procedures are required in addition to this one in order to conduct fish sampling for specific tasks such as biomarking/fish health studies. This technical procedure does not detail the Quality Assurance/Quality Control requirements for components of field programs, such as note taking/data recording, as they are included in other documents.

2. APPLICABILITY

This technical procedure is applicable to all personnel involved in fisheries surveys for lakes and streams, including all sizes and orders of streams. It covers sampling equipment and techniques currently owned/used by Golder. Additional techniques are available which may be the most suitable method for specific circumstances or project requirements. If this is the case, the project manager must authorize the use of any new technique or the purchase of additional equipment.

3. DEFINITIONS AND METHODS

3.1 Abundance, Relative

The proportional representation of a species in a sample or a community. In fisheries inventories, relative abundance is typically used to describe the relative number of fish captured for each different species at a sampling site. Relative abundance can also be determined for the same species at different sites or in different seasons. It can also be determined for different life stages of the same species.

In some limited cases, the number of fish captured can be used to describe relative abundance. This is suitable for a single effort in a single sampling area where relative abundance is simply the relative number of fish captured. For example, if 20 fish of one species and 10 fish of another species were captured in 100 seconds of electrofishing at a site, species one is determined to have a relative abundance twice that of species two.

For any sampling situation which is more complicated, Catch-Per-Unit-Effort (CPUE) values must be calculated to determine relative abundance. CPUE values take into account the sampling effort required to catch the fish as well as the number of fish captured. For example, if 20 fish of one species were captured in 100 seconds of electrofishing at one site, and 20 fish of the same species were captured in 200 seconds of electrofishing at a second site, CPUE data shows that this species has a relative abundance at the first site which is twice that of the second site. In this example, twice the effort was required to capture the same number of fish at site two. This example also shows why it would be unsuitable to derive conclusions about relative abundance based solely on the numbers of fish captured.

In order to be able to determine relative abundance, you must record all sampling efforts in a manner suitable for calculating CPUE data.

3.2 Ageing Structures

Ageing structures are bony parts of the fish which are taken for ageing analyses. In fish from temperate zones, these structures contain annual bands (annuli) which delineate seasonal variation in growth which can be counted to determine the fishes' age. Primary examples of these structures are scales, fin rays, saggital otoliths, cleithra and opercula. The appropriate ageing structures to collect vary according to fish species and life stage and include lethal and non-lethal sampling measures. Consult the table of "**Recommended Fish Ageing Structures**" (available in the aquatics reference file) for the appropriate structure and collection method for each species. With respect to fish ageing, all procedures used by Golder (i.e., the ageing structures which are collected and the methods used to determine age) conform to the manual of Fish Ageing Methods for Alberta (Mackay et al. 1990).

Following removal from the fish, ageing structures should then be placed in a "scale envelope", which consists of a small envelope which has been stamped with fields for recording the following information:

- date
- fish number
- species
- fork length
- weight
- life history stage
- sex
- state-of-maturity
- sampling gear
- sampling location
- ageing structure collected
- project number

Blank envelopes are ordered in batches of 1000 and must be stamped prior to use. If your project includes the collection of ageing structures, it may be necessary to order the required envelopes and stamp them before heading out into the field.

The scale envelopes should be allowed to dry overnight before being stored. Upon returning from the field, the envelopes should be stored frozen in a one of Golder's freezers.

3.3 Anaesthetic

An anaesthetic is used in situations requiring live fish to be removed from the water and handled for extended periods, such as during surgery to implant radio transmitters, or to quiet fish for measurements. The anaesthetic commonly used by Golder is MS-222, known as tricaine methanesulfonate. The concentration of anaesthetic to be used depends on the required level of sedation. For surgery, which requires the fish to remain sedated for a period of 5-10 minutes, a concentration of 100 mg/L is used (i.e. 4 g of MS-222 in 40 L of water). The fish is placed in the anaesthetic bath for 2-4 minutes until the desired level of sedation is reached. Care must be taken as overdoses lead to direct mortality. When monitoring the fish in the anaesthetic solution, watch for loss of coordination (when the fish no longer keeps itself upright) and respiration rate. Towards the end of the anaesthetization period, the fish will begin to "Cough".

Use of anaesthetic for quieting fish for measurements is not typically recommended unless the fish is difficult to handle or may injure itself. Fish anaesthetized with MS-222 are not recommended for consumption by anglers for a period of 2-4 weeks following exposure to the anaesthetic. Therefore, use only on fish which will not be captured and consumed or with permission of Alberta Fisheries Management Division.

3.4 Biomass

Biomass is the total mass (weight) of fish, or of fish of a given species, within a study area. It is a component of population estimates, as an estimate of the total number of fish in the study area is required to calculate biomass. Using either total removal data or a mark/recapture population estimate for the study site, the total biomass is calculated by multiplying the total population of fish by the average weight of the fish captured. Results can be expressed as units of weight over study area dimensions (e.g. kg/m of stream, kg/m^2 of lake).

3.5 Capture/Sampling Techniques

The following sampling techniques are used to capture fish. Some techniques are very specific to one life stage while others are more general. All sampling techniques have some degree of sampling bias associated with them with respect to fish size selectivity and sampling efficiencies based on environmental parameters such as water depth, conductivity, stream size etc. It is important to understand these biases when designing or implementing a study plan and when interpreting the data and drawing conclusions from the results.

3.5.1 Airlifting

Airlift sampling is used to collect fish eggs from the substrate for species which are broadcast spawners (i.e. do not bury their eggs). It can be used simply to determine if incubating eggs are present or to determine the relative density of eggs at each spawning site. The airlift sampler consists of a gas powered generator and compressor unit, a length of hose, an airlift head and couplers to connect the hose to the compressor and airlift head. The airlift head is attached to a long pole and consists of a 4" or 6" diameter hollow tube with a 90° bend at the upper end. The lower end of the airlift head has an internal tube which runs around the internal circumference and which is perforated. With the lower end of the airlift head held against the substrate, air is pumped from the compressor through a hose and into the perforated tube. Air rising inside the airlift head creates a vacuum effect which lifts loose particles up from the substrate. A removable collection bag placed over the upper end of the airlift head collects the particles. The sample is dumped into a sampling tray and examined for the presence of eggs.

This technique is employed when sampling water too deep to kick sample or when a quantitative sample is required. Since the area (cm^2) of the airlift head is known, simply count the number of times the head is touched to the substrate for each sample in order to determine the number of eggs/cm^2 in the sample. Quantitative sampling can be used to determine the relative use of the spawning areas sampled, as determined by egg density. Remember to record the size of the airlift head used.

3.5.2 Angling

Angling refers to the use of angling gear, such as rod and reel, to sample for fish. Angling is an active technique using lures, bait or flies. Leaving a static, baited line in one place is referred to as a Set Line and is not an angling technique. On the other hand, jigging with a baited line would be an angling technique.

Sampling effort should be recorded as both the number of hours angled and the number of angling tools used. It would be recorded as angler-hours, or as rod-hours or some equivalent if more than one piece of angling gear is used per angler. The types of hooks, size of hooks, and number of hooks should also be recorded. In addition, notes on the types of habitats fished and the length of shore line covered if trolling is conducted should be recorded.

3.5.3 Drift Net

Drift net is a passive sampling technique for use in flowing water for the capture of life stages which are moving or drifting downstream. A drift net consists of a long, tapering net with an open mouth at the upstream end and a detachable sample bottle at the downstream end. Drift nets are anchored in place in the stream and filter the water passing through them, collecting materials from the water column. They can be placed to sample the bottom, middle or top of the water column or can be stacked to sample the entire water column. At regular intervals, the nets are removed and cleaned by dumping the collection jars into a sampling tray and examining the sample for the presence of fish. Typically the drift nets are checked and cleaned twice per day, once first thing in the morning and once again in the evening. Record the catch separately for each period in order to be able to determine diurnal patterns.

Sampling effort is usually recorded as the number of hours between net cleanings to determine catch/hour. If more detail is required, it is also possible to estimate the volume of water sampled by the net during the period between net cleanings to determine the catch/m^3. To do this, measure the velocity of the water at the sampling site before setting the drift net and again after lifting the net for cleaning to determine the average water velocity through the net. Multiply the average velocity (m/s) by the area of the net mouth (m^2) to get the volume sampled per unit time (m^3/s) (remember to record the size of the drift net mouth). Multiply this value by the time the net was in place to calculate the total volume sampled. For this calculation, the drift net mouth must be completed submerged.

3.5.4 Electrofishing

Electrofishing refers to the use of electricity to stun and capture fish. An electrical current is passed between electrodes placed in the water and the resulting electrical field attracts passing fish (galvanotaxis) toward the positive electrode (anode). As fish pass close to the anode they encounter an increasingly stronger current gradient which acts as a narcotic and stuns the fish (galvanonarcosis), allowing them to be easily dip-netted from the water. Once captured, the fish may be identified, weighed, measured, tagged and then returned to the water. Fish taken by electrofishing revive quickly when returned to the water. Effort is automatically recorded by the electrofishing unit as the number of seconds of active electrofishing (i.e. the time current is applied to the water). **Record the effort (seconds) immediately after completion of sampling and reset the timer to zero.** Electrofishing techniques require experienced operators in order to reduce injury to the fish and to eliminate potential

injury to the personnel involved. Safety training or working with experienced personnel is required for operating electrofishing equipment.

Backpack Electrofishing

Backpack electrofishing is a sampling technique for small, wadable streams. A backpack electrofisher consists of a portable electrofishing unit and a power source (12v battery or mini generator) attached to a pack frame. It is equipped with a hand held, button-operated anode pole and a cathode plate which is left trailing in the water. The operator wears the pack unit and uses the button switch to activate the anode in order to stun fish while wading instream. One or more assistants wading next to the operator use dip nets to capture the stunned fish. The assistant also adjusts the electrofisher settings for the operator and monitors the electrical output. Sampling is normally conducted while moving upstream so that fish are not disturbed, prior to being sampled, by disturbances to the stream bed and material moving downstream with the flow.

Boat Electrofishing

Boat electrofishing is an extremely effective sampling technique for moderately shallow water and is used for intermediate streams, large rivers and shallow littoral areas in lakes. Two types of boat electrofisher are available, both of which consist of an electrofishing control box which is powered by a 5,000 watt generator. The ***portable boat electrofisher*** has a free control box and generator which can be loaded into an inflatable boat (Zodiac) and is ideal for small or intermediate sized rivers which cannot be waded and which cannot be effectively sampled by the low current outputs provided by a backpack electrofisher. Two anode configurations are possible, depending on stream size, and include either a hand-held, button operated anode pole or a foot-switch operated portable boom system. In both cases, a floating cathode plate is employed. The boat can be drifted downstream or an outboard jet can be used to provide increased mobility. In comparison, an ***electrofishing boat*** consist of an 18' aluminum river boat with an integral electrofisher control box and generator. It is also equipped with a work platform and flow-through live well for holding fish. It has a foot-switch operated anode boom system and uses the boat hull as the cathode. Boat electrofishers are designed for any intermediate or large river which is deep enough to allow a boat of this size to float and which has a site with a suitable boat launch. This unit has the largest anode/cathode surface area and is capable of generating the largest electrical field and the highest current outputs. Boat electrofishing sampling for both types of units is usually conducted while floating downstream, as this makes fish easier to dipnet and puts less stress on the dipnets and anodes.

3.5.5 Emergent Trap

An emergent trap is a passive sampling technique specifically designed to capture fry as they emerge from the substrate following hatching. A typical emergent trap consists of a square metal frame (0.3m x 0.3m) covered with a small mesh net and collection bottle. The mouth of the trap is placed on top of the substrate at a known or suspected spawning area where incubating eggs are known or thought to be present. It is left in place through the incubation period. Once the fry have hatched and absorbed their yolk sacs they emerge from the substrate. The fry from the eggs which were located under the trap mouth will be captured by the trap.

Emergent traps can be used to verify a suspected spawning area or to check for hatching success at a know spawning site.

