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REPORT ON

SUNCOR PROJECT MILLENNIUM – 1997 FALL FISHERIES INVESTIGATIONS

Submitted to:

Suncor Energy Inc., Oil Sands
Fort McMurray, AB

DISTRIBUTION:

5 Copies	**Suncor Energy Inc.** **Fort McMurray, Alberta**
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March 1998 **972-2205**

EXECUTIVE SUMMARY

Suncor Energy Inc., Oil Sands (Suncor) is proposing an expansion of their recently approved Steepbank Mine and Fixed Plant faciltities. The expansion is call Project Millennium. This report provides 1997 fall fisheries information for several small creeks located within and south of the Project Millennium local study area. This study is supplemental to other baseline studies of aquatic resources in the study area.

The objective of the study was to document fish habitat quality and quantity in McLean Creek, Shipyard Lake Creek Two (an upland tributary to Shipyard Lake), two small unnamed Athabasca River tributaries and Donald Creek. Fish utilization and access to these habitat was also examined.

No fish were captured in the upper areas (above the escarpment) of Donald and McLean Creeks likely due to beaver dams and debris piles which impede fish access to these areas. Brook stickleback was the only fish species captured in Shipyard Lake Creek Two.

A few juvenile sport fish were captured in the lower sections of the Athabasca River tributaries. Burbot were captured in Unnamed Tributaries #1 and #2. Arctic grayling were captured in McLean Creek and Unnamed Tributary #1. The presence of young-of-the-year Arctic grayling in McLean Creek and Unnamed Tributary #1 indicates that they were likely spawned during the spring in these creeks, or in the general vicinity of the sites examined.

No evidence of fall spawning activity was documented in any of the creeks There was some good quality rearing habitat located within sections of the creeks examined. However, many of these habitats have only limited potential for use given that fish passage may be blocked, particularly in the upper sections on the escarpment.

TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

LIST OF APPENDICES

1. INTRODUCTION

Suncor Energy Inc., Oil Sands (Suncor) is proposing an expansion of their recently approved Steepbank Mine and Fixed Plant facilities. The new project, which is called Project Millennium, includes an expansion of existing mine facilities as well as the construction of new facilities and associated infrastructure. This report examines the fisheries resources situated within the local study area (LSA) for the proposed Project Millennium. This report is supplemental to other Project Millennium baseline information that is available in the following:

- Aquatic Baseline Report for the Athabasca, Steepbank and Muskeg Rivers in the Vicinity of the Steepbank and Aurora Mines (Golder 1996a).
- Addendum to Suncor Steepbank Mine Environmental Impact Assessment (Golder 1996b).
- Shipyard Lake Environmental Baseline Study (Golder 1996c).
- Winter Aquatic Surveys - Steepbank River, Shipyard Lake, and Leases 19, 25 and 29 (Golder 1997).
- Reference Wetlands Reconnaissance Survey (Hamilton 1992).

Additional baseline information is also available in the Oil Sands Regional Aquatics Monitoring Program (RAMP) 1997 report (Golder 1998).

1.1 STUDY AREA

Suncor's Project Millennium is located on the east side of the Athabasca River, in the vicinity of the recently approved Steepbank Mine within Leases 97, 19 and 25 and Fee Lots 1, 3 and 4 (Figure 1). A large portion of the Steepbank River and several other Athabasca River tributaries (Shipyard, Leggett, Wood and McLean creeks) are located within these leases, as is Shipyard Lake, several small unnamed ponds and wetlands areas. The main inputs to Shipyard Lake are Unnamed Creek, which enters from the northeast, and Creek Two, which enters from the southeast (Golder 1997). Donald Creek and two unnamed tributaries to the Athabasca River are located south of the Project Millennium LSA.

Several of the above-mentioned watercourses have already undergone fisheries sampling and habitat inventories (Golder 1996a, 1996b, 1996c). This report addresses McLean Creek and Creek Two, which are located within the Project Millennium LSA, and Donald Creek and two Athabasca River tributaries, which are located south of the Project Millennium LSA.

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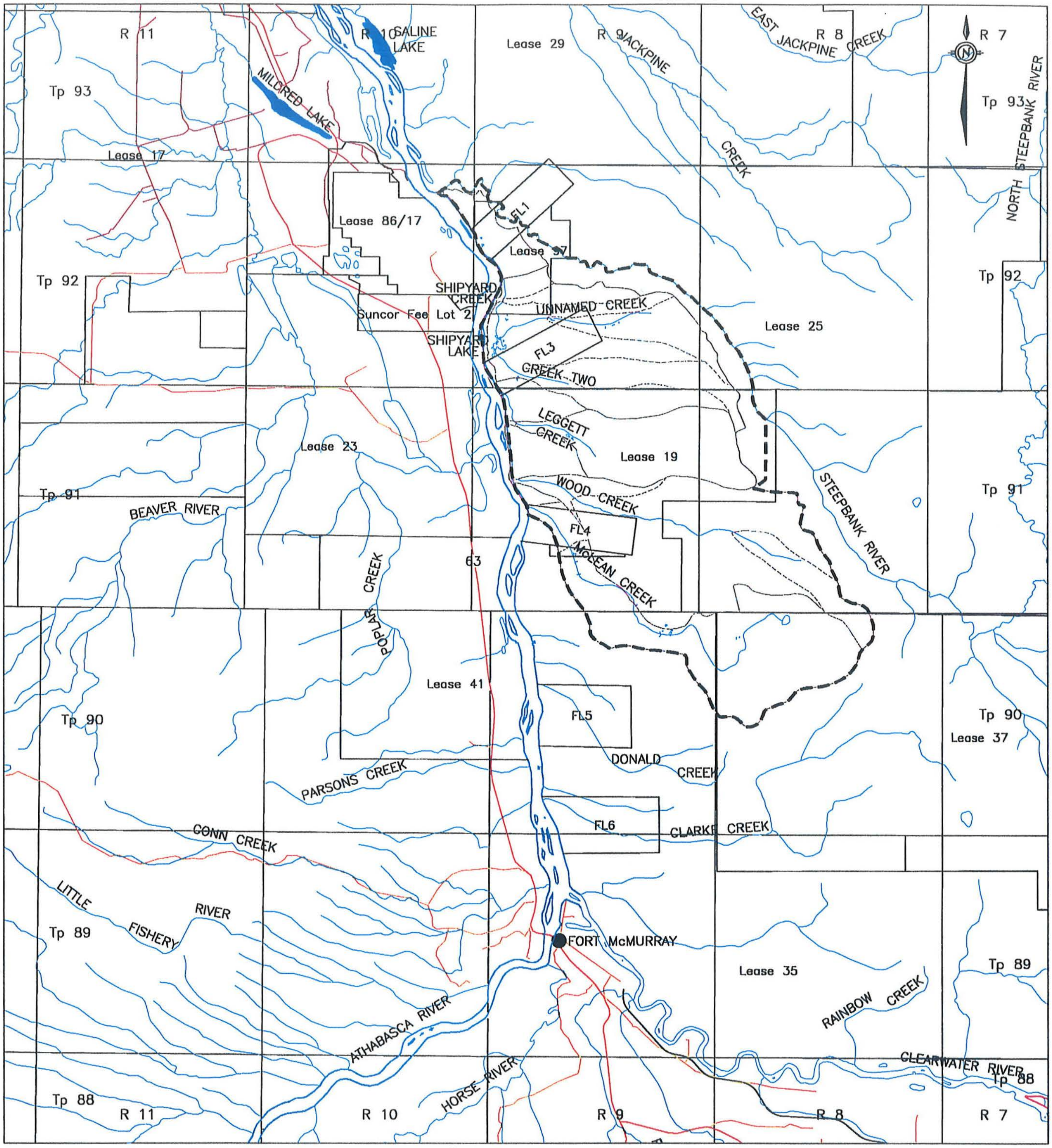

REFERENCE

- LOCAL STUDY AREA FOR HYDROLOGY, HYDROGEOLOGY, WATER QUALITY AND AQUATICS
- LOCAL DRAINAGE BASIN
- LOCAL DRAINAGE SUB BASIN

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

0 2.5 5 7.5km
SCALE 1:250,000

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LOCAL STUDY AREA

19 Mar. 1998	Figure 1	DRAWN BY: RFM/VS

Creek Two was selected for fisheries investigations because it has a defined channel and is considered one of the main inputs to Shipyard Lake (Golder 1996c). The other main upland tributary to Shipyard Lake is Unnamed Creek, which was sampled in 1996 (Golder 1996b). Several other upland creeks provide input to Shipyard Lake but these are intermittent in nature (Golder 1996c).

1.2 OBJECTIVES

The objectives of this study were to document:

- habitat quality and quantity in Donald Creek, two unnamed tributaries to the Athabasca River (Unnamed Tributary #1 and #2), McLean Creek and Shipyard Lake Creek Two; and
- fish utilization of and access to these habitats, particularly with respect to sport fish usage.

2. METHODS

Habitat mapping and fish inventories were conducted from October 12 to 18, 1997 at the sampling stations illustrated in Figure 2. The types of sampling conducted at each station are presented in Table 1. A Trimble Geoexplorer Geographic Positioning System (GPS) was used to record the position of all sampling locations, areas of significant habitats and concentrations of fish. All GPS data were differentially corrected using base station data from Pleiades Data Corp., Usher Canada Ltd.

Table 1 Sampling Stations Within the Area of Project Millennium, 1997

Station ID	Station Watercourse	Station Type	Station Description	Season Sampled	Fish Inventory [a]	Habitat Measurement
DOC-F-1	Donald Creek	Transect	Lower Section	Fall	BP, MT	X
DOC-F-2	Donald Creek	Transect	Upper Section	Fall	BP, MT, GN	X
UC1-F-1	Unnamed Tributary #1	Transect	Lower Section	Fall	BP, MT	X
UC2-F-1	Unnamed Tributary #2	Transect	Lower Section	Fall	BP, MT	X
MCC-F-1	McLean Creek	Transect	Lower Section	Fall	BP, MT	X
MCC-F-2	McLean Creek	Transect	Upper Section	Fall	BP, MT, GN	X
SHL-F-1	Creek Two to Shipyard Lake	Transect	Lower Section	Fall	BP, MT	X

[a] Inventory Methods: BP = Backpack Electrofisher, GN = Gill Net, MT = Minnow Trap.

2.1 FISH HABITAT

Detailed habitat mapping was conducted for a 100 m segment at each of the sampling stations investigated. For Donald and McLean creeks, a segment of habitat at both the mouth and in the upper reaches (on the escarpment) was surveyed. Habitat mapping was carried out using the Stream Habitat Classification and Rating System as described in Golder Technical Procedure (TP) 8.5-0 (Appendix I). The stream habitat mapping system is based on individual channel units (i.e., riffle/run/pool) in combination with depth, velocity and substrate characteristics to provide a subjective quality rating for each unit in relation to various fish life stages (i.e., spawning, rearing, feeding, overwintering).

Measurements of wetted width, water depth, substrate composition, cover availability, bank stability and bank vegetation were also taken at transects within these 100 m segments.

Discharge measurements previously recorded for Creek Two have also been included in this report (Klohn-Crippen 1997).