3.5.6 Fry Traps

A fry trap is a passive sampling technique used to capture fry which are drifting downstream in flowing water. It is suitable for capturing fry which are larger than post-emergent size but which are not yet strong swimmers. The fry trap is anchored to the stream bed using 2 rebar posts and consists of a large metal frame open at the upstream end and otherwise covered with small mesh metal screening. "Wings" lead from the trap mouth into a low velocity area at the downstream end of the trap where the fry accumulate. The trap is designed so that it will pivot at the anchor point on the stream bed. To check the trap, simply tilt it forward and hold a collection bucket in front of the "top" of the low velocity holding cell. Water and fry from the holding cell will pour into the bucket as the trap is tilted. Typically the traps are checked and cleaned twice per day, once first thing in the morning and once again in the evening. Record the catch separately for each period in order to be able to determine diurnal patterns.

Sampling effort is usually recorded as the number of hours between trap cleanings to determine catch/hour. If more detail is required, it is also possible to estimate the volume of water sampled by the trap during the period between trap cleanings to determine the catch/m^3. To do this, measure the depth and velocity of the water at the sampling site before setting the trap and again after checking the trap to determine the average water depth and velocity through the trap during the sampling period. Multiply the average depth (m) by the average velocity (m/s), then by the width of the trap mouth (m) to get the volume sampled per unit time (m^3/s) (remember to record the width of the trap mouth). Multiply this value by the time the trap was in place to calculate the total volume sampled.

3.5.7 Gill Netting

A method of capturing fish that involves the setting of nets of various mesh sizes anchored in place in a river or lake. A gill net consists of netting suspended between a weighted "lead" line and buoyant "float" line which, when set, forms a vertical wall of netting. The lead line is attached at both ends to heavy weights to hold it in place and keep the net taught. The float line is attached at either end to floats. In Alberta, the floats must each consist of a pole which stands upright at the water surface and extends above the water surface for a minimum of 1.0 m. The top of the poles must have a blaze red or orange flag measuring at least 20 cm x 20 cm and marked with the Fish Collection Licence Number in 20 mm high letters. Typically, we use sandbags filled with rocks or sand from the gill net site for lead line weights. This way, all we have to carry with us to the site is a few empty sandbags. New gill nets need to have a length of sideline attached to either end which extends from the float line to the lead line to take the tension when the net is lifted to ensure that the mesh does not rip.

Gill nets are designed to function by catching on the gill covers of fish as they attempt to swim through. Fish of a size for which the gill net mesh size is designed swim into the net but can only pass partway through the mesh. When the fish struggles the twine slips behind the gill covers (opercula) and the fish becomes "gilled". Therefore, the mesh size of the gill net is important when selecting a net or nets for your sampling activity as gill netting can be a very size selective technique.

Gill net mesh size can be measured as either the stretch measure or square measure of the openings in the mesh. At Golder, we always use the stretch measure to identify our gill nets and when reporting results. The stretch measure is the distance between two opposite corners of the square mesh opening, when the square is stretched flat. Gill net mesh sizes typically range from 1.9 to 14.0 cm (3/4"-5.5"). As most gill nets are sold using imperial units of measure, the following table will help you convert mesh sizes to metric units.

Stretch Mesh Sizes:

Imperial (inches)	3/4	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
Metric (cm)	1.9	2.5	3.8	5.1	6.3	7.6	8.9	10.2	11.4	12.7	14.0

Gill net meshes are constructed either of monofilament or nylon. Monofilament is sturdier and longer lasting but gill nets made from this material do not compress and take up a much larger volume than a nylon net of the same dimensions. For longer nets, the volume of a monofilament net becomes significant.

Gill nets can be simple or multi-mesh. Simple nets consist of one mesh size only, although different nets may have different lengths and depths. Multi-mesh nets are also called "gang" nets and consist of more than one mesh size. Each mesh size occurs in a discreet section of the net which is called a panel. Gang nets typically have from two to five different mesh sizes or panels. Usually, each panel has the same length, although this is not always the case. An important component of recording sampling effort is to record the dimensions of all gill nets that are set. Record the depth of each net as well as the total length. Also record the number of panels, the mesh size of each panel and the length of each panel. Effort should also be recorded as the number of hours the net is set and CPUE is expressed as either duration (hrs), panel-hours, or meter-hours, depending on the type and variety of nets set.

Since the size of the mesh will have a major role in determining the size of fish (i.e. species or life stages) that will be captured, it is extremely important to record the mesh sizes of any gill net used. It is also important to record the catch for each individual panel or mesh size. The field form used to record the catch has a space for recording the mesh size for each fish captured. When removing fish from the gill net, the fish must be separated by mesh size.

Selecting a gill net or nets to be used for a project will vary depending on your sampling goals. Long gang nets with several different mesh sizes, from small to large mesh, are best for general inventory sampling and have the smallest level of sampling bias. For single mesh nets or nets with few panels, it is generally true that the larger the mesh size used the larger the fish that will be captured. The small 1.9 cm mesh nets will capture fish as small as the larger minnow species and juvenile life stages of larger fish. Mesh sizes in the range of 5.1-7.6 cm are typically used for salmonid species while larger mesh sizes will be employed to capture adult northern pike and burbot. Most gill nets will capture a larger size range of fish than mesh size would dictate as some species will be captured without necessarily being "gilled". For example, suckers may be entangled by their large lips and northern pike often bite and roll in the mesh, becoming entangled in mesh sizes too small to capture them by gilling. Bullheads on the other hand are often captured in mesh sizes too large to gill them when their pectoral and dorsal spines become entangled in the mesh.

Nets selected for sampling in rivers are generally different from those used in lakes. River gill nets typically have large floats attached to the float line for added buoyancy. Shorter nets are used as they must be set in low velocity pockets such as backwaters or pools and heavy weights are used to anchor the net so that it will remain in position in flowing water. Caution should be taken when setting nets in a river at high stage if floating debris is moving downstream which could damage or move the net. In lakes, much longer nets can be used if required and, since lakes typically have greater depths than rivers, nets can be set at a variety of depths. Lake nets can be set so that they float near the surface, are set along the lake bed or are positioned in mid column. For floating sets, nets with large floats attached to the float line can be used and long leads are tied to the weights to allow the net to remain at the surface. For sinking sets, nets without additional floats or with small floats are used. For bottom sets, the weights are tied tight to the lead line and long leads are tied to the floats so that the net will sit on the bottom and the floats will remain at the surface. For mid column sets, leads are attached to both the weights and floats so the net will be positioned between the bottom and the surface.

Gill netting is a sampling technique that can be used in the winter as nets can be set under the ice. In lakes where there is no current a jigger is used to run a length of sideline under the ice. A large hole is opened in the ice and the jigger is placed under the ice. The sideline is tied to the jigger and the lever arm is manipulated to send the jigger moving away from the hole. Once the jigger has moved far enough it must be relocated, either by sight if the ice is clear or by sound as the jigger is equipped with a "clicker" device. A hole is drilled at the location of the jigger and a hook is used to pull the sideline up the hole. In rivers or in the case of thick lake ice a Murphy stick is used to set the net. A Murphy stick consists of two sections of aluminum pipe hinged together which extends as an under-ice probe. The far end of the probe has an eye-hook at the end and a float a short distance back. A length of sideline a little longer than the gill net is tied to the eye-hook and the far end of the probe is pushed down through one hole in the ice and maneuvered towards a second hole where the attached sideline is hooked and pulled up through the hole. The process is repeated several times to extend the rope as far as desired. Once the sideline has been placed under the ice it is then attached to one end of the gill net and used to pull the net under the ice.

As a sampling technique, gill nets can have a high mortality rate if the fish are left in the net for a prolonged period or if water temperatures are high. If fish mortality is a concern, the nets should be cleaned of fish on a regular basis (e.g. every two hours). If mortality is desirable (i.e. fish are to be sacrificed) or not a concern, nets should be set overnight in order to sample day and night periods of fish movements and to allow capture of fish which may avoid the net if it is visible during daylight hours in low turbidity water.

3.5.8 Hoop Net (Fyke Net)

A hoop net is cylindrical net distended by a series of hoops or frames with one or more internal funnel-shaped throats whose tapered ends are directed inward from the mouth to prevent fish from escaping once they enter the net. A fyke net is a hoop net with two wings or leads of webbing attached to the mouth to guide fish into the enclosure. Our hoop nets have large square hoops at the front of the net and taper to a smaller diameter with smaller ring hoops at the back end. Webbing extends inwards and backwards between the sides of the first square hoop to form a "V" slot at the net mouth and a funnel is attached to the back of the second square hoop. The chamber between the funnel and the rear of the net is termed the "pot". The net is tapered at the rear end and held closed with a draw string which can be opened to permit removal of the trapped fish from the pot, although trapped fish may also be present

between the "V" slot and the funnel. The funnel also has a draw string which allows removal of fish from this chamber. If it is desirable to have a fyke net, use two lengths of webbing tied to the sides of the hoop net mouth to convert the hoop net to a fyke net.

Fyke nets are typically set at a time and location where fish will be moving through the area in a direction that will lead them into the net mouth. They are very effective when set in small tributaries to lakes or larger rivers during a spawning run but can also be used in shallow areas of lakes and larger rivers. The net and wings are anchored in place by tying them to rebar posts embedded in the substrate. The wings of the net should be set at a 45° to the axis of the hoop net.

As the holding chambers in the fyke nets are small, they should be checked and cleaned of fish on a regular basis, particularly during an active spawning run. Try to set the net so that fish in the holding chamber will not be subjected to high water velocities. Sampling effort is usually recorded as the number of hours between net cleanings. Record fyke net dimensions such as mesh size, mouth size, wing lengths and, when used in streams, whether full or partial channel blockage was achieved and whether the net mouth was oriented upstream or downstream.

3.5.9 Kick Sampling

Kick sampling is used to collect fish eggs from the substrate in spawning areas, both for species which are broadcast spawners and for those which bury their eggs (i.e. from trout redds). It can be used to determine if incubating eggs are present but it is generally considered a qualitative (i.e. non-quantitative) sampling technique and, unlike airlifting, is not suitable for determining the relative density of eggs. The kick sampler is attached to a pole and consists of a tapered net attached to a metal frame which forms the mouth of the net. It is generally used in flowing water. To use, grasp the pole and place the kick net against the substrate. Stand upstream of the net mouth and use your feet to disturb the substrate, letting the disturbed materials float into the net. Remove the net from the water and examine the contents of the net for eggs.

Kick sampling can only be conducted in water shallow enough or which is flowing slow enough to allow instream wading. This technique is simpler to use than the airlift sampler and requires considerably less equipment. It is a very efficient and fast technique for identifying spawning areas in wadable streams, particularly over long lengths of stream.

3.5.10 Minnow Trap

Minnow trapping is a passive sampling technique used to sample for the presence of minnow species and small life stages (i.e. fry) of larger species which can be difficult to capture using other techniques such as electrofishing or gill netting. The traps we use are Gee Minnow Traps which consist of two pieces which are clipped together to form a small cylinder slightly tapered at either end. Each end has a funnel which leads into the centre of the trap which allows fish to enter but prevents them from escaping. The traps are generally placed on the substrate in the shallow shoreline areas of lakes and streams with the long axis of the trap parallel to the shoreline. A length of sideline is used to tie the trap to a stake or anchor on shore to keep it in place. The anchor site is usually flagged so that the site can be easily found when returning to check the trap. The traps can be baited or unbaited, depending on if the intent is to trap fish moving through the area or attract fish to the trap.

Sampling effort is recorded as the number of hours that the trap is set.

3.5.11 Observation

Underwater observation involves the use of either snorkeling or SCUBA techniques to observe, count or record the activities of fish. Scuba diving is generally restricted to lake habitats but may also be employed in deeper rivers. It is a fairly intrusive technique and is considered to be more disruptive than snorkeling and requires that the observer have a valid scuba certificate. Snorkeling is commonly employed by Golder to conduct fish observations in stream habitats which have low turbidities. It is less disruptive than SCUBA and logistically simpler. Equipment used for snorkeling includes a diving mask, snorkel, dry suit, diving gloves and an underwater writing slate. A wet suit can be used in place of a dry suit in warm water but a dry suit is preferable as it increases observation time. To date, snorkeling has been used by Golder to study the habitat preferences of some fish species but the technique can also be used to determine fish abundance and distribution.

3.5.12 Post-Emergent Trap

Post-emergent traps are a passive sampling technique for use in flowing water to sample for the presence of post-emergent fry. Unlike emergent traps which capture the fry as they emerge from the substrate, post-emergent traps capture the fry as they drift downstream following emergence. Unlike emergent traps, it is not required that they be set at a spawning site overtop of incubating eggs, there only needs to be a spawning area somewhere upstream of the set location. Post-emergent traps are essentially extremely large drift nets. Each trap consist of a tapered, small-mesh net attached to a metal frame which forms the trap mouth. The trap mouths are 0.9 x 0.9 m in size. Each net is equipped with a removable sample bottle attached at the downstream end of the net. A post-emergent trap is set by anchoring two rebar poles into the substrate and looping the four hoops attached to the trap over the poles and sliding the trap down until the bottom of the trap sits on top of the substrate with the mouth facing upstream.

Post-emergent traps should be checked at a minimum of twice per day, once in the morning and once in the evening. Definite diurnal/nocturnal patterns have been observed using these traps, so be sure to record the catch separately for each sampling period. To check the catch, remove the trap from the stream and wash all materials from the netting into the sample bottle. Dump the contents of the bottle into a sampling tray to look for the fry. Post-emergent fry are extremely small and almost transparent. They are best seen by looking for the large, dark eyes which will be their most obvious feature. They may also be seen to be swimming around in the sampling tray. It is also prudent to check the mesh of the trap for additional fry as they are so small that some become "gilled" on the mesh and do not wash down into the collection bottle. If more than one species may be hatching at the time and location of your study and you are not sure of the identification of fry in the sample, the sample should be preserved in 5% buffered formalin for laboratory identification.

Sampling effort is recorded as either catch/hr or catch/m^3, as described for fry traps (section 3.5.6). Post-emergent traps are used to check for the presence of post-emergent fry in the study area, either as proof of spawning activity in upstream areas or simply to tell if this life stage or a certain species is present. They are also used in entrainment studies, which are conducted to determine if fish are entering man-made structures such as diversion canals or water intakes. In addition, they may be used to

determine the timing of hatching periods and the relationship between hatching and environmental parameters such as discharge or water temperature.

3.5.13 Seine Netting

Seine netting refers to the use of a specifically designed net to catch fish by dragging it through the water. Seine nets consist of netting suspended between a float line and a lead line. The netting is constructed of thicker net material than gill nets so that fish do not become gilled in the mesh. Mesh sizes vary but most nets are constructed of minnow netting which has a small mesh size and is suitable for catching forage fish and small life stages of larger fish species. Larger mesh seine nets are also available for sampling for large fish and are much easier to drag through the water. Two types of seining operations are possible, beach seining and boat seining.

Beach seining is accomplished by two people dragging the net through the water while wading and is used in shallow water areas in lakes and streams. To beach seine, each person grabs one end of the net by placing one foot in the loop at the end of the lead line and holding the loop at the end of the float line in their hands. One person walks out from shore to a suitable depth. Both people then walk parallel to shore dragging the net between them. The lead line is kept in contact with the substrate to prevent fish from escaping under the net by dragging the foot looped to the lead line along the bottom. As they walk through the water, fish are herded in front of the net. The person near shore moves slower than the person further out. When the further person has passed the near shore person they curve back to shore, meeting the near shore person at the waters edge and bringing the two ends of the net together forming a pen holding the captured fish. Both people then drop the float lines and pick up the lead lines and standing side-by-side pull the net up on shore, ensuring that the lead line remains in contact with the substrate at all times. The trapped fish will congregate in the end of the looped net and will be dragged up onto shore.

Boat seining is a specialized technique used in water too deep to wade. It usually involves the use of long, large mesh seine nets for the capture of large fish. It is particularly useful in areas where fish congregate such as spawning areas of lakes or snye areas in rivers. The principle is similar to beach seining except that a boat is used to move the offshore end of the net through the water. A pole is attached to both the lead and float lines, at the boat end of the net, and is used to keep the lead line on the bottom.

Seine netting is a suitable technique only where the bottom is fairly smooth. If large substrate particles, debris, or aquatic vegetation is present which will cause the lead line to lift off the bottom as it passes, the technique will not be very efficient and most or all fish will escape. Seine netting is typically used to sample for the presence and abundance of small fish and life stages which are not effectively sampled for using other inventory techniques.

Sampling effort is recorded as the number of seine hauls made and either the distance (m) or the area (m^2) seined for each haul. Record the dimensions of the seine net used (length/depth/mesh size) and the shoreline distance of each seine haul. If area is required, multiply the length of the seine haul by the length of the seine net used.

3.5.14 Set (Trot) Line

A set line is a series of leaders and baited hooks strung from one central line which is anchored to shore. Set lines are used to catch predatory fish and are usually set out overnight. Golder set lines are 30 m in length, which includes a 10 m lead with no hooks and 20 m of line with a total of 10 leaders/hooks set at 2 m intervals. A large lead weight is attached to the end of the line to keep it in place once it is set. The 10 m lead is used to set the baited hooks well out from shore or can be tied short to keep the hooks near shore, as desired.

Sampling effort is recorded as the number of hours the line is set or the number of hook-hours if set lines of different lengths and number of hooks are used. Record the size of the hooks that are used (e.g. #8 hooks).

3.5.15 Trap/Counting Fence

Fish traps or counting fences are a passive sampling technique used to capture fish as they move past a specific location. They consist of one or more trap boxes with fences (wings) which stretch out in front of the entrances of the boxes to lead fish into the trap. The trap boxes are large holding pens enclosed on four sides as well as on the bottom with metal or plastic mesh. The front of each box has an opening equipped with a funnel which leads into the interior of the trap box. The boxes are also equipped with locking plywood lids to protect the fish as they congregate in the traps. The fences consist of angular aluminum frames with a series of holes into which are fitted round aluminum rods to form a barrier to fish passage. The counting fence is installed by attaching the components to rebar posts driven into the stream bed and by placing sandbags on cradles included in the fence design. The fences or wings are set as close as possible on a 45° angle to the trap box entrance.

Two types of counting fence set-up are possible, the **one-way fence** and the **two-way fence**. The one-way fence has only one trap box and one set of wings and is used to capture fish moving in one direction. The two way fence has two trap boxes facing in opposite directions, each with its own set of wings, to capture fish moving in both directions. Counting fences can be used to sample portions of the shoreline in lakes or large rivers but are typically used in small or medium sized streams to close off the entire channel and capture all fish moving past the trap location. In this case, the box which captures fish moving upstream is called the upstream trap and the box catching fish moving downstream is called the downstream trap. In streams, the trap boxes should be set in a location where the water velocity is not too high so that the fish caught in the trap can rest. If no such site is available, a piece of plywood placed upstream of the trap will provide a velocity shelter

The counting fence should be checked a minimum of twice a day, once first thing in the morning and once again in the evening and the fish removed from the traps using a dipnet. The fence should also be cleaned of debris to keep the water flowing freely through it and to reduce the build up of pressure on the fence. Record the day, time and catch each time the fence is checked. During an active spawning run, the fence may need to be checked more frequently so that the number of fish holding in the trap boxes does not become too large. Record the catch separately for each sampling period. After removing the fish from the trap boxes they should be released in the direction that they were traveling so that they can continue in that direction (i.e. fish from the upstream trap should be released upstream of the counting fence while fish from the downstream trap should be released downstream of the fence).

Counting fences are used to determine the species, relative abundances and timing of movements of fish past the sampling site. They are typically used to capture fish during their spawning runs in the spring or fall or to quantify the movements of fish into and/or out of tributary streams.

3.6 Catch-Per-Unit-Effort (CPUE)

Catch-Per-Unit-Effort is a measure which relates the catch of fish, with a particular type of gear, to the sampling effort expended; it is expressed as: ***number of fish captured/unit of effort***. Results can be given for a particular species or the entire catch. CPUE is used to define species relative abundance and to compare abundances between sites and/or seasons. Effort can be expressed a number of ways depending on the sampling equipment. If CPUE data is required, sampling effort must be recorded. Following are common CPUE calculations for traditional sampling gear:

• electrofishing (boat and backpack)	No. of fish/100 seconds (of active electrofishing)
• gill net	No. of fish/net-hour, or /panel-hour, or/100m of net-hour
• set line (trot line)	No. of fish/hour, or /hook-hour
• angling	No. of fish/hour, or /angler-hour, or /rod-hour
• minnow trap	No. of fish/hour, or /trap-hour
• seining	No. of fish/area seined (m^2), or /length of shoreline seined (m)
• counting fence (fish trap)	No. of fish/hour
• drift net/post-emergent trap	No. of fish/hour, or /volume of water (m^3)

It is important to recognize the components of the effort inherent in the sampling technique being employed so that effort will be recorded properly. Most field forms will have fields specifically designed to record the pertinent information. Record all aspects of your sampling effort (e.g., number of set lines used and number of hooks per line) so that CPUE can be calculated. CPUE values will be used in our own studies to establish relative abundance. Our data may also be used in a more historical context to compare the abundances we record with past or future research, using both similar and different sampling gear, and CPUE values may need to be recalculated to conform to other studies. The more detailed used when recording sampling effort, the easier it will be to accommodate these needs.

3.7 Coldwater Fish

When dealing with the general suitabilities of freshwater habitats for game fish species, temperature regime is often used to describe the habitat potential and the species assemblage which could possibly be present. Although the terms are not definitive or precise, the designations of habitats as "coldwater" or "coolwater" habitats and the associated fish fauna as "coldwater" or "coolwater" species are often used.

Coldwater fish are those which have a preference for summer water temperatures ranging from about 10-18 °C. In Alberta, this encompasses all of the salmonid species including the trouts, whitefishes and Arctic Grayling. Within this group the species will have differing temperature preferences and tolerances (see section 3.50 - Temperature Criteria).

3.8 Condition Factor (Ponderal Index)

Condition factors are used to describe the plumpness and, by inference, the well-being of individual fish. Formulas are used to calculate condition factors using the fish's length and weight and are based on the principle that the weight of a fish will vary with the cube of its length. Any variation in the shape or plumpness will be measured using the formula. Golder primarily uses the coefficient of condition *K*, also called the Fulton condition factor. The formula (**using metric length and weight data**) is as follows:

$$K = [\text{weight (g)} \times 10^5] / \text{fork length}^3 \text{ (mm)}$$

Condition factor is believed to reflect the nutritional state or well-being of an individual fish. The *K* value will be 1.0 for fish whose weight is equal to the cube of its length. Fish which have a *K* value >1.0 are more plump and are thought to have a higher degree of well-being or better nutritional state-of-health, whereas fish with a value <1.0 are considered to be less robust.

Condition factors vary with season, sex, sexual maturity, age and various other factors. Therefore, if sufficient data is available, average condition factors for a species should be calculated separately for each sex and should exclude young-of-the-year fish. Condition factors also vary by species, particularly if they have different shapes, and should not be used to compare well-being between fish species. They can, however, be used to determine differences in the condition of fish of the same species in different years or at different sites. Fulton's condition factor is also limited for comparisons between fish populations in different lakes because of differences in growth parameters. Other formulas for condition factor calculations are available and would be designated by the project manager if they are required.

3.9 Coolwater Fish

Coolwater fish are those which generally prefer summer water temperatures ranging from about 18-26°C. Alberta species generally considered to belong to this group include northern pike, walleye, sauger, yellow perch, goldeye, mooneye and lake sturgeon (see also Section 3.7 - Coldwater Fish).