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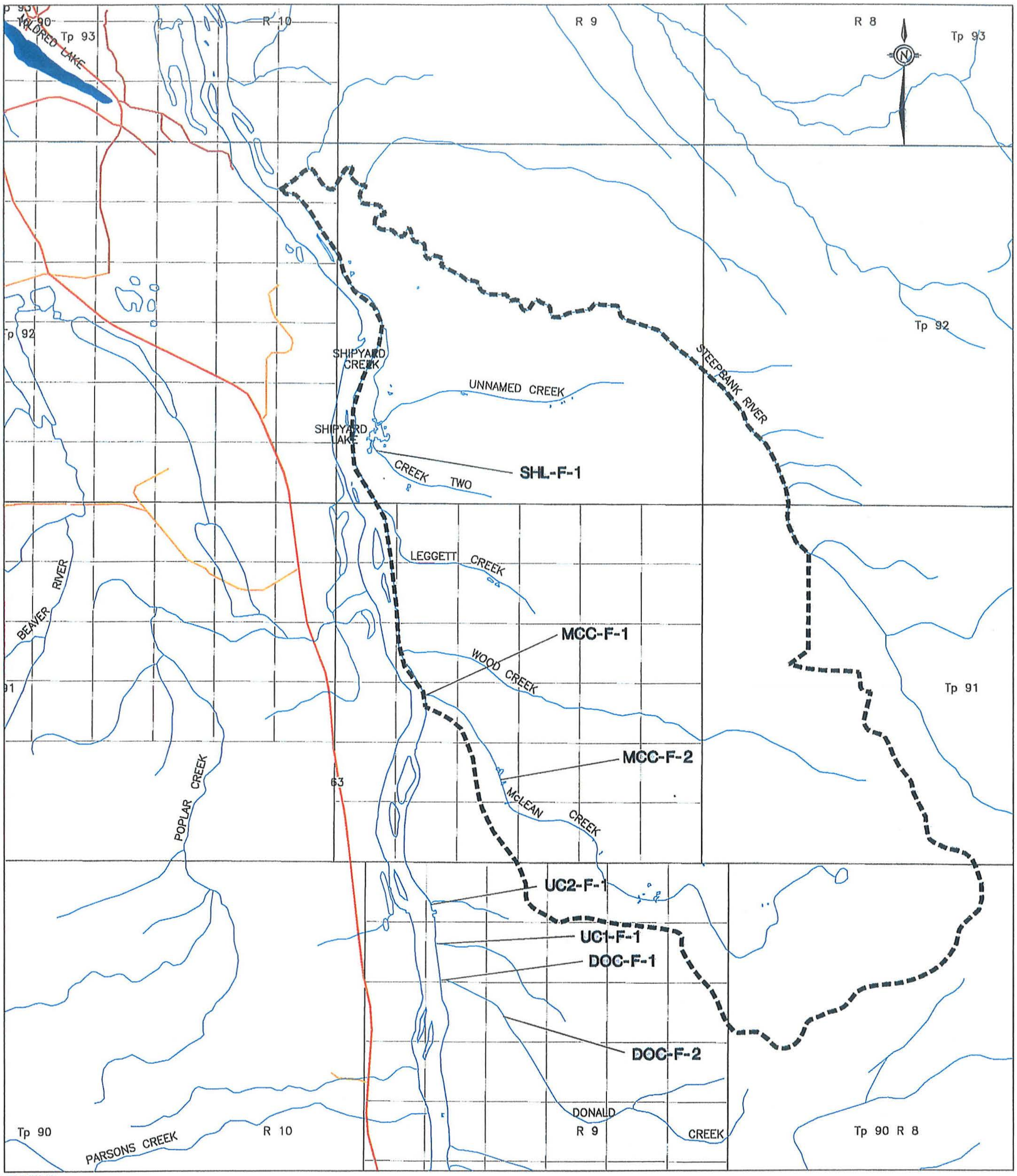

LEGEND

- - - LOCAL STUDY AREA FOR HYDROLOGY, HYDROGEOLOGY, WATER QUALITY AND AQUATICS

DOC-F-1 DONALD CREEK (Lower Section)
DOC-F-2 DONALD CREEK (Upper Section)
UC1-F-1 UNNAMED TRIBUTARY #1
UC2-F-1 UNNAMED TRIBUTARY #2
MCC-F-1 McLEAN CREEK (Lower Section)
MCC-F-2 McLEAN CREEK (Upper Section)
SHL-F-1 SHIPYARD LAKE CREEK TWO

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

0 1 2 3 4 5km
SCALE 1:150,000

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SAMPLING STATIONS WITHIN LOCAL STUDY AREA

31 Mar. 1998	Figure 2	DRAWN BY: RFM

2.2 FISH INVENTORY

In association with habitat mapping, fish were inventoried in the creeks using a backpack electrofisher (Smith Root Type VII backpack electrofisher). The number of seconds the electrofisher was operational was recorded at each sampling site as was the distance of watercourse sampled (Table 2). Gee minnow traps were also set at each sampling station for recorded periods of time (Table 2). The upper sampling stations on McLean and Donald creeks (on the escarpment) were also sampled using gill nets. The size of gill nets used and the sampling period in these creeks is also presented in Table 2. The lower reaches of the creeks were also examined specifically to determine if fish passage was possible and if the stream could potentially be used for spawning by fish stocks from the Athabasca River.

Table 2 Fish Sampling Information

Station	Watercourse	Distance of Watercourse Sampled by Electrofishing (m)	Time Sampled by Electrofishing (Sec)	Time sampled Using Minnow Traps (Hours)	Time Sampled Using Gill Nets (Hours)
DOC-F-1	Donald Creek (Lower Section)	150	614	38.43	0
DOC-F-2	Donald Creek (Upper Section)	600	1,593	13.45	5.4 [a]
UC1-F-1	Unnamed Tributary #1	150	478	3.07	0
UC2-F-2	Unnamed Tributary #2	110	389	4.52	0
MCC-F-1	McLean Creek (Lower Section)	125	542	6.4	0
MCC-F-2	McLean Creek (Upper Section)	750	1,589	12.9	11.8 [a,b]
SHL-F-1	Creek Two to Shipyard Lake	600	1,357	8.9	0
	Total	**2,485**	**3,488**	**28.2**	**17.2**

(a) sampling conducted using 18 m, 5.5 cm mesh gill net.
(b) sampling conducted using a 20 m, 6 cm mesh gill net.

All fish captured were identified and enumerated. Fork length and weight were measured and recorded for all fish. The life history stage, sex, state of maturity and any evidence of external pathology were also recorded. All fish inventories were conducted following Golder TP 8.1-0 (Appendix II).

Kick sampling was also conducted at Donald Creek, McLean Creek and Unnamed Tributary #2 in areas of potential mountain whitefish spawning habitat. This was performed as a means of checking for the presence of spawned eggs and thus determining if mountain whitefish (or other fall spawning species with similar spawning habitat requirements) had spawned in these areas.

3. RESULTS

3.1 HABITAT

Habitat maps for the 100 m segments examined at each sampling station are presented in Figures 3 through 9. Photos "a" through "h" provide pictures of sections of the creeks taken during the field program. (Note: all figures and photos are positioned at the end of section 3.1.)

3.1.1 Habitat Description

Donald Creek

The lower section of Donald Creek (near the confluence of the Athabasca River) is a high gradient watercourse. The mean wetted width of the watercourse was 2.0 m and it had a mean depth of 0.4 m in October 1997. Maximum depth did not exceed 1.0 m. Habitat consists primarily of riffles (72%) and low quality R3 run units (22%), with chutes resulting from woody debris piles at various points throughout (Photo A, Figure 3). Substrate in the riffle areas consists of large cobbles and small boulders although some bedrock was also noted. There is a general absence of pools in the lower section of Donald Creek, with the exception of one P2 (moderate quality) pool that was 0.9 m deep and comprised only 6% of the available habitat in this section of the creek. However, a number of backwater areas do provide some slower-moving habitat.

There are areas of undercut, unstable and slumping banks in the lower section of Donald Creek. Overhead cover is provided by the undercut banks as well as the deadfall and green alder which hang over the channel. Instream cover is provided by the abundant woody debris scattered throughout the channel. The chutes present in this section of Donald Creek are barriers to upstream migration or movement of fish in Donald Creek. In particular, 45 m upstream of the Athabasca River confluence, there is a chute with a drop-off of 0.85 m that presents an absolute barrier to fish passage.

The upper section of Donald Creek has habitat features similar to that of the lower (downstream) section. It had a mean channel width of 1.5 m and a mean depth of 0.4 m in October 1997. Depths did not exceed 1.0 m at any point in this section of the creek. Available habitat consists of R3 runs (73%) (Photo B, Figure 4), P3 pools (25%) (both low quality) and to a much lesser extent, riffles (1.3%). As with the lower section of Donald Creek, numerous backwater areas and chutes are present, the latter the result of woody debris piles. There is good flow in the riffle and chute areas; however, water velocity slows markedly in the depositional pool areas and in some of the runs. Substrate composition is closely linked with water velocity. The pools exhibit a high percentage of fines, with boulders and cobbles present only in limited quantities. In the run areas, fines are present in the slower segments and cobbles and boulders in the faster segments. In the riffle areas, substrate is composed entirely of cobbles and boulders.

Throughout the upper section of Donald Creek, the stream banks are low, stable and generally well vegetated which provides some overhead cover for fish. Instream cover is provided by the woody debris distributed throughout the channel. There are also areas of multiple channels and two narrow side channels (0.5 m wetted width) join Donald Creek within this section. The upstream portion of this section of Donald Creek is low gradient (2%), but farther downstream, beyond the reach mapped, the stream gradient increases as the terrain becomes steeper. At this point, riffle areas, undercut banks and small chutes predominate which provide excellent habitat for rearing fish. However, the chutes present in the lower section of Donald Creek likely prevent upstream migration of fish to this habitat.

Unnamed Tributary #1

Unnamed Tributary #1 at the confluence of the Athabasca River had a mean wetted width of 2.0 m and a depth that did not exceed 0.5 m at any point throughout the reach examined in October 1997. It has a moderate stream gradient (4%). Habitat consists predominantly of riffles and/or riffle/boulder garden areas (83%) (Photo C, Figure 5), with the occasional low quality P3 pool present (17%). Substrate in the riffle areas is comprised of various sized boulders, cobbles and gravel. The stream banks are frequently undercut and unstable. The undercut banks provide overhead cover along with overhanging vegetation and woody debris. Good instream cover is also provided by woody debris and boulders. This tributary has excellent habitat for rearing fish; however, there are barriers which will likely prevent upstream fish migration (e.g., beaver dams, chutes).

Unnamed Tributary #2

Unnamed Tributary #2 at the confluence of the Athabasca River had a mean wetted width of 1.5 m and was relatively shallow (mean depth 0.65 m in October 1997). It has a steep gradient (6%) and the habitat consists almost entirely of low quality R3 runs (63%) and riffles (35%). Boulder gardens are situated amidst some of the upstream riffle areas. Two very small P3 (low quality) pools and the occasional backwater area are also present. Chutes formed by woody debris that is scattered throughout the channel are evident (Photo D, Figure 6). Substrate varies from fines in areas of low velocity (pools and backwater areas) to cobbles and boulders in faster moving areas (riffles and runs) and boulders predominate in the upstream sections. There is good flow in the riffle and run areas which predominate, but water velocity dissipates in the pool and backwater areas.

The morphology of the stream banks also varies throughout such that there are areas of low stable banks, but also areas of steep unstable banks. Overhanging vegetation, woody debris and undercut banks provide overhead cover for fish and the numerous boulder gardens and woody debris provide instream cover.

McLean Creek

The average annual stream flow for McLean Creek in 1997 has been estimated at 0.12 m^3/s (Klohn-Crippen 1997). The lower section of McLean Creek (near the confluence of the Athabasca River) had a mean wetted width of 2.8 m, a mean depth of 0.6 m and a maximum depth of 0.8 m in October 1997. The gradient is moderate-to-high (5%) and habitat consists of a series of riffle-run-pool sequences. There is also the occasional backwater area created by root wads and instream woody debris. Substrate in most areas consists of small boulders, cobbles and gravel, with fines present in the slower backwater areas. The stream banks are unstable throughout most of the reach and are undercut and/or slumping at certain points. There is abundant instream woody debris, overhanging vegetation and undercut banks that provide cover for fish. The woody debris piles and chutes present in this section of McLean Creek may pose potential barriers to upstream migration of fish (Photo E, Figure 7).