3.10 Creel Census

The term "creel" refers to the basket a fisherman uses to hold the fish which have been angled and a creel census refers to a survey in which recreational fisherman are censused in order to determine aspects of the recreational fishery. Important survey goals typically include determining angler effort and success (i.e. fishing pressure and harvest) and may include examining the fisherman's catch for tagged fish or to collect ageing structures.

3.11 Dissolved Oxygen Criteria

The dissolved oxygen concentration in the water is an important habitat component. Different fish species have different dissolved oxygen requirements and have different tolerances to low dissolved

oxygen levels. Dissolved oxygen criteria provide minimum dissolved oxygen levels that are necessary to protect various life stages and have been developed for selected game fish species. Golder has prepared a document which list the criteria for selected Alberta species (Taylor and Barton 1992).

3.12 Fecundity

The most common measure of reproductive potential in fish. Female reproductive potential is the total number of eggs (ova) in both ovaries of a gravid female fish. Fecundity normally increases with the size of the female within a given species. For most studies conducted by Golder, fecundity is determined for female fish only. Fecundity is determined by recording the total weight (g) of both ovaries and removing a small sub-sample of known weight from the middle of the ovaries (usually a 1.0 g sample). Count the number of eggs in the sub-sample to determine the number of eggs/g of ovary. Multiply this value by the total ovary weight to calculate the total number of eggs.

3.13 Field Forms

Golder uses a number of specially designed field forms to aid in recording field data. They are not meant to replace the use of a field book or the recording of detailed field notes. They are intended to provide a template showing the type of supporting data that must be recorded for each sampling technique and provide an organized method of recording the sampling results. For each specific or general type of sampling technique there is a ***Catch Record Form*** (e.g. Gill Net Catch Record Form) for recording sampling information such as location, technique, effort and is used to summarize the results. The main form for recording the catch results is the ***Fish Sample Record Form*** which has fields for recording length and weight data and other particulars for each individual fish. On the back of this form you will find a list of all abbreviations to be used when recording data.

A copy of each field form is kept in the aquatics reference file located at Carole Collins desk (Aquatic Ecology Group Secretary). Copy the forms you will require onto waterproof paper and return the originals to the file.

3.14 Fish Collection Licence

Fish collection licences or permits are granted by provincial governments or by DFO and are required for all fisheries sampling activities. Obtaining a license varies from province to province. In Alberta, a Fish Collection Licence is granted to Golder by Alberta Environmental Protection, Fisheries Management Division. Each Licence is specific to the waterbody(s) being sampled and is valid for a specified time period. To obtain a Licence you must forward a letter of request to the F & W District office for the region in which you wish to sample. Include in the letter the reason for sampling, the location(s) to be sampled, the period the permit should be valid for, the capture techniques to be employed, the fate of the fish captured (i.e. will any be sacrificed), and the personnel to conduct the sampling. They will then send a Licence granting permission to carried out the proposed activities. They may impose specific restrictions on the licence (i.e., restricted number of fish allowed to be sacrificed, designation of a certain landfill for fish disposal, or specific reporting requirements) and the permits should be read carefully to ensure all restrictions will be followed. The original permit or licence should be immediately placed in the project file and a copy of the document given to the field personnel. You must be prepared to produce a copy of the permit while conducting any field sampling.

The Fish Collection Licence will also specify a date by which a permit return is to be submitted to the issuer. In Alberta, the permit return is a form which accompanies the Licence. The form requests information regarding the sampling conducted under authority of the Licence, such as sampling locations and results. Fill out the form and send it to the office which issued the Collection Permit following completion of sampling activities and prior to the date specified on the Licence.

3.15 Forage Fish

A general term applied to smaller species of fish that "forage" on small invertebrate animals or plant materials. This includes minnow species and other small fish such as sculpins, stickleback, trout-perch and darters.

3.16 Game (Sport) Fish

Fish used by anglers for recreational fishing or sought after by the commercial fishing industry, e.g., northern pike, walleye, trout, etc.

3.17 Geographical Position

All sampling sites, whether they are point locations (such as a minnow trap site) or sections (such as a section of river that was electrofished), should be recorded on a map of the study area. The standard is to use a 1:50,000 NTS topographical map but other maps or airphotos can be used if they provide greater detail. The geographical position of sampling sites can also be recorded using Universal Transverse Mercator (UTM) grid coordinates or by degrees of latitude/longitude. UTM coordinates are particularly useful in case the map is lost as they can be used to pinpoint the sampling site on a new map.

UTM and latitude/longitude are two different systems of grid coordinates used to establish geographical location. Both systems appear in the margins of 1:50,000 scale National Topographical Service maps. A calibrated ruler is used to calculate coordinates of any point on the mapsheet. Golder always uses UTM coordinates rather than lat/long, unless otherwise specified by the client.

The most accurate way to record the position of the sampling site is to use Geographical Position System (GPS) technology. If possible, use a GPS rover unit to record a position file at the sampling site that can be stored for differential correction. You should also use the GPS unit to record a "real-time" waypoint in the event that the stored file is lost or accidentally deleted. If you do not have a GPS unit capable of differential correction, a simpler unit will allow you to record a waypoint, which will be less accurate.

3.18 Gradient

Gradient refers to the vertical drop in elevation along a watercourse over a horizontal distance. It is recorded as the percent gradient. To determine the gradient over a length of stream, measurements are taken off of a 1:50,000 scale NTS map of the watercourse. Locate a point upstream and downstream of the study area on the map where contour lines cross the stream and determine the difference in elevation

(m) between these two points. Measure the distance (m), following the channel, between the same two points using a map wheel. The gradient is calculated as follows:

$$\text{gradient (\%)} = [\text{difference in elevation (m)}/\text{distance (m)}] \times 100$$

In very flat terrain determining gradient from a map may not be possible. In these situations, gradient may also be measured in the field using a clinometer. With this method one person with a clinometer stands at the upstream end of the section to be measured, a second person moves as far downstream as possible while still visible to the upstream person. Both individuals stand at the very edge of the stream with their feet at the water surface. The upstream person uses the clinometer to measure the angle from his or her eyes to the eyes of the other person. If your clinometer measures in % then this value should be recorded. If the clinometer measures in degrees, then percent can be calculated by taking the tangent of that number and multiplying by 100. This technique may need to be repeated several times and averaged to determine the gradient of a large section of stream.

3.19 Growth

Fish show indeterminate growth in that they continue to grow throughout their lives rather than stop growing once they reach an "adult size". However, growth rate is asymptotic, meaning the growth rate decreases with increasing age approaching some maximum value for the individual or population. As growth rate is a function of time, true growth rates can only be determined when fish length and age is known. Two parameters related to growth rate are: 1) the maximum size which is possible for fish in a given population, and; 2) the rate at which maximum size is achieved. The maximum size value indicates whether the population is "stunted" (i.e. does not have the potential to reach the normal maximum size for the species) and differentiates between populations that are stunted and those which do not achieve their potential maximum due to a short life span. If the maximum size for the population is at the lower end of the normal range for the species, than the population is slow growing rather than stunted. See Mackay et al. (1990) for methods of calculating maximum size and rate.

3.20 Gonads

Organs which are responsible for producing haploid reproductive cells in multicellular animals. In the male, these are the testes and in the female, the ovaries. In fish they are located in the peritoneal cavity, extending between the diaphragm and the cloaca, and running along the dorsal side of the cavity along both sides of the spine. When the fish is gravid, the gonads will fill much of the peritoneal cavity.

3.21 GSI (Gonadal:Somatic Index)

Gonad-Somatic Index is the proportion of reproductive tissue in the body of a fish to total body weight. It is calculated by dividing the total weight (g) of the gonads by the total body weight (before gonad removal) and multiplying the result by 100. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth. It is believed to be an indicator of fish health in that a fish with a comparatively low GSI for its species is considered to not have sufficient energy available for proper gonad growth. Fish are seasonal spawners and the size of the gonads changes dramatically as they pass through the various stages of gamete maturation. It is preferable to conduct

GSI measurements for fish just prior to the spawning season when the gonads are fully developed (i.e. gravid).

3.22 Habitat

Fish habitat refers to aspects of the physical environment which provide the requirements of a fish community, species or life stage. Habitat evaluations conducted for fisheries studies generally involve measurements or evaluations of macro- and/or micro-habitat conditions in order to determine the types of fish or life stages an area might support, the quality of available habitats or habitat limitations.

Macro-habitat

Macro-habitat refers to habitat components which are attributable to a general region or section of the study area. They are general conditions related to geographical location, climate, stream order, lake type, etc. For macro-habitat evaluations, we typically measure general water quality parameters (dissolved oxygen, temperature regime, pH, conductivity, turbidity, visibility (secchi depth), stream gradient), as they relate to describing coldwater and coolwater habitats and the types of fish species which may be present. Different fish species have different tolerances for macro-habitat conditions which affect their abundances and distribution.

Micro-habitat

Micro-habitat conditions are the physical conditions at a specific location. For micro-habitat assessments we measure or evaluate water depth, velocity, substrate particle size and condition, and the availability of cover for fish. Cover includes instream cover (i.e. any objects which provide velocity shelters) and overhead cover (i.e. anything which provides visual isolation). Each fish species has a range of micro-habitat conditions which are suitable, ranging from barely useable to optimal. In addition, each species has a series of life stages which may also have different habitat requirements. These life stages include spawning, incubation/embryo, nursery, rearing, feeding (adult summer) and overwintering.

Knowledge of the suitable and preferred habitat conditions for different species and life stages is very useful when conducting fisheries inventories, habitat evaluations and impact assessments. Information concerning these habitat requirements is available in the form of Habitat Suitability Index (HSI) models and Habitat Preference Criteria (HPC). HSI models were developed by the U.S. Fish and Wildlife Service and are species-specific models, with each model containing information for all life stages of one fish species. The models include all the habitat variables (macro- and micro-habitat) that accumulated research has determined to be significant to each species with respect to population abundance. Each habitat variable is provided along with the range of suitable and optimal conditions. HPC are species-specific curves showing suitable and preferred conditions for micro-habitat variables (depth, velocity, substrate and cover). HPC curves are available for a limited number of game fish species and were developed from snorkeling observations of the different species and life stages (developed for the most part by Golder from streams in Alberta).

Measurements of macro- and micro-habitat conditions in lakes and streams are useful in combination with inventory data and existing information to establish habitat potential for a study area. Habitat based assessments are being used more frequently to provide a complete picture of habitat potential, with respect to use by different fish species and life stages, rather than relying on fish inventory data from a specific point in time.

3.23 Length

Refers to the whole body length of a fish. There are three types of length measurements: standard length, fork length, and total length. The measurement most commonly used in Canada and ***required for use by Golder*** is the ***Fork Length*** and is ***always recorded in millimetres (mm)***. Fork length is the distance from the most anterior point on the head to the tip of the median caudal fin rays. The fork length of captured fish is measured on a fork length board, which is a trough or flat board with a ruler attached to the surface and a vertical block at the anterior (zero mm) end. Place the fish on the board with its head flush with the block and spread the caudal fin to show the mm mark under the anterior point of the fork.

Some fish species such as burbot, sculpins and darters do not have a fork in their caudal fins. For these species, the standard measurement is Total Length, which is the distance from the most anterior part of the head to the distal tip of the longest caudal fin ray.

The fish which must be measured for length and weight may vary between projects. You will always be measuring game species but will not necessarily have to measure rough or forage fish. The project manager will be able to tell you what is required. For instances where large numbers of individuals are being captured and the time required to measure length and weight is excessive, it may be possible to measure length only for some fish. A large number of lengths are required to produce a complete length-frequency distribution (see section 3.25) while a lesser number of weight measurements are required to provide an accurate length-weight analysis (see section 3.26). If fish are being preserved, always measure length and weight before preserving.

3.24 Length-at-Age

Length-at-age analysis is used to determine the average length of fish in each age class in the population. This analysis can only be conducted for individuals for which age is known. For each age class (i.e 1 year old fish, 2 year old fish, etc.) calculate the range of lengths, mean length and the standard deviation of the mean. Plot this data graphically showing the range, mean and standard error (error bars) (see section 3.47 standard error and standard deviation) with age as the X-axis.

3.25 Length-Frequency Analysis

Length and weight data provide the statistics that are the cornerstone of fisheries research and management. Rate of change of length in individuals and length-frequency distributions are key attributes of fish populations. Length-frequency analyses provide an important description of population structure and are used to provide information for the interpretation of age and growth, especially for young fish. Length-frequency distributions reflect the interaction of rates of reproduction, growth and mortality of the population. However, when interpreting length-frequency data it is important to evaluate

sampling biases for the capture technique that was used, particularly with respect to size selectivity. The length-frequency distribution of a population is shown graphically by plotting the number of fish in each size class using a histogram chart. Typically, size classes include every 50 mm fork length interval (i.e. 0-50 mm, 51-100 mm, 101-150 mm..... etc.) but may be more frequent if you have a large sample size. When plotting the length-frequency distribution using Microsoft Excel, label the size classes on the X-axis of the graph using the complete label (i.e. 0-50 mm, not 50 mm).

Using the length-frequency analysis to determine fish age and growth rates is called the Peterson method. The plot of the length-frequency analysis is examined for peaks which are believed to represent each of the year classes in the population. The peak closest to the Y-axis would represent zero aged fish (young-of-the-year) and each peak after that should represent another year class. Great care must be exercised when conducting age analysis with this technique. Typically, distinct peaks are only evident for the first few year-classes. Individual fish exhibit different growth rates and as they get older, the overlap in size ranges for each age class becomes too great and the peaks in the length-frequency distribution are lost. In addition, this method requires measurement of a large number of fish which represent an unbiased sample of the population. The size intervals (fork length classes) chosen for plotting these data are particularly important, as size intervals which are too large or too small will obscure the peaks. Other problems with this method include dominant year-classes which may obscure the peaks of weaker year-classes and divergent growth rates of male and female fish complicates the analysis as does the small incremental changes in length which occur in older fish. However, the Peterson method is quite suitable for some forage fish populations where the life-span is short. It is the recommended ageing method for some minnow species which may have life-spans as short as three years.

3.26 Length-Weight Relationships

Length-weight relationships can be used in order to assess the state of well-being of a fish population. These relationships can be used to compare the condition or "fatness" of fish in a population to other populations, or to that in previous years. As a fish population size increases and/or food resources decline, individual fish become thinner and the ratio of weight to length decreases.

The relationship between fish length and body weight is curvilinear, and can normally be represented by the following function:

$$W = aL^b$$

where W = weight, L = length, and 'a' and 'b' are constants which are characteristic of the population being examined. The constant 'b' reflects the rotundness of the fish or the rate at which weight increases for a given increase in length. In general, a value of 'b' less than 3.0 represents fish becoming less rotund as length increases, and 'b' greater than 3.0 indicates a population where fish become more rotund as length increases. If 'b' is equal to 3.0, growth is isometric, meaning shape does not change as fish grow.

The length-weight relationship that we typically use is called length-weight regression analysis. The length-weight relationship can be changed from curvilinear to linear (straight line) using a $\log_{10}$ transformation of both length and weight. The relationship between length and weight becomes:

$$\log W = \log a + b \log L$$

where log a is the 'Y' intercept of the regression line and b is the slope of the line. A regression analysis can be conducted from length and weight measurements of a sub-sample of the fish population. Be sure to measure fish which are representative of the size range in the population, that is an even number of fish should be measured from all size groups in the population, from the smallest to the largest fish. A general rule is that at least 30 fish should be measured to provide a large enough sample size to calculate an accurate regression. The regression analysis plots the log weight versus log length for all the fish measured and then produces the "best fit" straight line that approximates the mathematical relationship between length and weight. The regression analysis can be conducted by entering the length-weight data on a computer spread sheet (Microsoft Excel) and having the program conduct the log transformation of the data. The computer program will provide the regression equation, including the values for 'a' and 'b'. When conducting a regression analysis, you should also record the 'R' value (coefficient of determination) that the computer calculates as this value represents properties of the linear relationship. The higher the 'R' value, the more closely the data conforms to a straight line and the better the regression equations represents the data.

Differences often exist in the body weight to length relationship for males and females in the same population. If possible, length-weight regressions should be calculated separately for the two sexes. The relationship also changes throughout the annual growing season, particularly for females, as gonad size and weight increases, so care should be taken when comparing various sets of data. Prior to conducting a length-weight regression analysis, the length-weight data should be plotted on a scatter diagram in order to spot 'outlying' data points. Points which are well outside the range represented by the other data points should be checked for accuracy to make sure both length and weight were recorded properly.

3.27 Lesion

Lesions are the result of a pathological change in body tissue. External hemorrhagic lesions (bloody sores) may be observed on the body surface of the fish and should be recorded on the Fish Sample Record form. Reddened areas and lesions on the body surface are evidence of systemic (widespread, internal) infections of bacteria or superficial bacterial infections. Skin lesions in wild fish are seen most often in the early spring when rising water temperatures encourage bacterial growth at a time when fish are least resistant to it. An increased prevalence of skin lesions also has been associated with fish from water with a high organic load and bacterial community, such as below a sewage outfall.

3.28 LSI (Liver:Somatic Index)

Liver-Somatic Index is also known as hepato:somatic index. It is the ratio of liver weight (g) versus total body weight, expressed as a percentage of total body weight. The LSI is used as an indicator of fish health. Energy is stored in the liver in the form of glycogen and the relative size of the liver is believed to correlate with nutritional state.

3.29 Marking/Tagging

Identification of individual fish or simply identification of fish which have been captured is required for some projects. Different marking techniques are available, depending on the goals of the study.

3.29.1 Anchor (Floy) Tagging

A practical and inexpensive method of permanently marking individual fish. The tag, shaped like an inverted "T", is most commonly inserted through the fishes' back at the base of the rear portion of the dorsal fin and anchored between the epipleural bones of the dorsal fin using a special tag-gun. The tip of the gun is a hollow needle which is inserted through the skin and muscle. As the handle of the tag-gun is depressed, an injector rod pushes the anchor portion of the tag out the end of the gun through the needle. The tag-gun needle will not pass through fish scales. In order to insert the needle, use the tip of the needle to lift the posterior edge of a scale and slip it in under the scale. Fully insert the needle through the skin by inserting it to the base of the needle and depress the handle. Once the tag-gun handle has been fully depressed, hold it in the depressed position while giving the gun a quarter turn to free the tag from the needle. Still with the handle depressed, remove the tag-gun needle from the fish and the tag will remain anchored in place.

The posterior portion of the Floy tag remains outside the fishes' body and is usually brightly coloured and carries a numeric identification code. This tagging method is used when conducting mark-recapture population estimates and basic fish movement studies. It is also the preferred marking technique when seeking angler return data to aid in establishing fish movements. Tags marked with the researchers address and the phrase "$2 reward" are often used to ensure angler response.

When sampling, always record the recapture of marked fish, even if the tag is not one that was inserted during your present study. It is common to catch fish carrying old Floy tags inserted by other agencies who will provide the date and location the fish was tagged; information which will provide movement data for all of the researchers involved. Older tags will usually have a build up of algae and will need to be scraped clean with a knife in order to read the tag number and other information.

Floy tags will usually carry the name and address of the client/agency that Golder is working for and, therefore, the tags are usually provided by the client. If this is not the case, Floy tags will need to be ordered and discussion with the client may be necessary to decide what writing the tags will carry.

3.29.2 Visual Implant (VI) Tagging

A "micro-tag" method using tags which are inserted under the skin. VI tags are suitable for use when a tagging method is required which has minimal effects on the swimming and feeding efficiency of the fish. Good for tagging smaller fish than is possible with the anchor tag method, such as small fish species or juvenile fish. Each tag consists of a small metal strip with an individual alpha-numeric code (typically three digits) which is inserted using an injector into a clear tissue somewhere on the fishes body (e.g., post-ocular tissue for salmonids). If working with non-salmonids, it will be necessary to determine a suitable implant location for the fish species you are working with. The implant location should have a sufficiently thick layer of clear tissue so that there will be room to insert the flat injector

needle and the tag can be read through the tissue. Record in the field notes the location (including left or right side) of tag insertion for each fish species that you are tagging. To tag a fish, insert the injector needle into the selected tissue, depress the injector and hold it down while removing the needle from the fish.

3.29.3 Batch Marking

A marking method which does not distinguish between individual fish. Common methods are fin clipping or dye marking. Batch marking can be used to distinguish fish from specific sites by varying the location on the fishes' body which is dye marked, the colour of the dye or varying which fin is clipped by sampling site. This method is suitable for simple movement studies and for simple mark-recapture population estimates. This method is also used when extremely large numbers of fish need to be marked, as it is simple and more economical than anchor or VI tagging.

Dye marking is accomplished by injecting a small amount of a coloured dye or liquid plastic sub-cutaneously. It can be used for marking very small fish, such as minnows and other forage fish, since a very small hypodermic needle can be used as the injector. One disadvantage of dye marking forage fish is that it is difficult to avoid using a colour which is readily visible to the researcher without increasing the probability of predation of the marked individuals.

Fin clipping includes removing or distinctively altering a fin in a recognizable manor. Fin removal is usually only conducted for non-essential fins such as the adipose fin on salmonids. For other fins such as the pectoral or pelvic fins, the first two fin rays may be removed. For larger fish, a hole punch can be used to make a distinctive mark on a fin. When clipping a fin, it is important to make straight, regular cuts to distinguish the mark from naturally frayed or eroded fins. Record the fin which is marked for each sampling site.

3.29.4 Radio Tagging

Attachment of a battery powered radio transmitter to a fish in order to follow its movements using a radio telemetry receiver. The transmitter is affixed externally or surgically implanted in the body cavity. To avoid adverse effects on swimming ability, the transmitter should be <2% of the fishes' body weight. Ground, boat or aerial surveys are conducted with the telemetry receiver in order to follow the fishes movements.

3.30 Maturity (State-of-Maturity)

Maturity refers to the state of gonad maturation of an individual fish at the time it is examined. It does not refer to whether or not the fish is "mature" (i.e adult); classification of a fish as juvenile or adult is referred to as life-history stage (see Section 3.46).

For adult fish, the gonads will typically progress through a series of conditions or phases of maturation each year during the seasonal development cycle. Although juvenile fish have only one possible state-of-maturity, adult fish can be one of several maturities. The state-of-maturity is used to determine the current reproductive status of the individual. For fish populations, state-of-maturity data can be used to

determine the size or age at first spawning, the proportion of the stock that is reproductively active, or to illustrate the nature of the reproductive cycle.

Golder uses a system that includes **9 maturity categories**. The 9 categories, their definitions and abbreviation codes are presented on the back of the Fish Sample Record forms used to record the data. More detailed definitions and descriptions of each maturity category, for both males and females, are provided in Appendix I. Maturity is best determined by conducting an internal examination of the gonads, which requires sacrificing the fish. Maturity can sometimes be determined by external examination of the fish based on fish size and by knowing the typical spawning period for the fish in relation to the capture date or, for some species, by external secondary sexual characteristics which become pronounced during the spawning season (see Section 3.41). The classification system includes an "unknown" category for fish which are examined externally and for which maturity cannot be determined.

For many studies, most or all fish will be released live and only external examinations will be conducted. For other studies, a sub-sample of fish captured will be sacrificed for definitive state-of-maturity data. The following are some hints for establishing state-of maturity from external examination. *Pre-spawning* fish will be found immediately prior to the species spawning season. Fish of a size large enough to be adult or displaying secondary sexual characteristics at this time and with a strongly distended body cavity may be *Pre-spawning*. During the spawning season, gametes (milt or roe) can be extruded from the fish with gentle pressure on the abdomen and it will be obvious that the fish is *Ripe*. *Spent* female fish can be identified by a flaccid, concave abdomen resulting from shedding of the large egg mass and abdominal abrasions obtained during spawning activity. They may extrude a small number of residual eggs in response to pressure on the abdomen. *Spent* males may also have abdominal abrasions and will probably still extrude milt with abdominal pressure, but the milt may appear "watery". Other maturity classifications are very difficult to determine from external examination.