The upper section of McLean Creek is low gradient (1%) and wider than the downstream section (mean wetted width 4.0 m, October 1997). However, as with the downstream section, habitat consists primarily of riffle-run-pool sequences with backwater areas created by the irregular bank morphology. Water depth in October 1997 ranged from 0.3 to 0.9 m.

There is considerable variability in substrate composition throughout the upper section of McLean Creek. The areas of high flows have a substrate of medium-sized boulders and/or cobbles and gravel, while the lower velocity areas have a substrate predominantly of fines. The stream banks are generally stable and vegetated throughout the reach (except for one small section). There are no undercut banks in this section of McLean Creek, but overhead cover is available in the form of woody debris. Aquatic plants provide some instream cover. Beaver dams, chutes (Photo F, Figure 8 and Photo G) and debris piles in this section of McLean Creek are barriers to fish movement and upstream migration. There are large active beaver dams that have resulted in the creation of beaver ponds and impounded areas. Upstream of these dams, there is excellent habitat for rearing, spawning and overwintering fish, although the likelihood of fish passage to these points is poor.

Creek Two (tributary to Shipyard Lake)

In October 1997, Creek Two was sampled near Shipyard Lake. The creek discharge had a mean wetted width of 2.0 m, a mean depth of 0.7 m, and a discharge at that time, of 0.06 m^3/s (Golder 1996c). The average monthly flow in 1997 from July to October was 0.09 m^3/s (Klohn-Crippen 1997, Golder 1996c).

Creek Two is a low gradient watercourse (2%) composed almost entirely of low quality R3 runs (98%) (Photo H, Figure 9) which form multiple shallow slow moving channels in some areas. Two very small P3 (low quality) pools are also present and comprise the remaining 2% of available habitat in the study section. Substrate throughout this section of the creek is composed of fines and low stable stream banks predominate. Woody debris provides both instream and overhead cover, as does the overhanging and inundated riparian vegetation (willows). There are chutes, woody debris piles and old beaver dams at points throughout this reach of the creek. In particular, 400 m upstream of the beginning of the section examined, there is a 1 m high falls beyond which a shift in habitat occurs. Upstream of the falls, water flows swiftly through a series of very old beaver dams and there are areas of clean gravel with little instream debris and low turbidity levels.

3.1.2 Habitat Quantity

Mean wetted widths and estimates of habitat quantity (area) for the watercourses examined are presented in Table 3. A Geographic Information System (GIS) was used to determine the stream lengths from digital NTS 1:50,000 scale maps. Average stream widths were determined from numerous field measurements of wetted width at points throughout the reaches examined during October 1997.

Table 3 Habitat Area (hectares) for Watercourses Examined in this Study

Watercourse	Section	Average Wetted Width [a] (m)	Stream Length (m)	Area [b] (hectares)
Donald Creek	Lower	2		
	Upper	1.5		
	Average	1.75	14,100	2.47
Unnamed Tributary #1		2	n/m	n/m
Unnamed Tributary #2		1.5	n/m	n/m
McLean Creek	Lower	2.8		
	Upper	4		
	Average	3.4	17,050	5.8
Creek Two		2	3,880	0.8

[a] Wetted width sampled in October 1997.
[b] Area is calculated from stream length and average wetted width.
n/m = not measured.

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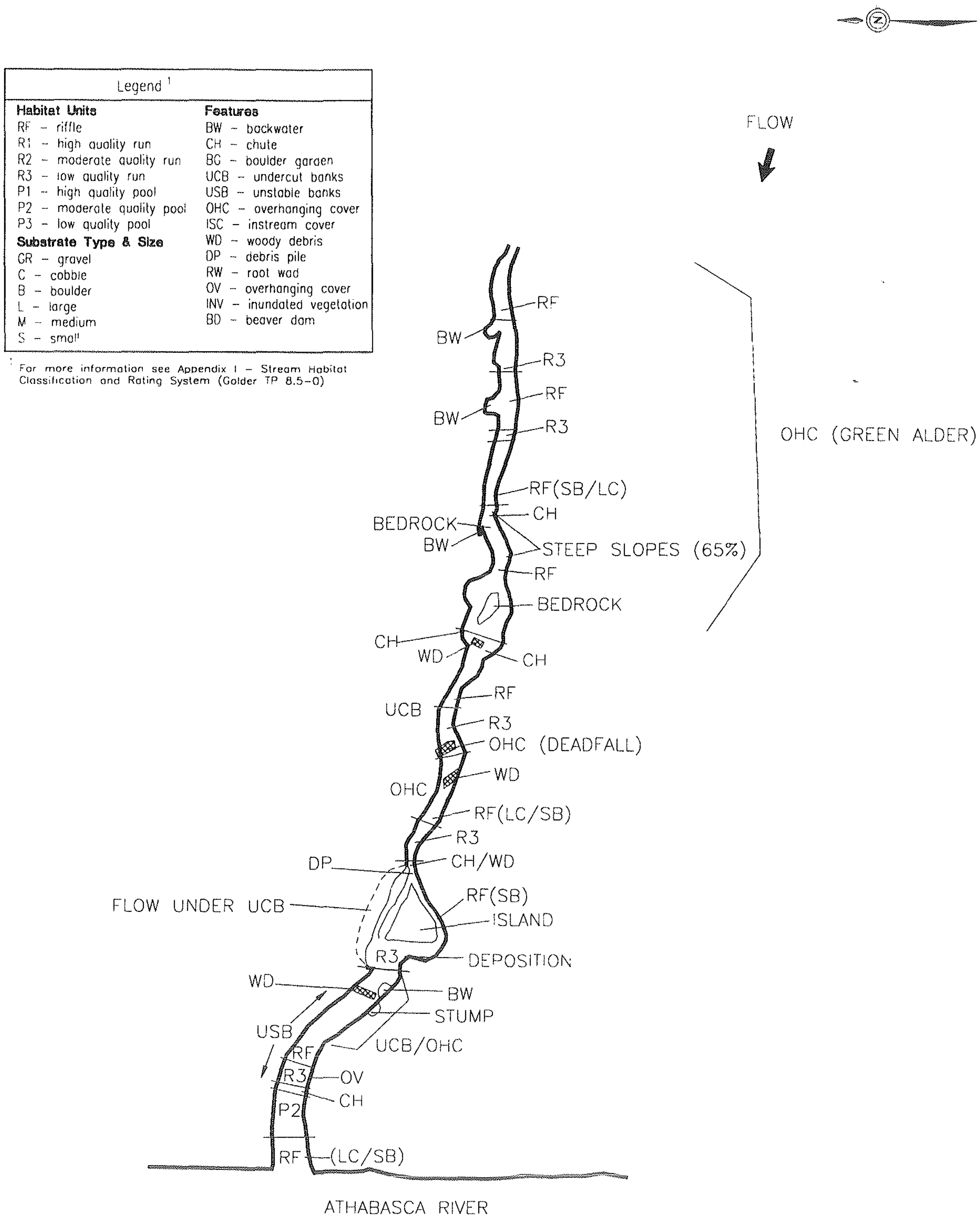

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DONALD CREEK (LOWER SECTION)
(DOC-F-1)

12 Mar. 1998	Figure 3	DRAWN BY: DC/VS

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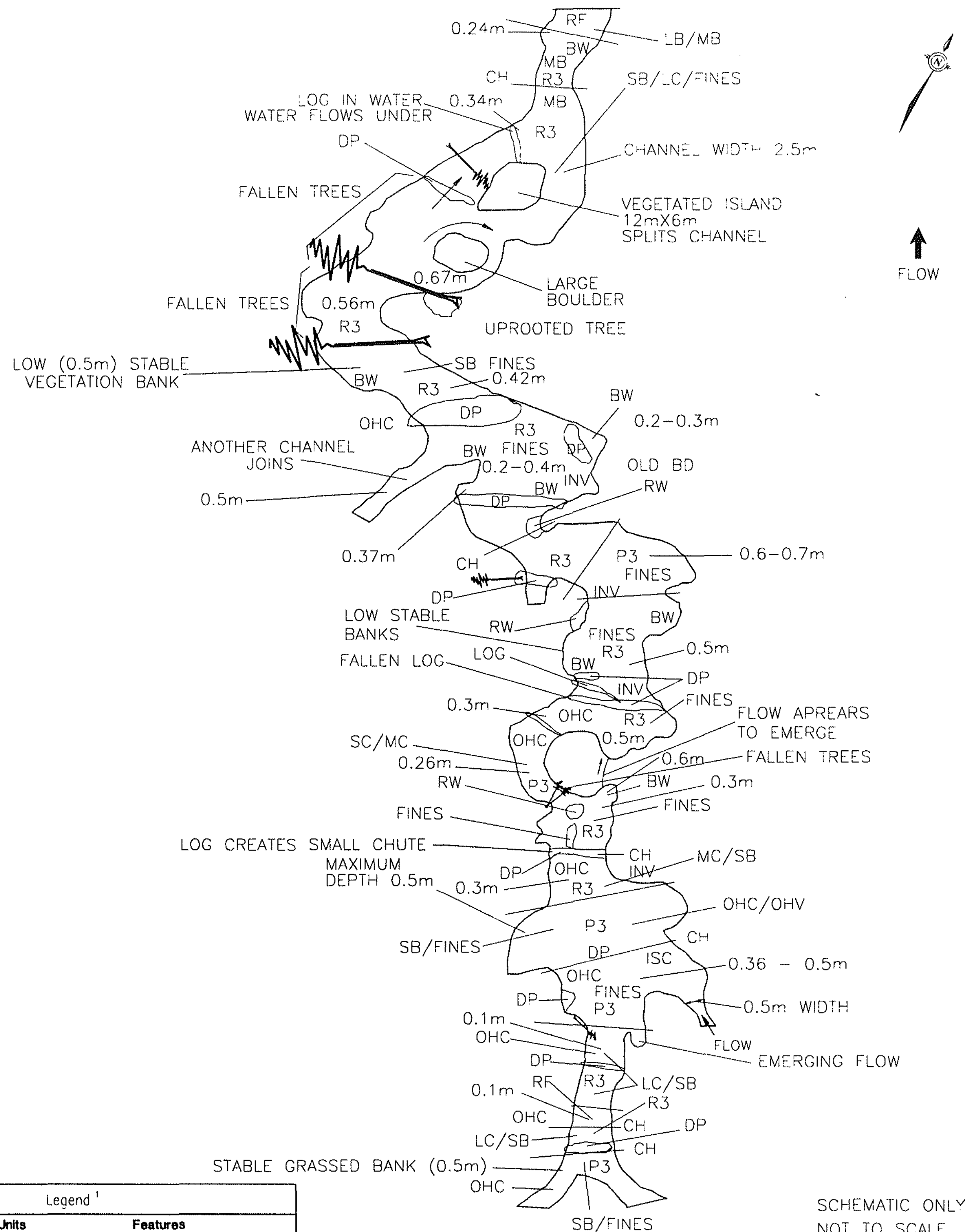

Legend[1]

Habitat Units	Features
RF - riffle	BW - backwater
R1 - high quality run	CH - chute
R2 - moderate quality run	BG - boulder garden
R3 - low quality run	UCB - undercut banks
P1 - high quality pool	USB - unstable banks
P2 - moderate quality pool	OHC - overhanging cover
P3 - low quality pool	ISC - instream cover
Substrate Type & Size	WD - woody debris
GR - gravel	DP - debris pile
C - cobble	RW - root wad
B - boulder	OV - overhanging cover
L - large	INV - inundated vegetation
M - medium	BD - beaver dam
S - small	