3.31 Milt

Milt is a milky white fluid extruded by male fish during spawning activity and contains the sperm. During spawning season, ripe male fish will extrude milt in response to pressure on the abdomen.

3.32 Necrosis

The death of a tissue due to injury or disease.

3.33 Parasites

Fish are subject to several types of internal and external parasites. A complete parisitological examination requires sacrificing of the subject and microscopic examination of some tissues. For general fisheries inventories, the occurrence of macro-parasites which can be readily observed by the an-aided eye should be recorded on the Fish Sample Record Form. A basic external examination is conducted while measurements of length and weight are conducted. An internal examination is conducted for fish which have been sacrificed. Common external parasites include body lice, gill lice,

leeches and lamprey. Common internal parasites include tapeworms, nematodes and flukes associated with the gastro-intestinal tract and other internal organs.

3.34 Pathology

For fisheries inventory studies, pathology refers to the field examination of captured fish for indications of parasites, disease and abnormalities, without the use of special procedures (e.g. tissue collection) or tools (e.g. microscope). This can include either external pathology or external and internal pathology.

External Pathology

Examination of the body surface , fins, eyes, gills and gill chamber for signs of parasites, disease or abnormalities (deformations). Components of the external examination include body form, body surface, lips and jaws, snout, barbels, opercles, isthmus, eyes, fins, gills, pseudobranch, branchial cavity, anus, and the urogenital opening. A basic external examination can be conducted for most fish while measurements of length and weight are being conducted and the results recorded on the Fish Sample Record Form.

Internal Pathology

Examination of the body cavity and internal organs for signs of parasites, disease and abnormalities. Components of the internal examination include body cavity, mesenteric fat, liver, gall bladder, hind gut, stomach, pyloric caeca, intestines, spleen, gas bladder, kidney, gonads, and muscle. A basic internal examination can be conducted for fish which have been sacrificed.

3.35 Population Estimates

Population estimates are used to determine or approximate the total number of fish, for one species or a number of species, within a study area. Population estimates may be calculated for a portion of a waterbody (e.g. a section of stream - #fish/km) or an entire waterbody (e.g. a lake - #fish/ha). Two basic types of population estimates are used; Removal and Mark-Recapture.

Removal (Reference - Armour et al. 1983)

Removal population estimates involve the isolation of the study area using a physical barrier to block fish movements followed by the removal of fish from the area to provide a population estimate. This technique is restricted to study areas which can be isolated and is typically used in small streams. Small-mesh blocking nets are placed at the upstream and downstream boundaries of the study area to prevent immigration or emigration of fish from the study area. Long minnow seine nets are used as blocking nets and are held in place using rebar posts embedded in the substrate. Care must be taken to ensure the bottom of the net remains in contact with the stream substrate to form an effective barrier.

Electrofishing is used as the capture technique, typically backpack or portable boat electrofishing, depending on stream size and water depth. It is vital that the capture technique be very efficient. If the

stream is too deep or wide for effective sampling by backpack electrofishing, the portable boat electrofisher should be used or use two backpack units working simultaneously. Multiple electrofishing passes are conducted within the study area and the catch (species and length) and sampling effort are recorded for each pass. Captured fish are retained in a holding pen or are released outside the study area. The catch will decline with each pass as the number of fish in the study area is reduced. Ideally, the catch on the final pass will be zero as total removal is achieved, however, total removal is not required. What is required is that the capture efficiency must be high enough that the probability of capture for each individual is high. When this requirement is met, most of the fish in the study area will be captured on the first pass. After two electrofishing passes, the capture probability is calculated (Armour et al. 1983). If the capture probability is 0.8 or greater, the capture efficiency is high enough to provide an accurate population estimate and a sufficient number of passes has been conducted. In practice, capture probabilities as high as 0.8 are uncommon and additional passes must be conducted. Typically, 3 or 4 passes must be conducted to get a good estimate of capture efficiency and to get enough data to calculate a population estimate. If after 4 passes the number of fish being captured has not declined to near zero, the sampling technique is not sufficiently effective and the population estimate will have poor accuracy. A population estimate can be calculated from such data, but the confidence intervals will be very large.

It is very important that the diminishing catch on subsequent passes be due to the reduced number of fish in the study area and not to a reduced amount of sampling effort. It is vital that a similar effort be expended on all passes. The number of seconds of electrofishing and the search pattern in the study area should be similar for all passes. Monitor the electrofishing seconds throughout each pass in order to ensure this requirement is met.

If total removal is achieved, the population estimate for each species is equal to the total number of individuals captured. If total removal is not achieved, formulas are used to calculate the population estimate. Two formulas are available; the first is a simple formula for computations for two removal passes and the second is more complex for computations for more than two removal passes (Armour et al. 1983). Both of these formulas are presented on a Microsoft Excel spreadsheet in the G:\Aquatics directory. Simply type in your data for each species (i.e. number of fish captured on each pass) and the spreadsheet will calculate capture probability, population estimate, standard error and the 95% confidence interval. The lower limit for the 95% confidence interval is sometime lower than the number of fish that was captured. If this is the case, the lower limit should be changed to equal the number of fish captured as this number represents the minimum population size.

Mark-Recapture

Mark-recapture population estimates are used in situations where isolation of the study area is not possible or for situations where removal of a significant portion of the population is not practical. Using this technique, a sub-population of fish is captured, marked and released. These fish are then allowed to mix with the larger unmarked population. A sub-sample of fish is then captured and the number of marked and unmarked fish is used to determine the proportion of the total population represented by the marked sub-population. As the size of the marked sub-population is known, the size of the total population can be calculated. This technique is useful in large and intermediate sized streams and in lakes. Any sampling technique with good sampling efficiency can be used but is typically limited to electrofishing, particularly in flowing waters. The mark-recapture technique assumes a closed population (no immigration/emigration) which is not usually true in many situations. Study design should include aspects to reduce the effects of immigration/emigration of fish. For size selective

sampling techniques such as electrofishing, population estimates should be conducted separately for different size classes.

For most mark-recapture population estimates, it is recommended that multiple sampling passes be conducted to capture and mark fish. This is followed by a few days without sampling to allow mixing of marked fish in the general population. A sampling pass (census) is then conducted to determine the portion of marked to unmarked fish in the census sample. Batch marking (see section 3.29) can be used for this technique. The population estimate is calculated using the Chapman modification of the Peterson method (Ricker 1975) as follows:

$$N = (M+1)(C+1) / R+1$$

where N = population estimate, M = number of marked fish, C = sample taken for census, and R = number of marked fish in the census sample.

At Golder we generally use the ***CAPTURE*** program (Otis et al. 1978) for mark-recapture population estimates. For this method, the fish marking technique must be Floy or VI tagging (see section 3.29) as each individual fish must be identifiable. Multiple sampling events are conducted in order to tag fish and to keep daily counts of the number of tagged and untagged fish that are captured. The results are then arranged in a matrix which has one line for each individual fish that was captured, along with the day or days it was captured/tagged and recaptured. This matrix is used by the CAPTURE software to provide the population estimate. The CAPTURE program is located in the G:\Aquatics directory. The CAPTURE software tracks the capture/recapture history for each individual fish over each pass and calculates the population estimate based on these results. This technique is believed to provide a more accurate result than the single census-pass estimate presented above. This technique does not require a rest period between the marking passes and a census pass and is more suitable for use in open populations where fish movements in or out of the study area may occur.

3.36 Riparian

With respect to fisheries habitat evaluations, riparian areas are terrestrial habitats bordering water bodies (lakes and streams). Riparian areas are not included within the boundaries of the waterbody but are significant in providing habitat features such as overhanging vegetation, inputs of large-woody-debris, sediment stabilization, shading, moderation of surface water run-off, nutrient inputs, etc. Riparian conditions, including species of bank vegetation and floodplain vegetation when possible, are an important part of habitat evaluations.

3.37 Roe

Fully developed, unfertilized eggs produced in the ovaries of adult female fish. During spawning season, ripe female fish will extrude roe in response to pressure on the abdomen.

3.38 Rough Fish

Large fish species (i.e. non-forage fish) which are not included as game fish. Primarily sucker species.

3.39 Sacrifice

Fish which are killed in order to allow internal examination or collection of ageing structures are referred to as sacrificed. For each fish captured, information on whether or not the fish was sacrificed is recorded on the Fish Sample Record Form (i.e. capture code), which helps to identify fish which have been examined internally versus those which were only examined externally. Fish which are sampling mortalities (accidentally killed as a result of capture) are also recorded as sacrificed. Even if intentionally sacrificing fish is not a part of the study design, dead fish should be examined internally for definitive sex and state-of-maturity data, as well as stomach contents and internal pathology when time allows.

3.40 Sampling Bias

Sample inaccuracy caused by bias or imprecision in sampling; e.g., bias towards large fish because of the type of sampling gear. In statistics, a sampling bias may be represented as skewedness or as variance.

3.41 Sex

Sex refers to the sex of the individual fish, usually recorded as either male or female. However, since determination of sex may be difficult from external examination or from internal examination of juvenile fish, sex may also be recorded as unknown.

Sex Determination (Lethal)

To determine the sex of a fish, an incision should be made on the ventral surface of the body from a point immediately anterior of the anus toward the head to a point immediately posterior to the pelvic fins exposing the gonads. If necessary, a second incision may be made on the left side of the fish from the initial point of the first incision toward the dorsal fin. To observe the gonads, fold back the tissue. Ovaries appear whitish to greenish to orange and have a granular texture. The eggs will be readily apparent in developed ovaries. Testes appear creamy white and have a smooth texture.

Sex Determination (Non-Lethal)

Determination of sex from external examination of the fish is generally more difficult. For some species, sex may be determined from external secondary sexual characteristics, observable either during the spawning season or, for some species, at any time of year. For most fish species, sex of adult fish can be determined during the spawning season by forcing extrusion of the sexual product (milt/roe).

Secondary sexual characteristics are external physical characteristics displayed by fish which distinguish sex. Some species do not display secondary sexual characteristics. Other species show secondary sexual characteristics during the spawning season and these characteristics are only useful for distinguishing sex for adult fish during the spawning season. Still other species have morphological differences which allow determination of sex from external examination at any time.

Mountain whitefish develop small tubercles (raised bumps) on the lateral scales prior to spawning. These tubercles are generally more pronounced in males than in females but, alone, tubercles may not be a reliable indicator of sex. Trout may show differences in jaw morphology with females having a rounded jaw and male developing a kype (extended, upwardly hooked lower jaw). This characteristic is not reliable in that the male may not develop a kype, particularly in smaller adults. Males for most sucker species develop obvious tubercles which show as hard nodules in the pelvic, lower caudal and, particularly, the anal fin during the spawning season and which are very reliable for determining sex in adult fish. Many species, such as minnows, suckers and some trout develop distinct body coloration or markings during the spawning season which may aid in separating the sexes. Two species, goldeye and mooneye, show a difference in anal fin structure between mature male and female fish which is a reliable external indication to distinguish sex at any time. In the female, the longest rays of the anal fin are the first four and all of the anal fin rays are slender. The overall shape of the fin is "smoothly concave". The first half of the anal fin of the male has long rays followed by much shorter rays at the back, giving the fin a "lobed" appearance. In the male, the anterior rays are thick near the base. This characteristic is not reliable for juvenile fish.

3.42 Spawning Surveys

Spawning surveys refer to the visual observation of spawning activity or sampling for the presence of incubating eggs and are used to determine if a site has been used as a spawning area, to determine the distribution of spawning sites within a study area, or to collect micro-habitat data (Habitat Preference Criteria) at known spawning areas. Spawning occurs when eggs (roe) and milt (sperm) are extruded by the fish so as to mix and produce fertilized ovum. This is accomplished in a number of ways by different species. Most game fish species for which spawning surveys are typically conducted are either spring or fall spawning species. There are two basic types of spawning surveys (***egg surveys or redd surveys***) depending on the spawning strategy of the species involved.