[1] For more information see Appendix I - Stream Habitat Classification and Rating System (Golder TP 8.5-0)

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**DONALD CREEK (UPPER SECTION)
(DOC-F-2)**

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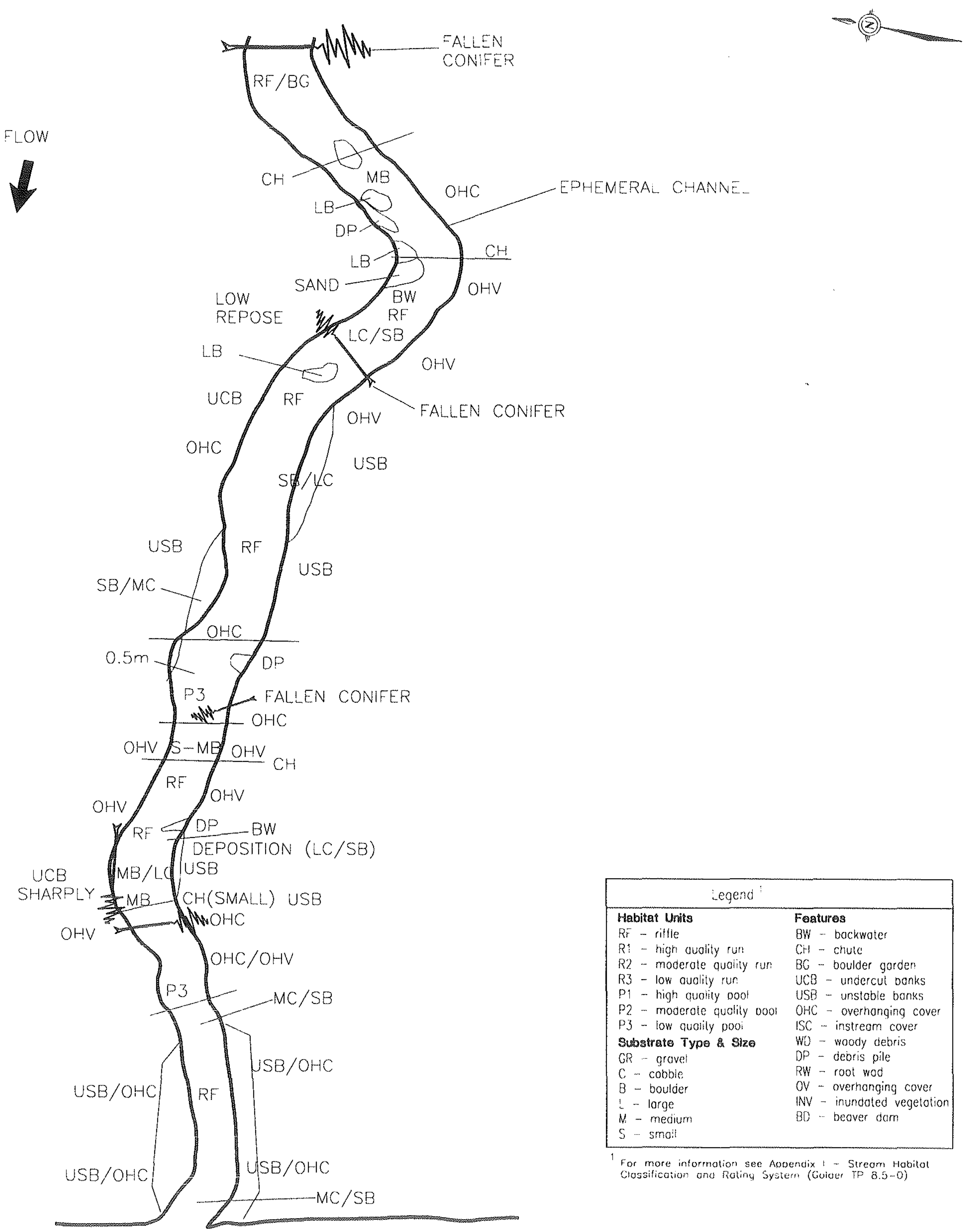

Legend[1]

Habitat Units	Features
RF - riffle	BW - backwater
R1 - high quality run	CH - chute
R2 - moderate quality run	BG - boulder garden
R3 - low quality run	UCB - undercut banks
P1 - high quality pool	USB - unstable banks
P2 - moderate quality pool	OHC - overhanging cover
P3 - low quality pool	ISC - instream cover
Substrate Type & Size	WD - woody debris
GR - gravel	DP - debris pile
C - cobble	RW - root wad
B - boulder	OV - overhanging cover
L - large	INV - inundated vegetation
M - medium	BD - beaver dam
S - small	

[1] For more information see Appendix I - Stream Habitat Classification and Rating System (Golder TP 8.5-0)

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UNNAMED TRIBUTARY #1 (UCI-F1)

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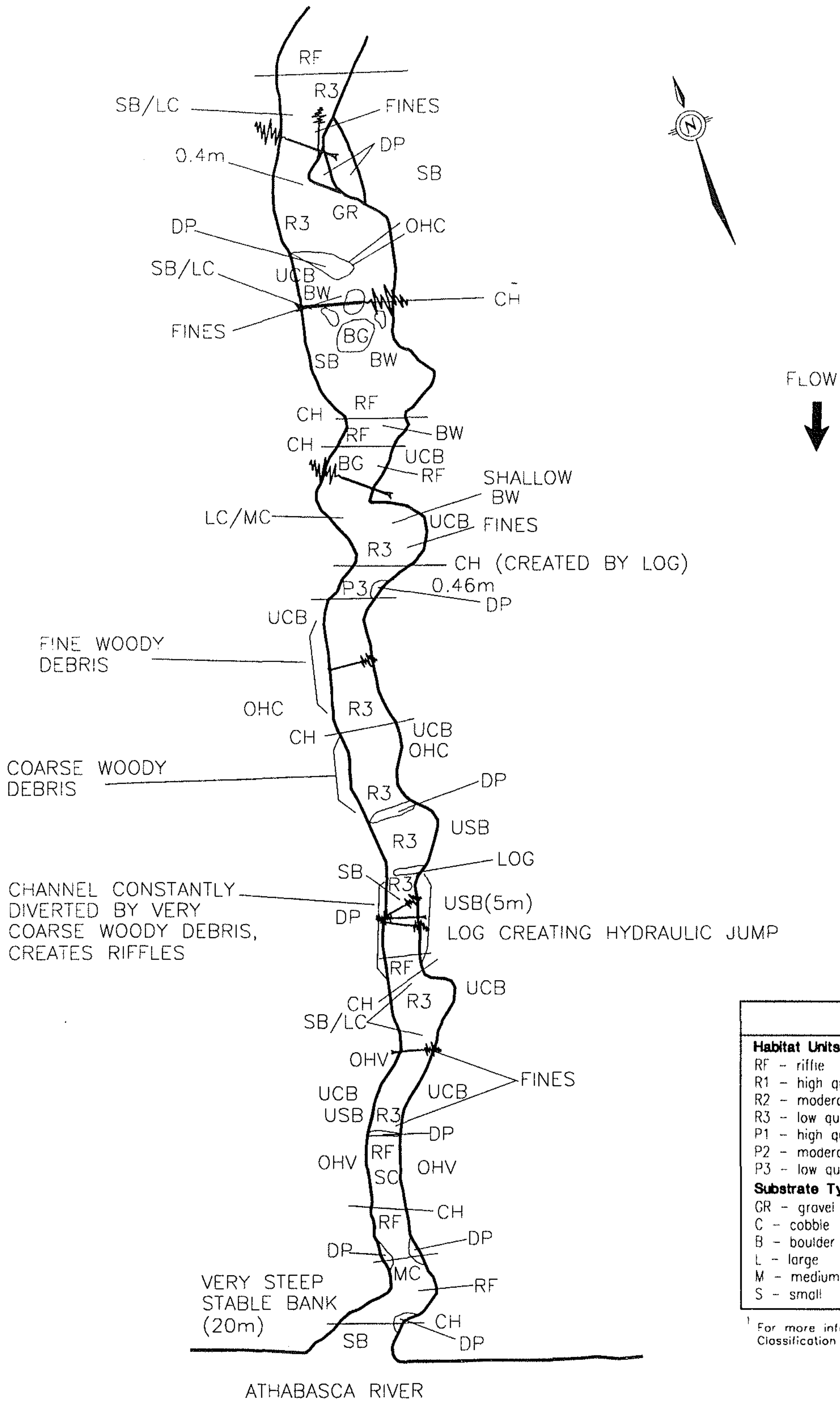

Legend[1]

Habitat Units	Features
RF – riffle	BW – backwater
R1 – high quality run	CH – chute
R2 – moderate quality run	BG – boulder garden
R3 – low quality run	UCB – undercut banks
P1 – high quality pool	USB – unstable banks
P2 – moderate quality pool	OHC – overhanging cover
P3 – low quality pool	ISC – instream cover
Substrate Type & Size	WD – woody debris
GR – gravel	DP – debris pile
C – cobble	RW – root wad
B – boulder	OV – overhanging cover
L – large	INV – inundated vegetation
M – medium	BD – beaver dam
S – small	

[1] For more information see Appendix I – Stream Habitat Classification and Rating System (Golder TP 8.5-0)

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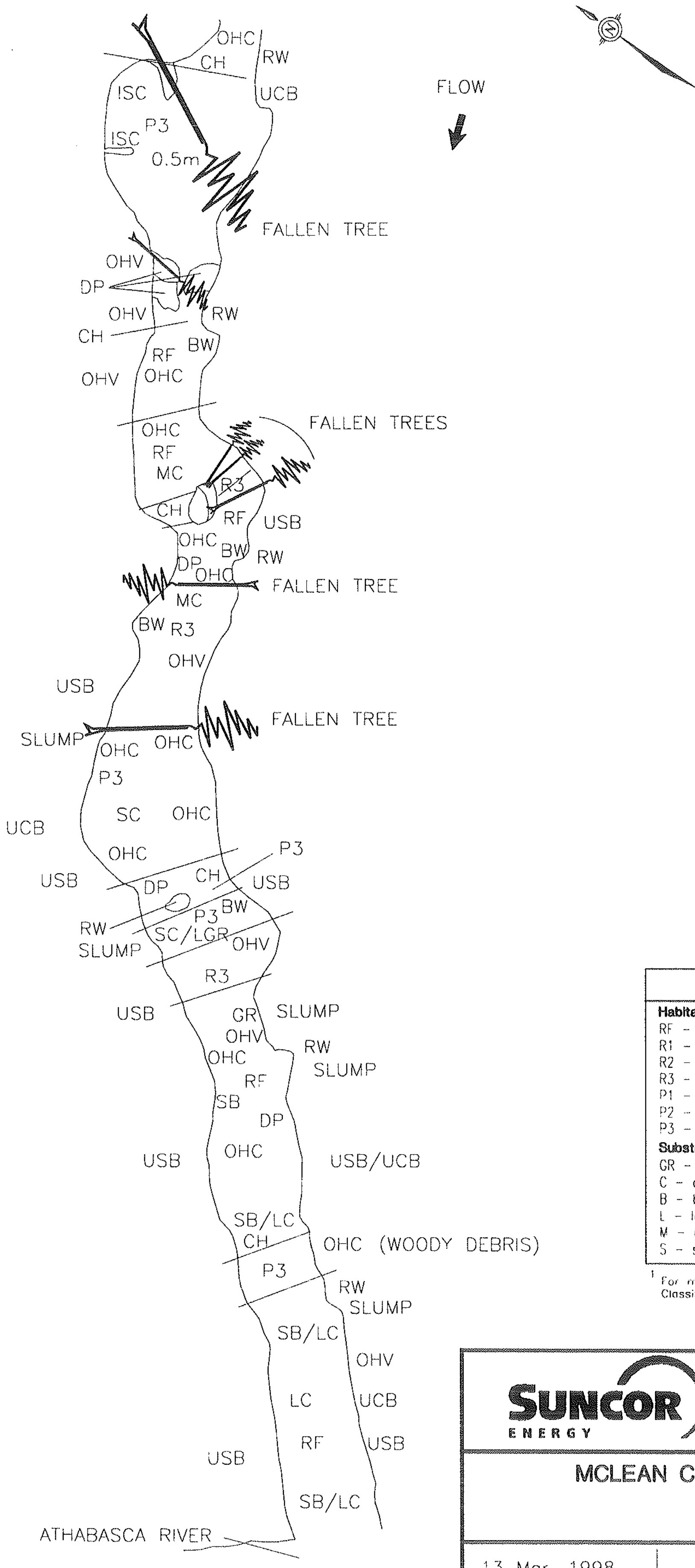
UNNAMED TRIBUTARY #2
(UC2-F-1)

12 Mar. 1998	Figure 6	DRAWN BY: DC/VS



Legend[1]

Habitat Units	Features
RF – riffle	BW – backwater
R1 – high quality run	CH – chute
R2 – moderate quality run	BG – boulder garden
R3 – low quality run	UCB – undercut banks
P1 – high quality pool	USB – unstable banks
P2 – moderate quality pool	OHC – overhanging cover
P3 – low quality pool	ISC – instream cover
Substrate Type & Size	WD – woody debris
GR – gravel	DP – debris pile
C – cobble	RW – root wad
B – boulder	OV – overhanging cover
L – large	INV – inundated vegetation
M – medium	BD – beaver dam
S – small	

[1] For more information see Appendix I – Stream Habitat Classification and Rating System (Golder TP 8.5–0)

SUNCOR ENERGY | **Project Millennium** Taking Suncor Into the 21st Century

MCLEAN CREEK (LOWER SECTION) (MCC-F-1)

13 Mar. 1998 | Figure 7 | DRAWN BY: DC/VS

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Legend [1]

Habitat Units	Features
RF - riffle	BW - backwater
R1 - high quality run	CH - chute
R2 - moderate quality run	BG - boulder garden
R3 - low quality run	UCB - undercut banks
P1 - high quality pool	USB - unstable banks
P2 - moderate quality pool	OHC - overhanging cover
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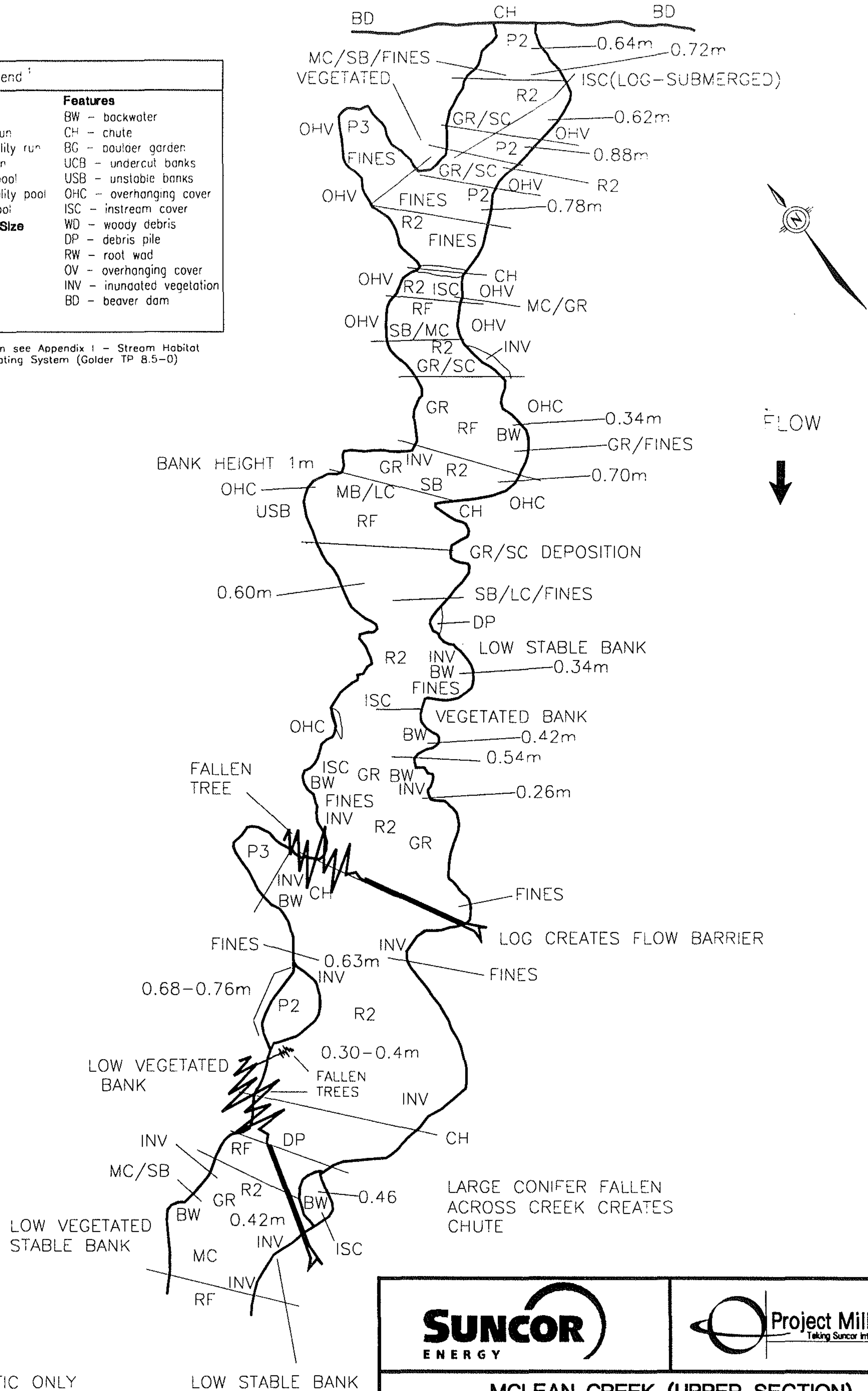
[1] For more information see Appendix I - Stream Habitat Classification and Rating System (Golder TP 8.5-0)



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MCLEAN CREEK (UPPER SECTION)
(MCC-F-2)

12 Mar. 1998	Figure 8	DRAWN BY: DC/VS

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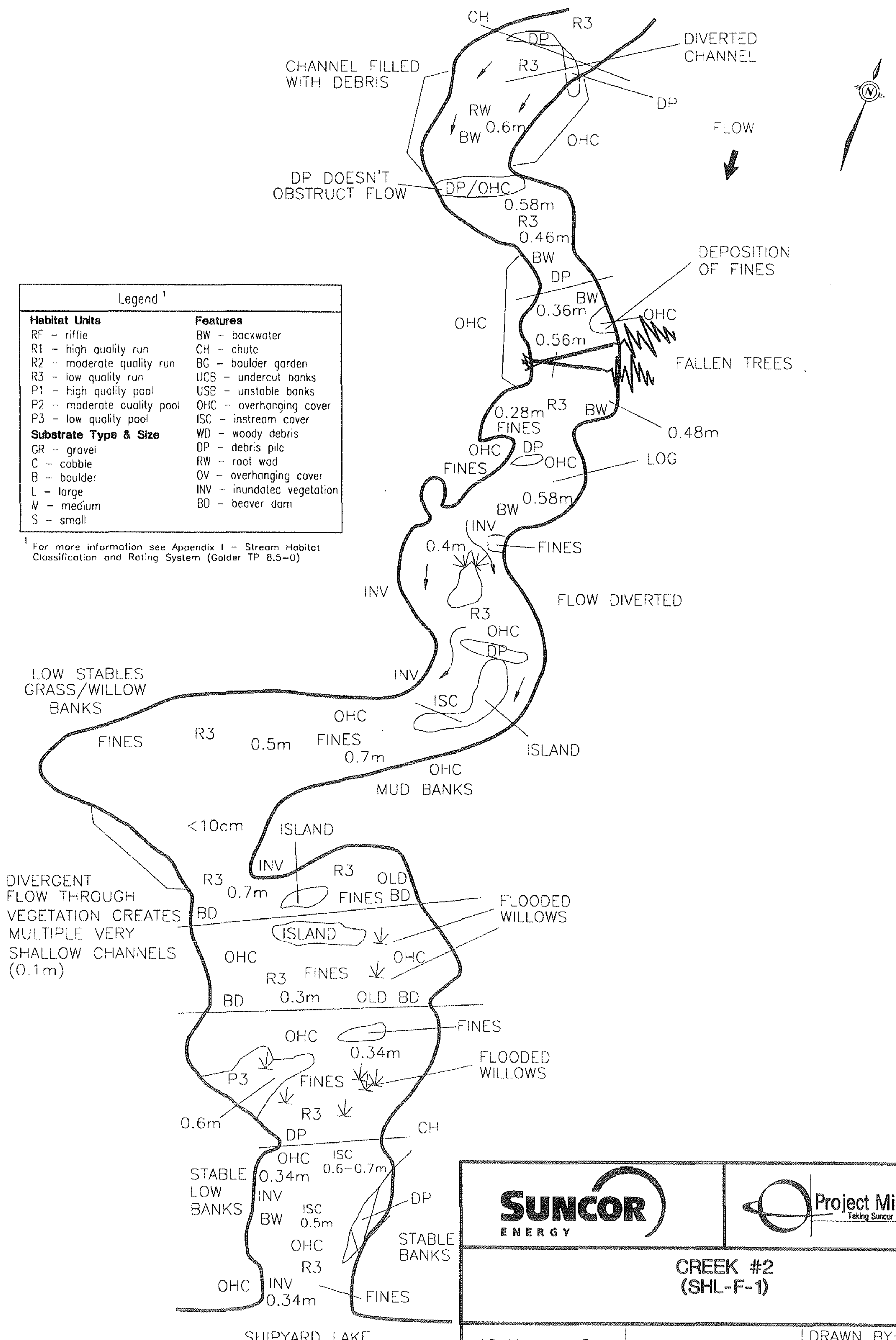

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CREEK #2
(SHL-F-1)

12 Mar. 1998	Figure 9	DRAWN BY: DC/VS

Photographs

Photograph A Donald Creek (lower section) – Chute 15 m upstream of confluence with Athabasca River.

Photograph B Donald Creek (upper section) – R3 run habitat with instream woody debris.

Photographs

Photograph C Unnamed Tributary #1 – Riffle area with boulder garden.

Photograph D Unnamed Tributary #2 – Chute formed by instream woody debris.

Photograph E McLean Creek (lower section) – Area of overhanging woody debris and vegetation.

Photograph F McLean Creek (upper section) – Deep pool created by beaver dam and backflooding.

Photograph G McLean Creek (upper section) – Chute created by a breached beaver dam.

Photograph H Creek Two – R3 run habitat.

3.2 FISH INVENTORY

All fish were captured during October 1997 using the backpack electrofisher. The minnow traps and gill nets yielded no catch. The total catch and catch-per-unit-effort for backpack electrofishing is presented in Table 4. Sampling effort expended using minnow traps and gill nets is reported in Table 2.

In total, 23 fish were captured as a result of fish sampling efforts. This catch consisted of four different species, including brook stickleback (*Culaea inconstans*) (n=16), longnose sucker (*Catostomus catostomus*) (n=1), Arctic grayling (*Thymallus arcticus*) (n=4) and burbot (*Lota lota*) (n=2). All fish were captured from the sampling stations that were located near the creek mouths (i.e., no fish were captured from the upper sampling stations at Donald and McLean creeks). A brief description of the fish fauna captured is provided below.