Egg Surveys

Some species, such as mountain whitefish, lake whitefish, lake trout, walleye and sauger are ***broadcast spawners*** which distribute their eggs over the substrate in areas of suitable depth, velocity and substrate type. The eggs fall into the interstitial spaces (crevices) in the substrate to incubate, although some species will spawn over hard sand if rocky substrates are not available. Spawning surveys for broadcast spawners are conducted using kick sampling and/or airlift sampling techniques (see sections 3.5.1 and 3.5.9). If the study area is small, systematic sampling can be used to examine the entire area for eggs. In large study areas where this type of sampling is impractical, sampling is conducted by examining areas of suitable spawning habitat for the target species. Habitat preference information (see section 3.22) is used to determine the habitat types that should be examined. The section of the stream or portion of lake that is examined during the survey and the location of all spawning sites where incubating eggs are recovered should be identified on maps of the study area. The standard is to use 1:50,000 scale topographical maps but other maps or air photos may be used if they provide greater accuracy. The

number of eggs recovered is also recorded for each spawning site and, depending on the sampling technique, sampling effort may also be recorded at each site.

If incubating eggs are found in a study area where more than one species may be spawning, measure egg diameter for the recovered eggs and use egg size, colour and features such as the presence or absence of oil globules to identify the eggs. Egg diameter can be measured using an egg measuring trough. Place 10 eggs in the trough and measure the total amount of the ruler covered, divide this distance by 10 to get an average egg diameter. Scott and Crossman (1973) provide egg descriptions for most species. If egg identification is still doubtful, collect a sample of eggs, measure the egg diameter, and preserve the sample in 5% buffered formalin.

Some fish species use spawning strategies which are part-way between broadcast spawners and species which construct spawning nests. These species include Arctic grayling and several sucker species such as longnose and white sucker. No actual nest or redd is prepared but spawning occurs close over the substrate while the fish are vigorously vibrating and the fertilized eggs become somewhat covered by the substrate material stirred up during this vibration. In some cases, such as spawning areas used by a large number of suckers, disturbances of the substrate can be visually observed but it is not possible to enumerate the number of spawning acts or the number of fish involved. For species such as Arctic grayling, these disturbances are indistinct. Spawning surveys for these species are conducted using egg surveys, as for broadcast spawners.

Still other species, such as northern pike and yellow perch, attach their incubating eggs to submerged vegetation (aquatic macrophytes or flooded terrestrial vegetation). Spawning surveys for these species are conducted by searching for eggs in areas of submerged vegetation. A kick sampling net or other small mesh net is swept through the vegetation and the net contents are examined for eggs.

Redd Surveys

Most trout species (including brook, brown, bull, cutthroat and rainbow trout) construct excavations in the substrate into which the fertilized eggs are deposited. A similar excavation immediately upstream of the depression is dug and the materials from this excavation are used to cover the incubating eggs. These excavations or spawning "nests" are termed ***redds*** and are typically constructed in flowing water, although areas of ground-water upwellings in lakes may also be used. As the algae and silt covered rocks are turned over during redd construction, the redds can usually be readily observed due to their "clean" nature and distinctive shape (i.e. distinct depression upstream of a mound). Redd surveys are conducted by one or more observers walking or floating through a study area, enumerating the redds observed, and recording the locations of the redds on a 1:50,00 map of the study area. The study area (section of stream or portion of lake) examined should also be recorded on the map. Not all excavations are redds which contain incubating eggs and it may sometimes be difficult to determine if a disturbance of the streambed is truly a redd. Therefore, redds should be enumerated and classified into the following categories: 1) Class A redd - large or distinct, well formed or spawning fish present; 2) Class B redd - less distinct, most likely an active redd; 3) Class C redd - small or indistinct, possible redd but not definite.

If more than one trout species may be spawning in the study area, enumeration of the redds by species may be difficult. If this is the case, species identification for each redd is best facilitated by conducting

the redd survey during the active spawning period so that it is likely that the fish will be present at the redds to aid in identification. Knowing the species and size of the fish in the study area will also help, as some species build larger redds than others. If only one species is expected to be spawning in the study area, the redd survey is usually conducted towards the end of the spawning season when the maximum number of redds will be present.

Repeated redd surveys in the same study area can be used to define the spawning season if required. Surveys are conducted at regular intervals from the start of the spawning season and the number and location of redds on each successive survey is used to determine the length and peak of spawning activity.

3.43 Species Code

Standard abbreviation of fish species names is based on the following rules (MacKay et al. 1990):

a) use a four letter abbreviation
b) for a one word name - use the first four letters
   e.g., GOLD for goldeye
c) two word names - use the first letter in each word plus the next consonant in each word
   e.g., ARGR for Arctic grayling,
   LKWH for lake whitefish, and,
   WHSC for white sucker
   (exception - due to duplication, use BRTR for brook trout and BNTR for brown trout)
d) three word names - use the first letter in the first two words and the first letter and next consonant in the last word
   e.g., NRDC for northern redbelly dace

The species codes for all Alberta species are presented on the back of the Fish Sample Record Form.

3.44 Species Composition

A term that refers to the species found in the sampling area.

3.45 Species Distribution

Where the various species in an ecosystem are found at any given time. Species distribution varies with season and life history stage.

3.46 Stage (Life History Stage)

Stage refers to the life history stage (or life stage) of the individual fish. Three stage categories are used to describe free swimming fish: ***fry, juvenile or adult.*** The incubating egg is also a life stage and is referred to as the embryo stage.

Fry are also called young-of-the-year (YOY) and are fish from their hatching date until the first anniversary of their hatching date. Juvenile fish are fish from one year old until reaching sexual maturity. Adult fish are fish which are sexually mature.

Definitive life history stage is determined for an individual by internal examination of the gonads. Fry and juvenile fish would have undeveloped gonads and would be classified as immature with respect to state-of-maturity. Fry can usually be separated from juvenile fish by their small size (i.e. smallest fish in the population) and, for some species, by secondary characteristics such as parr marks. Adult fish are sexually mature fish which have spawned in the past or will spawn in the upcoming spawning season. Their state-of-maturity can be one of several categories, from maturing to spent.

Determination of stage from external examination is not always possible. Identification of fry is based on their small size. However, it is not always possible to tell large juvenile fish from small adult fish, in which case an ***unknown*** category is provided in addition to the three main categories. Evidence of sexual maturity, such as secondary sexual characteristics or extrusion of milt or roe during the spawning season can be used to identify adult fish.

3.47 Standard Error and Standard Deviation

Standard error (SE) and standard deviation (SD) both express the variability of results around the mean. However, standard error takes the sample size into consideration when calculated. By including sample size, SE gives an indication of how well we've measured the entire population. This is particularly true if you have very different sample sizes for the groups you are comparing; the larger the sample size, the more confidence you have that the data represents the population.

Standard error is calculated as: $SE=SD \div \sqrt{n}$; where n=sample size. Microsoft Excel will calculate SD automatically. In order to calculate SE the formula in Excel would be " =StDev(cells with data)/(sample size)^0.5". The "^.05" denotes square root (by asking excel to calculate to the power of 0.5).

Standard error is now considered to be the appropriate measure to use in any technical presentation of data and should be used in any figures or tables of fish population statistics.

3.48 Stomach Content/Gut Analysis

Stomach content analysis is used to determine the diet and food preferences of fish. The stomach is removed from the sacrificed individual and opened to allow examination of its contents. Record stomach fullness as the percentage of fullness, from 0 to 100%. Record the contents of the stomach as percentage of the material in the stomach, not as percentage of the total stomach volume (e.g. a stomach that was half full, with all the contents being mayflies would be recorded as follows: 50% full, 100% mayfly).

For invertebrates in the stomach contents, record the contents to the lowest taxonomic level possible. Family level is usually required, but Genus should be recorded if known. Unidentifiable, overdigested invertebrates should be recorded as IR (invertebrate remains) and unidentifiable fish remains should be recorded as FR (fish remains).

3.49 Study Site/Sampling Location

A study site or sampling location is the portion of a study area at which sampling is conducted. The site may be a ***point location*** (such as a gill net or set line location) a ***transect*** (cross section of a stream channel or lake) or a ***section*** (such as a section of stream electrofished or an area of a lake which is seined). In any event, the location of the sampling site must be recorded in the field notes. For large studies or studies with multiple sampling locations on the same waterbody, you may wish to number each sampling site. For a single waterbody, sample site may be numbered sequentially (i.e #1, #2, etc.). For multiple waterbodies, you may wish to combine the number with an abbreviation for the waterbody (e.g. BR1 = Bow River Site #1). You may also wish to identify the type of sampling conducted (e.g. GN1 = gill net set #1). All study site abbreviations must be clearly identified in the field notes. At a minimum, all study sites should be recorded on a 1:50,000 scale topographical map. Other maps or air photos may also be used if they provide greater detail than the 1:50,000 map. See section 3.17 for additional methods of recording location.

Study areas on flowing watercourses are often divided into homogeneous sections called reaches. A ***reach*** is a relatively homogenous section of stream having a uniform set of characteristics and habitat types. A reach is relatively uniform with respect to channel morphology, flow volume, gradient and habitat types and is separated from other reaches by changes in these characteristics. Conventionally, reach numbers are assigned in an upstream ascending order starting from the mouth of the stream. Typically, reach lengths are too long to sample in their entirety, in which case representative study sections will be selected in each reach for determining species distribution and abundances.

3.50 Temperature Criteria

Water temperature is a very important habitat component. Different fish species have different temperature requirements and have different tolerances to high water temperatures. Temperature regime in lakes and rivers can affect the presence, distribution and abundance of fish species (see sections 3.7 and 3.9). Temperature criteria provide maximum temperature levels that are tolerable by various life stages and have been developed for selected game fish species. Golder has prepared a document which list the criteria for selected Alberta species (Taylor and Barton 1992).

3.51 Underwater Video

Underwater video equipment includes a remote control underwater camera, light and above surface monitor and video recorder. Underwater video is used to determine fish presence, general abundance and activity. It is not generally useful for recording fish numbers. It is a sampling technique that is effective in both the open water season and for winter sampling under the ice.

3.52 Water Quality

Water quality is a basic aspect of fisheries habitat and can influence fish survival, distribution, abundance and reproductive success. Basic water quality parameters that are measured for fisheries studies include; temperature, dissolved oxygen, pH, conductivity, visibility (secchi depth), turbidity, total suspended solids (TSS) and total dissolved solids (TDS).

3.53 Weight

Weight refers to the total body weight (wet weight) of fish. It is measured for live fish before they are released or for sacrificed fish immediately after they have been killed. Along with length, weight is one of the most basic parameters measured evaluate the key attributes of fish populations.

Weight should be measured **in grams (g)** using a properly calibrated dial scale or electronic scale, depending on fish size. Golder uses dial scales fitted with fork length troughs for measurements of intermediate and large fish. Two types of dial scale are used; small scales which are rated for 0-4 kg in weight are used for most fish species, large scales rated for 0-25 kg are used for large fish species. For forage fish species and fry life stages of large fish species, more sensitive digital electronic scales are used.

3.54 Weight-at-Age

Weight-at-age analysis is used to determine the average weight of fish in each age class in the population. This analysis can only be conducted for individuals for which age is known. For each age class (i.e 1 year old fish, 2 year old fish, etc.) calculate the range of weights, mean weight and the standard deviation of the mean. Plot this data graphically with age as the X-axis, showing the range, mean and standard deviation (error bars). Weight -at-age is usually plotted on the same graph as length-at-age data.

4. REFERENCES AND SUGGESTED READING

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5. DISCUSSION

All basic aspects of each fisheries sampling program should be clear before commencement of field work. The field supervisor and field crew should be appraised by the project manager of all study design details. This will include study objectives, delineation of the study area, sampling techniques, data requirements and budgeting. Conditions at the field site may require alteration of the study design. The field crew should act in coordination with the project manager regarding changes to sampling protocols.