Table 4 Total Catch and Catch-Per-Unit-Effort for Fish Captured by Backpack Electrofishing, 1997

Station	Watercourse	Brook Stickleback	Longnose Sucker	Arctic Grayling	Burbot	**Total**
DOC-F-1	Donald Creek	-	1 (0.0016)	-	-	**1**
DOC-F-2	Donald Creek (Upper Section)	-	-	-	-	**0**
UC1-F-1	Unnamed Tributary #1	-	-	1 (0.0021)	1 (0.0021)	**2**
UC2-F-1	Unnamed Tributary #2	-	-	-	1 (0.0026)	**1**
MCC-F-1	McLean Creek	-	-	3 (0.0055)	-	**3**
MCC-F-2	McClean Creek (Upper Section)	-	-	-	-	**0**
SHL-F-1	Shipyard Lake Creek Two	16 (0.0118)	-	-	-	**16**
	Total	**16**	**1**	**4**	**2**	**23**

Donald Creek

One juvenile longnose sucker was captured from Donald Creek approximately 40 m upstream of the confluence of the Athabasca River (lower section). Kick net sampling was also conducted in the lower section of Donald Creek, but no fall spawning areas were located. No fish were captured from the upper section of Donald Creek, indicating that fish passage to this reach of the creek may not be possible because of numerous debris piles, chutes and beaver dams.

Unnamed Tributary #1

One juvenile burbot and 1 juvenile Arctic grayling were captured from Unnamed Tributary #1.

Unnamed Tributary #2

One juvenile burbot was captured from Unnamed Tributary #2.

McLean Creek

Three young-of-the-year Arctic grayling were captured from the lower section of McLean Creek near the confluence of the Athabasca River. All three of these individuals were captured from slower moving sections of the watercourse (i.e., pools, backwater areas). The presence of young-of-the-year Arctic grayling indicates lower McLean Creek may provide spawning habitat for this species in the spring.

No fall spawning areas were located during the kick net sampling survey that was conducted in the lower section of McLean Creek. No fish were captured from the upper section of McLean Creek, again indicating that upstream migration by fish is likely not possible because of debris piles, beaver dams and chutes.

Creek Two

Sixteen brook stickleback were captured from Creek Two. Two additional brook stickleback were observed, although not captured. The majority of the fish were captured within 400 m of the creek mouth at the Shipyard Lake wetland. No northern pike were captured from this tributary to Shipyard Lake, although the wetlands is known to support northern pike (Golder 1996b).

3.3 CONCLUSIONS

This fisheries investigation revealed no evidence of fall spawning activity in any of the creeks examined. There was some good quality rearing habitat located within sections of the creeks examined; however, many of these habitats have only limited potential for use given that fish passage may be blocked, particularly in the upper sections on the escarpment.

The lower sections of the watercourses that were examined (i.e., those near the creek mouths) tend to support fish, although in a very limited capacity, based on the number of individuals and the diversity of species captured. However, because these creeks were sampled in mid-October, fish that may potentially utilize them for spawning or other life stages may have since returned to the mainstem waterbody (i.e., the Athabasca River or Shipyard Lake).

Very few sport fish were captured during this investigation (four Arctic grayling and two burbot), none of which were adults, again indicating that these creeks provide nursery and rearing habitat for young-of-the-year and juvenile fish. The presence of young-of-the-year Arctic grayling in McLean Creek and Unnamed Tributary #1 indicates that they were likely spawned in these creeks during the spring (in the general vicinity of the sites examined). Additional fisheries investigations will be conducted at these sites in the spring of 1998 to assess the potential use of these creeks by spawning Arctic grayling.

4. CLOSURE

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

Respectfully submitted,

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APPENDIX I

STREAM HABITAT CLASSIFICATION AND RATING SYSTEM

1. PURPOSE

This technical procedure details the classification system and map coding system to be used for habitat mapping a watercourse and provides instructions on habitat mapping procedures and standards. The habitat mapping system consists of two components: 1) The **Large River Habitat Classification System** - a general system for mapping large mainstem rivers; and, 2) The **Stream Habitat Classification and Rating System** - a more detailed system for mapping discrete channels units which is primarily used for intermediate rivers and smaller streams.

2. APPLICABILITY

This technical procedure is applicable to all personnel involved in habitat mapping of all sizes of watercourses in Alberta. The technique was developed primarily in Alberta in consultation with Alberta Fish and Wildlife. With respect to describing aquatic habitats it is applicable to some areas outside of Alberta but may be superseded by local criteria (e.g., B.C. MOE guidelines). This procedure may not be applicable to low gradient streams in the plains areas east of Alberta without some modification. Portions of the stream classification system were developed in relation to salmonid species and would require interpretation in order to be suitable for evaluating habitat conditions for other fish species.

3. DEFINITIONS

Each of the habitat mapping system components includes a set of habitat types or categories, the definitions of which are included in the two different classification systems in Tables 1 and 2. Some more general definitions are presented here.

3.1 Bank

Banks are components of a watercourse. Banks comprise the borders of the stream channel and form the typical boundaries of the channel. The banks are only in contact with the water during high flow or flood events. They typically have rooted vegetation to distinguish them from the normally active channel. Certain bank features can influence the quality of instream fish habitat, particularly with respect to cover for fish.

3.2 Bank Stability

The stability or erodability of the banks is based on factors such as bank slope, bank material, evidence of seepages, undercutting, erosion and slumping. Unstable banks are banks which shed material (bank material or vegetation) into the watercourse. The input of fine sediments into rivers and streams can result in detrimental sedimentation of instream habitats. Alternatively, vegetation and other bank materials which fall in the channel may be beneficial by providing cover for fish or may be detrimental by causing blockages.

3.3 Channel

The channel is the main component of a watercourse. It is the area of the watercourse that typically has flowing water, on at least a seasonal basis, and is usually defined by the area of the stream substrate. The channel is distinguishable from the banks since it has contact with flowing water for at least a portion of each season which usually prevents establishment of permanent vegetation.

3.4 Channel Form

Channel form refers to the cross-sectional shape of the channel as defined by the width:depth ratio of the channel. Channel form will range from deeply incised (low width:depth) to broad (high width:depth).

3.5 Channel Unit (sometimes referred to as habitat type)

Channel units are the hydraulic and morphological features of a stream channel. A channel unit is a section of channel which is homogeneous with respect to water depth, velocity and cover and is separated from other channel units by gradients in these parameters. Channel units are sometimes referred to as habitat types. The most common channel units are **pool**, **riffle** and **run**, although a total of 12 channel units have been defined (Table 2).

The pressure or absence of channel units in a watercourse is the determining factor when choosing which component of the habitat mapping system to employ when working on large rivers. If a river does not show any channel unit differentiation, the *Large River Habitat Classification System* is used. If channel units are present, then the *Stream Habitat Classification and Rating System* is used.

3.6 Channel Width

The horizontal distance along a transect line from stream bank to stream bank (rooted vegetation to rooted vegetation) at the normal high water marks measured at right angles to the direction of flow.

3.7 Cover

Cover is defined as aspects of the physical environment which provide resting places or protection from predators for fish. Cover consists of two categories: 1) **Instream Cover** - any feature which provides a velocity shelter (e.g., large substrate particles, submerged debris, etc.); 2) **Overhead Cover** - any feature which provides visual isolation for the fish (e.g., overhanging vegetation, undercut bank, turbulence, water depth, etc.).

When habitat mapping a watercourse, available cover for fish is evaluated for each section of the channel as it is assigned a classification. For the *Large River Habitat Classification System*, near-shore cover is a part of assigning shoreline habitat types. For the *Stream Habitat Classification and Rating System*, cover is evaluated when assigning a channel unit rating for pool and run channel units.

Cover is assessed by the visual examination and estimation of the quality and quantity of the available features with respect to instream and overhead cover for different fish life stages. Smaller life stages such as fry require smaller cover compared to adult fish. Areas of high quality cover would provide cover for a number of individuals of all life stages. Areas of moderate cover would provide little or no cover for adults but some cover for juveniles and fry. Areas of poor cover would not provide cover for adults and only limited cover for juveniles and fry.

3.8 Discharge

A measurement of the volume of surface water flowing in the stream channel, measured as the volume flowing past a specific point over a given time (i.e., m^3/s). Stream discharge has significant effect on water level and depth in the various habitat types. In order to reduce the effects of variable discharge levels on habitat mapping, it is recommended that habitat mapping be conducted during the late summer low flow period.

3.9 Habitat Associations

Habitat associations are the relationships between habitat categories and fish presence, abundance and use. If the habitat mapping activities are conducted in conjunction with fisheries inventory sampling, the species, numbers and life stages of fish captured should be assessed by habitat type. That is, for each habitat type (either shoreline habitat type or channel unit type and class) the types of fish captured should be recorded. This not done for each individual habitat area but for each general type (e.g., fish captured in all Class 1 Pool channel units, versus Class 2 Pools or each class of run habitat or in riffle channel units).

3.10 Habitat Map

A habitat map is a map of a section of watercourse showing the location and extent (i.e., boundaries) of each habitat type. What constitutes a habitat type depends on which of the two mapping systems is employed. With the *Large River Habitat Classification System*, habitat types are the bank habitat features as described in Table 1. With the *Stream Habitat Classification and Rating System*, the habitat types are the channel units described in Table 2.

3.11 Stream Confinement

Stream confinement refers to the confinement of the watercourse within the boundaries of the floodplain. It is the degree to which the lateral movement of the stream channel is limited by terraces or valley walls.

3.12 Stream Habitat

The physical stream environment which provides a place for aquatic biota (fish, invertebrates, plants, etc.) to live, grow and reproduce. Several types of fish habitat should be considered when habitat mapping and include **spawning habitat**, **fry nursery habitat**, **juvenile rearing habitat**, **adult feeding habitat** and **overwintering habitat**.

3.13 Stream Gradient

The slope of the streambed over which the stream runs. Some channel characteristics are directly related to the gradient. Examples include average velocity, substrate coarseness, and presence and extent of various channel units. Gradient classification: low <2%; medium 2-5%; high >5%.

3.14 Stream Pattern

Channel pattern describes the sinuosity of the channel or the degree to which the channel deviates from straightness. Sinuosity is the channels meander pattern which can range from straight to tortuously meandering.

3.15 Substrate

Stream substrate is the material found on the bottom of the channel portion of the watercourse. It refers to the surficial deposits that can be seen when viewing the streambed. As part of the habitat evaluation process, the substrate is evaluated with respect to particle size composition. Particle size composition refers to the proportions of the substrate particles within each category from a series of size categories. The size categories employed are presented on Table 4. These range from fine sediments (fines are particles <2 mm in size and include clay, silt and sand) through gravels, cobbles, boulders and bedrock. A substrate evaluation is conducted by visual observation. The observer estimates the percentage of the substrate particles, by surface area, in each of the size categories.

3.16 Undercut Bank

An undercut bank has been eroded at the base by flowing water, allowing water to be present underneath a portion of the bank. Although undercutting usually adds to bank instability, it may also provide cover for fish. If the overhanging portion of the bank provides and effective with >9 cm over water with a depth of >0.15 m, it provides a cover feature.

3.17 Watercourse

A natural or artificial waterway which periodically or continuously contains moving water. It has a definite channel, banks which normally confine water and displays evidence of fluvial processes.

3.18 Wetted Width

The width of the water surface measured at right angles to the direction of flow. Multiple channel widths are summed to obtain total wetted width.

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5. DISCUSSION

The habitat mapping and classification system is used to provide an ecologically relevant inventory of stream habitats within a designated study area. The mapping procedure is meant to describe the habitats available within the stream and to detail the location and extent of each habitat type/class. The habitat classification system is intended to be ecologically meaningful with respect to describing and cataloguing physical habitats in relation to the requirements of fish species and their various life stages (spawning, incubation, nursery, rearing, summer feeding, holding, overwintering, migration); and also to a lesser extent the relationship between physical habitat and benthic invertebrate productivity, at least with respect to fish food production. Researchers have determined that fish distinguish between the habitat types and sub-classes of habitat types that have been used to map streams. It is intended that this classification system will provide an ecological association of habitat characteristics and fish use/abundance.

Streams are habitat mapped to provide an inventory of the available habitats and to show the locations of habitats that are of importance to fish such as migration routes, spawning habitats and rearing habitats. Habitat maps are used in several applications. A habitat map can be used to show the habitat types that may be impacted by a proposed point disturbance such as a pipeline crossing or bridge construction. A habitat map of a length of stream can also be used to evaluate alternate locations of disturbances in order to minimize the impacts. Habitat maps may be applied to document changes to a stream environment over time, from disturbances or due to habitat rehabilitation or improvement programs. A primary use of the habitat mapping procedure is to provide an inventory of the habitats present in a stream that is subject to a proposed impact in order to ensure compliance with the Federal Regulations stating that "No Net Loss" of productive fish habitat is to occur as a result of a proposed disturbance or alteration of the stream.

The habitat mapping and classification system is composed of two components. The first is a general system called the **"Large River Habitat Classification System"** which is used to map large mainstem rivers such as the Peace or Athabasca rivers where habitat heterogeneity is less than for smaller streams, and use of a more detailed system is not appropriate. The second component is a the more detailed **"Stream Habitat Classification and Rating System"**, which is used for watercourses with a greater degree of channel complexity and which display different types of channel units. Whether the Large River Habitat Classification System (Table 1) is used or the Stream Habitat Classification and Rating System (Table 2) is used will depend on the size of the watercourse and the types of available habitats.

5.1 How to Draw a Habitat Map

It is best to have a **base map** prepared on which to record the habitat map. This is much preferred to drawing a free-hand schematic diagram of the watercourse while in the field. Base maps must usually be prepared in the office before heading out for the field. Air photos provide a good template to prepare basemaps. Air photos can be borrowed from the University Photo Library and photocopied to avoid having to purchase the photos. Topographical maps may also be used to prepare a base map but usually need to be enlarged on a photocopier to provide a map. For small streams which appear on the map as only a single line, it is still best to make an enlargement and then to draw in a second line parallel to the line on the map, approximating the channel. Base maps should be sufficiently large to allow for sufficient detail to be recorded.

Once a map or air photo has been obtained and the enlargement has been made, the watercourse can be traced onto a mylar overlay then traced onto waterproof paper to provide a base map for use in the field. Do not photocopy the mylar tracing onto waterproof paper as you will not be able to erase the lines. You may need to do to redraw portions of the channel if changes have occurred since the photo or map was made. It may be possible to reduce the number of steps here if you can use a light table to trace the map or photo directly to waterproof paper. While producing the base map, be sure to record the scale of the map, particularly if the original map was enlarged to make the base map. If the map used to produce the base map has a scale drawn on it, enlarge this scale along with the map to provide the scale for the base map.

Base maps are very important to provide an accurate representation of the watercourse, to aid in drawing in the boundaries between habitat types, the location of each habitat type and the area and length of each habitat type. This type of accuracy is very difficult with free-hand drawings made onto blank paper. If base maps are not available and this type of accuracy is required, a tape measure or hip chain can be used to measure the lengths for each habitat type. This will help ensure the free-hand drawing is accurate and to scale. Simple free-hand schematic drawings are acceptable if this type of accuracy is not required of a large number of streams are to be mapped making the preparation of a base map for each stream impractical.

The habitat map is produced by **delineating on the base map the location and extent of each of the habitat features**. To do this, the channel is divided into a continuous series of habitat types by drawing on the base map the boundaries of each habitat type and attaching a label to identify the habitat type. The habitat types to be drawn on the map depend on which of the two habitat mapping systems is being employed. For the *Large River Habitat Classification System*, bank habitat types are delineated. For the *Stream Habitat Classification and Rating System*, channel units are delineated. The habitat types to be included, the definitions of these features, and the abbreviations (map symbols) used to label each feature on the habitat map are detailed in Tables 1 and 2. It is important to draw on the map the boundary of each habitat type so that the length of each habitat type can be measured during the data analysis and interpretation process.

Also to be recorded during on the habitat map are the following: **Project Number/Title**, **Watercourse Name** or some type of identifier if the stream is unnamed, **Location** of the stream or section of stream being mapped, **Date**, and **Personnel (Crew)**. If more than one page is required to complete the habitat map for a given watercourse, record the **page number** on each page (i.e. Page 1 of 2, Page 2 of 2, etc.). If possible, the discharge or relative water level at the time of mapping should be recorded since the water level greatly affects the depths, and potentially the classification of the habitat types. For this reason, **it is preferable to conduct all habitat mapping procedures under late summer base flow conditions**.

Other information to be recorded on the habitat map in order to standardize the maps between projects and observers. The map must show a **North arrow**, an arrow showing the **direction of flow** in the channel, a **scale** or the words 'schematic diagram-not to scale, and a **legend** explaining the abbreviations and symbols used on the map. Before turning the map into drafting for preparation for inclusion in a report, add a **Figure Name** and **Number**.

In addition to habitat types, qualitative descriptions of substrate conditions can be recorded on to the habitat maps the general substrate conditions. Typically, this process would be applied during use of the *Stream Habitat Classification and Rating System* to describe the substrate conditions for specific areas, such as potential spawning habitats, or to describe the substrate type within each individual channel unit. Substrate composition is presented as the percent occurrence (visual estimation) of each substrate size category. Substrate particle sizes are presented on Table 4.

5.2 Large River Habitat Classification System

This is a general system based on gross morphology and habitat types along the river banks and shoreline. It consists of two primary components: 1) "major habitat type", which defines the type of channel present; and, 2) "bank habitat type", which details the structure of the bank and near shore habitats. "Special habitat features" considered significant to fish distribution/use in these large rivers are also to be included on the map. Table 1 presents the details of the large river habitat classification system.

The Large River Habitat Classification System is to be used on large rivers which do not show any differentiation of channel units; distinct pool, riffle and run habitats are absent. In most large rivers, such as the Peace or Athabasca Rivers, the lower segments of the river are wide with relatively low gradients and large flow volumes. Channels do not contain physical or hydraulic features which create riffle/pool sequences. There is little or no differentiation of habitat types in the channel. It should be realized, however, that at any given point, depths across the width of the channel may vary. Habitat features that fish might use are generally associated with shoreline areas, areas of instream islands and tributary confluences. These features should be identified on the habitat map.

Shoreline habitats change as the structure of the banks change, providing one of the few characteristics that can be mapped. Elements of the bank structure which affect fish habitat include: water depth along the shoreline, substrate type and cover features to substrate, fallen debris/vegetation, and protrusions from the bank which create low velocity related habitats. Therefore, bank features are the basis of the Large River Habitat Classification System.

To draw a habitat map using the large river system, begin by **dividing the length of the watercourse in the study area into *Major Habitat Types***, depending on the number of permanent/vegetated islands present. This can often be done from the base map or air photo which will normally show all permanent islands. Any islands not on the original base map should be drawn onto the habitat map. Next, the **shorelines should be divided into *Bank Habitat Types*** according to the criteria in Table 1. This should be done for both shorelines as well as the shorelines around all permanent islands. Remember to show the boundaries of each Bank Habitat Type. This is usually done by demarcating the boundaries with a short line drawn at the shoreline, perpendicular to the shoreline, and labeling the area inside the boundaries with the appropriate Bank Habitat Type (e.g. A1, E5, etc.). Bank Habitat Types should be a continuous series along the shorelines without any blank, unlabelled sections. For any tributaries which enter the river within the study area, examine the tributary mouth and **label the tributary confluence according to the categories in Table 1**. To complete the map, **draw in the location and extent, again showing the boundaries, of all *Special Habitat Features***, as defined in Table 1.

5.3 Stream Habitat Classification and Rating System

This is a detailed mapping system based on individual channel units. These units are defined as sections of stream of homogenous with respect to depth, velocity and cover. The extent of each channel unit should be delineated on the map, as should the class rating for each unit (where appropriate). Some of the channel units also have modifiers (types) which should also be recorded. Table 2 presents the details of the stream habitat classification and rating system. This system is employed for mapping all watercourses which have distinct channel units such as pool, riffle and run habitats.

To draw a habitat map using the stream mapping system, the **length of stream in the study area is divided into a continuous series of channel units**. Table 2 presents the definitions for each of the 12 types of channel unit. Lines drawn across the channel are used to delineate the location and extent of each channel unit. The appropriate channel unit symbol (abbreviation) is used to label the channel unit. In addition to the channel unit type, three types of channel units have different sub-classes. **Run, pool and impoundment channel unit types should be further divided into Class 1, Class 2 or Class 3, depending on water depth and available cover for fish**, as described in Table 2. The classification should be included in the label on the habitat map (e.g. a riffle would simply be labeled RF on the map but a pool would be labeled as P1, P2 or P3, depending on the Class). Make sure the entire length of the channel in the study area has been divided into channel units on the map, including boundary lines, and that each unit has a complete label. In order to better define the available habitats in the study area, **record the maximum water depth in each channel unit and include it in the channel unit label** (e.g. a Class 1 pool that has a maximum depth of 4.0m should be labeled P1-4.0m).

Dividing the run, pool and impoundment units into subclasses is based on water depth and the quality of available cover for fish. Some general water depth guidelines are included in Table 2 to assist in classifying these channel units. However, these depths are not the only criteria. The classification of each channel unit is also based on its potential use by different life stages of fish (Table 1). For example, if a run channel unit is slightly shallower than the minimum depth for a Class 1 (Table 3), but high quality cover for adult fish is present, it would be classified as Class 1. Conversely, a run channel unit that is deeper than the minimum depth for a Class 1 run but with very poor cover would be classified as a Class 2 run.

The use of the channel unit and class categories are meant to relate instream habitats to the potential utilization by fish species and life stages. Much of the criteria used to establish the classifications are based on the habitat requirements of salmonid species. In Alberta, this includes non-anadromous trout and whitefish. Table 5 provides the fish utilization expected for each of the habitat types. The overall goal of the Stream Habitat Classification and Rating System is to provide habitat classifications that relate to fish utilization. Therefore, the associations within Table 5 should be kept in mind when assigning classifications.