APPENDIX I

MATURITY CODES AND DEFINITIONS

UNKNOWN (UN): This category is used when state-of-maturity cannot be determined. This will most often occur for fish which have only been examined externally, where no examination of the gonads has been conducted. It may also be used following internal examination of the gonads when the observer cannot definitely determine the maturity of the fish. The gonads have been examined but the observer is unsure which maturity category to use, or the conditions of the gonads do not appear to match any of the maturity categories. If this is the case, record a complete description of the gonads and, if possible, collect a sample for microscopic examination.

IMMATURE (IM): This category is for immature fish (fry or juvenile life stages); defined as fish which have never spawned before and will not spawn in the coming spawning season. The gonads will be undeveloped and will be small and largely transparent. They will be string-like organs situated on the dorsal surface of the body cavity (dorsal to other internal organs) and will lie close under the vertebral column. In very young or small fish, determination of sex from examination of the immature gonads may be difficult or impossible.

Male: The testes will typically be smooth in texture and yellow, pink or white in colour. In suckers and percids, immature male testes can be identified by the position of the testicular artery. The artery is usually totally or partially imbedded in the organ.

Female: The ovaries will typically have a granular texture and will be yellow or pink in colour. In suckers and percids, immature female ovaries can be identified by the position of the ovarian artery. The artery is usually completely outside the organ, resting on top of the surface tissue and attached with connective tissue.

MATURING (MA): A maturing fish is a fish which has not spawned before but will spawn in the coming spawning season. This category refers to a fish whose gonads are developing for the first time. Fish in the maturing category are, for the first time, considered adult fish as they are hormonally similar to sexually mature individuals. Since the gonads are developing for the first time, development may not be complete at the time the fish is examined. The gonads may be developed (enlarged and showing sperm or egg development) primarily at the anterior end. The posterior end of the gonad may still be undeveloped and appear thinner (similar to an immature gonad). This category can be difficult to interpret in the field, being difficult to tell from the *Green* category, and examination of the gonads by microscope may be required. In general, the gonads of a maturing fish will be smaller than those for a *Green* fish.

Male: In the field, maturing testes will be smaller and paler than those of fully developed males but considerably larger than immature testes. If unsure, take a sample for histological analysis and designate the fish as *Green* (GN).

Female: In the field, maturing ovaries will be smaller and paler than those of fully developed females but considerably larger than immature ovaries. If unsure, take a sample for histological analysis and designate the fish as *Green* (GN).

SEASONAL DEVELOPMENT (SD): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons and will spawn in the coming spawning season. The gonads are undergoing their seasonal development following the last spawning season. This is the longest of the sexually mature stages as it extends from just after the post-spawning period until the next pre-spawning period, as the fish utilizes its resources to produce new gametes. For spring spawning fish (e.g. walleye, northern pike, longnose sucker, rainbow trout, etc.), this category would last from late May to early April of the next year. For fall spawning fish (e.g. lake whitefish, mountain whitefish, bull trout, brook trout, etc.) this category would last from the end of the fall spawning season one year (September to November) through to the fall of the next year. However, for most fish, gonadal development occurs primarily during the growing season with only limited gonadal development during the winter months.

Male: The testes will vary greatly in size and colour within this category depending on the time of year the fish is examined. Early in development (i.e. after the post-spawning period), the testes will be small and yellow to light orange in colour. By early fall (i.e. after the primary gonad development period in the summer), they will have grown to nearly mature size and be white in colour. At this point, the testes will be large and distinct. Note: Suckers have a black coloured testicular membrane which may mask the white colour of the testes.

Female: The ovaries will vary greatly in size and colour within this category depending on the time of year they are sampled. Early in development (i.e. after the post-spawning period), the ovaries will be small and yellow to light orange in colour. Developing oocytes will be small and dark orange in colour and will give the ovary a granular appearance. By early fall (i.e. after the primary gonad development period in the summer), the ovaries will have grown considerably to nearly mature size and be bright yellow to orange in colour. The individual eggs will be readily apparent.

PRE-SPAWNING (PR): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons and will spawn in the coming spawning season. The *Pre-spawning* category follows right after the *Seasonal Development* category, with respect to both time and stage of gonadal development, and occurs when the gonads have completed their seasonal development prior to the spawning season. This is a short term condition which extends from time the gonads are fully developed until the start of spawning activity.

Male: Externally the abdomen will be slightly distended. Semen can sometimes be extruded with pressure to the abdomen. If this is the case, small amounts of loose semen will be extruded followed by more viscous semen if pressure is re-applied. Internally, the testes will be large and white and will fill much of the body cavity. Pre-spawning condition can also be inferred by the capture location of the male. Males will usually only enter spawning condition once they are on the spawning grounds and around mature females. Thus a male caught away from the spawning grounds as the spawning season approaches is most likely still in pre-spawning condition, even if some sexual products can be extruded. Note: Semen can be extruded from sexually mature males as early as February in spring spawning species.

Female: Externally the abdomen will be noticeably distended. Sometimes a few eggs can be extruded with strong pressure to the abdomen. Care must be taken when applying pressure as the eggs are difficult to extrude and injury to the female can occur. The abdomen will feel tight and hard. Internally, the ovaries will be large and bright yellow to bright orange in colour. The size can be up to 25% of the total body weight and the gonads will fill much of the body cavity. Individual eggs will be large, round and obvious, some eggs will be translucent. Pre-spawning condition can also be inferred by capture location. Females will usually only enter spawning condition once they are on the spawning grounds and around mature males. Thus a female caught away from the spawning grounds as the spawning season approaches is most likely still in pre-spawning condition, even if some sexual products can be extruded.

RIPE (RP): Fish in this category are sexually mature adults. *Ripe* is the term for the spawning condition. The *Ripe* category follows right after the *Pre-spawning* category, with respect to both time and stage of gonadal development, and occurs when the gametes (semen and eggs) have become loose in the gonads. This is a short term condition which extends from start to the end of spawning activity. Externally the fish will appear as they do during the *Pre-spawning* stage but extrusion of the gametes will occur in response to slight pressure on the abdomen.

Male: Externally the abdomen will be slightly distended. Semen can be extruded with light pressure to the abdomen. Large amounts of loose semen will be produced if pressure is applied. Internally, the testes will be large and white.

Female: Externally the abdomen will be greatly distended. Eggs immersed in ovarian fluid can be extruded with light pressure to the abdomen. Large amounts of loose eggs will be produced if pressure is applied. Internally, the ovaries will be large and yellow or orange. The eggs will be large and translucent and some will appear to be loose as the ovarian tissue is weak (i.e. the ovarian sac will be transparent and thin). Eggs will be loose inside the sac and they will be immersed in clear ovarian fluid.

SPENT (SP): Fish in this category are sexually mature adults. *Spent* is the term for the post-spawning condition. The *Spent* category follows right after the *Ripe* category, with respect to both time and stage of gonadal development, and occurs following spawning activity when the gametes (semen and eggs) have been largely extruded during spawning. This length of time a fish will spend in this category depends on how long it takes for the fish to begin the next cycle of seasonal gonadal development, at which time the fish will again be classified as *Green*.

Male: Externally, the abdomen will be slightly flaccid, especially ventrally. Some semen can still be extruded with pressure to the abdomen but it will most likely be watery (i.e. not as intense a white colour as in spawning males). Internally, the testes will be reduced in size and gray to creamy-white in colour. Hemorrhaging and distended blood vessels on the surface of the organ are common. Post-spawning males are known to stay on the spawning grounds for some time (up to 2 weeks) so capture location is not always a reliable indication of whether the fish has finished spawning.

Female: Externally, the abdomen will be noticeably flaccid, especially ventrally. The surface of the abdomen may be red or roughened with abrasions and the urogenital opening may be extended or swollen. Some eggs can still be extruded with pressure but will be few in number and they will be associated with watery ovarian fluid. Internally, the ovaries will be greatly reduced in size and dark orange to brown in colour. Hemorrhaging and distended blood vessels on the surface of the organ as

well as within it are very common and normal. Some residual eggs (from a few up to 25% of the ovary volume) are common. It is not common for post-spawning females to stay on the spawning grounds, most spawn and leave the area immediately. However, capture location is not always reliable indicator.

REABSORBING (RB): Fish in this category are sexually mature fish which have developed to some extent for the coming spawning season but, instead of completing gonadal development or instead of spawning after completing gonadal development, these fish are reabsorbing materials from the gonads back into the body. This category represents arrested gonadal development or interrupted spawning activity. There are several reasons why a fish may terminate gonadal development or decide not to spawn after completing gonadal development. These include the condition of the fish with respect to nutrition and/or health, aspects of population dynamics or environmental cues such as improper water temperatures, poor water quality conditions or adverse water level conditions. Interrupted gonadal development can occur at any stage of development and prior to entering the reabsorbing category the fish may have been *Maturing*, undergoing *Seasonal Development* or in *Pre-spawning* condition.

Male: This condition is *extremely rare in males* and difficult to observe as reabsorption of the semen by the testes is usually a rapid process. Very rarely will a case be observed of a male actually retaining the entire contents of the testes for re-absorption. Should you suspect this condition the testes should be preserved and stage verified by a qualified biologist.

Female: This condition is primarily observed in females. Reabsorption of the eggs by the ovary is usually a lengthy process which can take up to a full year. Some females may retaining the entire contents of the ovaries for re-absorption. Identification of this stage is not always easy. Externally, the female will still have a distended abdomen if caught within a few months of the spawning season. The abdomen will feel unusually hard as compared to normally developing females. Later in the season, it will be impossible to distinguish a normally developing female from a reabsorbing one without an internal examination. Internally, reabsorbing ovaries go through a series of distinct stages. Early in the reabsorption process, the ovary is dark orange to brown in colour. The eggs are dark and flaccid. Heavy amounts of watery ovarian fluid collect at the posterior of the ovary. This fluid most often is ejected readily if the fish is handled. Later, the ovary becomes smaller and hard. The colour becomes darker and the eggs become atritic. Atritic eggs are easily identified as they are small, hard and white. Ovaries in the later stages of eggs reabsorption have few new oocytes. The remnants of the old eggs collect in the middle of the organ. New oocytes production is restricted to the periphery of the ovary. Should you suspect this condition the ovaries should be preserved and stage verified by a qualified biologist. Occasionally, females have been observed which aborted spawning activity after they had became *Ripe*. Functionally speaking, eggs at this stage are no longer connected to the ovaries and cannot be reabsorbed. Instead they remain in the body cavity. Internal examination of a fish in this condition will show the newly developed gonad as well as residual (brown, desiccated) eggs which could not be reabsorbed in the posterior portion of the body cavity.

RESTING (RS): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons but will not spawn in the coming spawning season. These fish are different from *Reabsorbing* fish in that their gonads are either not developing or are developing too slowly to be ready for the upcoming spawning season. This is a common condition for fish which do not spawn every year (alternate year spawners).

Male: This condition is *extremely rare in males*. It can only be used as an alternative to the Green category. A few cases of males in the resting condition have been observed. They are most common in northern latitudes where the growing season is short or in ultra-oligotrophic lakes. Testes will appear flaccid and dirty-white to yellow in colour. They will be larger in size than the testes of immature fish. A good indication is the size of the testicular artery in relation to the organ. In immature fish this artery is very thin whereas in resting males the testicular artery is much larger because of prior testicular development. Should you suspect this condition the testes should be preserved and stage verified by a qualified biologist.

Female: This condition is primarily observed in females but is still relatively infrequent, affecting usually only 0.5 to 1% of the population. This stage can only be used as an alternative to the *Green* category. It is most common in northern latitudes where the growing season is short or in ultra-oligotrophic lakes. The ovaries will appear to have some oocytes but they will be few in number and arrested in their development. The colour of resting ovaries varies greatly with fish species but most often they are a light orange. They will be larger in size than the ovaries of immature fish. A good indication is the size of the ovarian artery in relation to the organ. In immature fish this artery is very thin whereas in resting females the ovarian artery is much larger because of prior egg development. Should you suspect this condition the ovaries should be preserved and stage verified by a qualified biologist.