TABLE 5

CHANNEL UNIT CLASSIFICATION AND HABITAT ASSOCIATIONS FOR SALMONIDS

Spawning		Nursery/Rearing	Adult Feeding	Overwintering
Trout (gravel sub.)	Whitefish (cobble sub.)			
RF	R2	RF	R1	P1
RF/BG	R2/BG	RF/BG	R2	R1
R3	RF	R1	R2/BG	R2
R3/BG		R2	P1	R2/BG
		R2/BG		
		R3/BG		

From Table 5 it can be seen that the potential utilization of some channel units, particularly those suitable for spawning, depends on substrate particle size. Therefore, a quick assessment of substrate size should be made for each channel unit. **For each channel unit record the dominant and co-dominant substrate size classes** and include this information with the channel unit label. For some projects, substrate particle sizes should be recorded in full detail as presented on Table 4. However, for most projects general substrate sizes could be used such as fines, gravel, cobble and boulder, without further dividing the substrate particles. For example, a Class 2 run channel unit with a maximum depth of 0.8 m and a cobble dominant and gravel co-dominant substrate would be labeled *R2-0.8m, cobble/gravel.*

Table 3 presents additional habitat features along with their symbols and abbreviations. These features include structures that would occur at specific points rather than for sections of the channel such as beaver dams or ledges. Other relevant features in Table 4 include aspects of cover such as areas of undercut or unstable banks, overhanging vegetation, inundated vegetation, debris piles or root wads. **Draw the appropriate symbol on the map to show the location of these features.**

5.4 Habitat Map Interpretation

Once the habitat map is completed, it is analyzed to determine the relative proportion of each habitat type in the study area. Measure the overall length of watercourse in the study area (i.e. section of watercourse habitat mapped) and the length of each habitat type; either bank habitat type (if using the large river system) or channel unit type (stream system). Sum the lengths of stream in each habitat type and calculate the percent composition, by length, of each habitat type for the study area as a whole. For the large river mapping system, the results will be presented as the percent composition of each bank type: e.g. 60% E5, 30% A1, and 10% D1. For the stream mapping system, the results are presented for each type and class of channel unit; e.g. 40% RF, 5% R1, 10% R2, 20% R3, 5% P1, 15% P2 and 5% P3.

If a coincidental fisheries inventory was conducted during the classification of fish habitat associations, observed fish use for each habitat type along with the proportion of each type should be included for a more accurate assessment of fish use in the study area. Otherwise, Table 5 can be compared to the habitat composition of the stream to evaluate the potential fish use in the study area.

TABLE 1: LARGE RIVER HABITAT CLASSIFICATION SYSTEM

MAJOR HABITAT TYPES

Type	Symbol	Description
Unobstructed channel	U	single main channel, no permanent islands, side bars occasionally present, limited development of exposed mid-channel bars at low flow
Singular island	S	two channels around single, permanent island, side and mid-channel bars often present at low flow
Multiple island	M	more than two channels and permanent islands, generally extensive side and mid-channel bars at low flow

BANK HABITAT TYPES

Type	Symbol	Description
Armoured/Stable	A1	largely stable and at repose; cobble/s.boulder/gravel predominant; uniform shoreline configuration; bank velocities low-moderate; instream/overhead cover limited to substrate and turbidity
	A2	cobble/s.-l.boulder predominant; irregular shoreline due to cob/boulder outcrops producing BW habitats; bank velocity low (BW)-mod; instream/overhead cover from depth, substrate and turbidity
	A3	similar to A2 with more l.boulder/bedrock; very irregular shoreline; bank velocities mod-high with low velocity BW/eddy pools providing instream cover; overhead cover from depth/turbidity
	A4	artificial rip-rap substrates consisting of angular boulder sized fill; often associated with high velocity areas; shoreline usually regular; instream cover from substrate; overhead cover from depth/turbulence
Canyon	C1	banks formed by valley walls; l.cobble/boulder bedrock; stable at bank-water interface; typically deep/high velocity water offshore; abundant velocity cover from substrate/bank irregularities
	C2	steep, stable bedrock banks; regular shoreline; mod-deep/mod-fast water offshore; occasional velocity cover from bedrock fractures
	C3	banks formed by valley walls, primarily fines with some gravel/cobble at base; moderately eroded at bank-water interface; mod-high velocities; no instream cover
Depositional	D1	low relief, gently sloping bank; shallow/slow offshore; primarily fines; instream cover absent or consisting of shallow depressions or embedded cobble/boulder; generally associated with bars
	D2	similar to D1 with gravel/cobble substrate; some areas of higher velocities producing riffles; instream/overhead cover provided by substrate/turbulence; often associated with bars/shoals
	D3	similar to D2 with coarser substrates (cobble/boulder); boulders often imbedded; mod-high velocities offshore; instream cover abundant from substrate; overhead cover from turbulence
Erosional	E1	high, steep eroded banks with terraced profile; unstable; fines; mod-high offshore velocity; deep immediately offshore; instream/overhead cover from submerged bank materials/vegetation/depth
	E2	similar to E1 without the large amount of instream vegetative debris; offshore depths shallower
	E3	high, steep eroding banks; loose till deposits (gravel/cobble/sand); mod-high velocities and depths; instream cover limited to substrate roughness; overhead cover provided by turbidity
	E4	steep, eroding/slumping highwall bank; primarily fines; mod-high depths/velocities; instream cover limited to occasional BW formed by bank irregularities; overhead cover from depth/turbidity
	E5	low, steep banks. often terraced; fines; low velocity; shallow-moderate; no instream cover; overhead cover from turbidity
	E6	low slumping/eroding bank; substrate either cobble/gravel or silt with cobble/gravel patches; moderate depths; mod- high velocities; instream cover from abundant debris/boulder; overhead cover from depth/turbidity/overhanging vegetation

SPECIAL HABITAT FEATURES

Type	Symbol	Description
Tributary confluences	TC	confluence area of tributary entering mainstem
[sub-classified according	TC1	intermittent flow. ephemeral stream
to tributary flow and	TC2	flowing, width <5m
wetted width at mouth at	TC3	flowing, width 5-15m
the time of the survey]	TC4	flowing, width 16-30m
	TC5	flowing, width 31-60m
	TC6	flowing, width >60m
Shoal	SH	shallow (<1m deep), submerged areas in mid-channel or associated with depositional areas around islands/side bars
	SHC	submerged area of coarse substrates
	SHF	submerged area of fine substrates
Backwater	BW	discrete, localized area exhibiting reverse flow direction and, generally, lower velocity than main current; substrate similar to adjacent channel with more fines
Rapid	RA	area with turbulent flow, broken surface (standing waves, chutes etc.). high velocity (>1 m/s), armoured substrate (large boulder/bedrock) with low fines
Snye	SN	discrete section of non-flowing water connected to a flowing channel only at its downstream end, generally formed in a side channel or behind a peninsula (bar)
Slough	SL	non-flowing water body isolated from flowing waters except during flood events; oxbows
Log Jam	LJ	accumulation of woody debris; generally located on island tips. heads of sidechannels. stream meanders; provide excellent instream cover

TABLE 2: STREAM HABITAT CLASSIFICATION AND RATING SYSTEM

(Adapted from R.L.&L. 1992 & Hawkins et. al 1993)

Channel Unit	Type	Class	Map Symbol	Description
Falls			FA	Highest water velocity; involves water falling over a vertical drop; impassable to fish
Cascade			CA	Extremely high gradient and velocity; extremely turbulent with entire water surface broken; may have short vertical sections, but overall is passable to fish; armoured substrate; may be assoc. with chute (RA/CH)
Chute			CH	Area of channel constriction, usually due to bedrock intrusions; associated with channel deepening and increased velocity
Rapids			RA	Extremely high velocity; deeper than riffle; substrate extremely coarse (l.cobble/boulder);instream cover in pocket eddies and associated with substrate
Riffle			RF	High velocity/gradient relative to run habitat; surface broken due to submerged or exposed bed material; shallow relative to other channel units; coarse substrate; usually limited instream or overhead cover for juvenile or adult fish (generally ≤0.5m deep)
Run (glide)			R	Moderate to high velocity; surface largely unbroken; usually deeper than RF; substrate size dependent on hydraulics
	Depth/Velocity Type			Run habitat can be differentiated into one of 4 types: deep/slow, deep/fast shallow/slow, or shallow/fast
		Class 1	R1	Highest quality/deepest run habitat; generally deep/slow type; coarse substrate; high instream cover from substrate and/or depth (generally >1.0 m deep)
		Class 2	R2	Moderate quality/depth; high-mod instream cover except at low flow; generally deep/fast or moderately deep/slow type (generally 0.75-1.0m deep)
		Class 3	R3	Lowest quality/depth; generally shallow/slow or shallow/fast type; low instream cover in all but high flows (generally 0.5-0.75m deep)
Flat			FL	Area characterized by low velocity and near-laminar flow; differentiated from pool habitat by high channel uniformity; more depositional than R3 habitat
Pool			P	Discrete portion of channel featuring increased depth and reduced velocity relative to riffle/run habitats; formed by channel scour
		Class 1	P1	Highest quality pool habitat based on size and depth; high instream cover due to instream features and depth; suitable holding water for adults and for overwintering (generally >1.5m deep)
		Class 2	P2	Moderate quality; shallower than P1 with high-mod instream cover except during low flow conditions, not suitable for overwintering
		Class 3	P3	Low quality pool habitat; shallow and/or small; low instream cover at all but high flow events
Impoundment		Class 1-3	IP (1-3)	Includes pools which are formed behind dams; tend to accumulate sediment/organic debris more than scour pools; may have cover associated with damming structure; identify as Class 1, 2 or 3 as for scour pools
	Dam Type			Three types of impoundments have been identified based on dam type; debris, beaver and landslide
Backwater			BW	Discrete, localized area of variable size exhibiting reverse flow direction; generally produced by bank irregularities; velocities variable but generally lower than main flow; substrate similar to adjacent channel with higher percentage of fines
Snye			SN	Discrete section of non-flowing water connected to a flowing channel only at its downstream end; generally formed in a side-channel or behind a peninsula
Boulder Garden			BG	Significant occurrence of large boulders providing significant instream cover; always in association with an overall channel unit such as a riffle (RF/BG) or run (e.g. R1/BG)

TABLE 3

ADDITIONAL HABITAT MAPPING SYMBOLS

Feature	Abbr.	Symbol	Description
Ledge	LE		Area of bedrock intrusion into the channel; often associated with chute or plunge pool habitat, may have a vertical drop affecting fish passage
Overhead Cover	OHC		Area of extensive or high quality overhead cover
Instream Cover	ISC		Area of high quality instream cover (velocity shelter) for all life stages
Undercut Bank	UCB		Area of extensive/high quality undercut bank providing overhead cover
Unstable Bank	USB		Area of unstable bank with potential to collapse instream, affecting instream habitat or producing sedimentation
Overhanging Veg.	OHV		Area of high quality overhanging vegetation providing overhead cover and stream shading
Inundated Veg.	INV		Area of inundated vegetation; either submergent macrophytes or flooded terrestrial
Debris Pile	DP		Debris pile (e.g. log jam) which influences instream habitat; include effect on cover
Root Wad	RW		Fallen terrestrial vegetation large enough to provide cover for fish
Beaver Dam	BD	XX	Include effect on fish passage

Considerations

Overhead cover includes overhanging vegetation, undercut bank or debris which has an effective width >9 cm over water with a depth > 0.15 m.

Instream cover is provided by aquatic vegetation or by substrate particles as large or larger than small cobbles when associated with water depths >0.15 m.

Deep water may provide cover if depth is >0.5 m.

Vertical drops >0.8 m are potentially impassable for resident trout species.

Generally suitable spawning sites for trout occur in pool tail-outs, riffles and the transition areas from runs to riffles where the dominant substrate sizes range from small gravel to small cobble, fines (particles <2 mm) comprise <30% of the substrate, minimum water depths exceed 0.15 m, and velocities range from 0.3 to 1.0 m/s. Individual patches of gravel must be 1-2 m^2 to be considered as spawning habitat.

TABLE 4

SUBSTRATE CRITERIA

SUBSTRATE DEFINITIONS, CODES AND SIZE-RANGE CATEGORIES

CLASS NAME	SIZE RANGE	
	MM	INCHES
Clay/Silt	<0.06	<0.0024
Sand	0.06-2.0	0.0024-0.08
Small Gravel	2-8	0.08-0.3
Medium Gravel	8-32	0.3-1.3
Large Gravel	32-64	1.3-2.5
Small Cobble	64-128	2.5-5
Large Cobble	128-256	5-10
Small Boulder	256-762	10-30
Large Boulder	>762	>30
Bedrock	-	-

APPENDIX II

FISH INVENTORY METHODS

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

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:

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

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.