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Fisheries Habitat Evaluation on Tributaries of the Coeur d'Alene Indian Reservation

1990 Annual Report

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ABSTRACT

Ranking criteria were developed to rate 19 tributaries on the Coeur d'Alene Indian Reservation for potential of habitat enhancement for westslope cutthroat trout, *Oncorhynchus clarki lewisi*, and bull trout, *Salvelinus malma.* Cutthroat and bull trout habitat requirements, derived from an extensive literature review of each species, were compared to the physical and biological parameters of each stream observed during an aerial - helicopter survey. Ten tributaries were selected for further study, using the ranking criteria that were derived. The most favorable ratings were awarded to streams that were located completely on the reservation, displayed highest potential for improvement and enhancement, had no barriers to fish migration, good road access, and a gradient acceptable to cutthroat and bull trout habitation. The ten streams selected for study were Bellgrove, Fighting, Lake, Squaw, Plummer, Little Plummer, Benewah, Aider, Hell's Gulch and Evans creeks.

ACKNOWLEDGEMENTS

Funding was provided by the U.S. Department of Energy, Bonneville Power Adminstration, Contract Number 90 -044-00. Additional financial support for this project was provided by a grant from the U.S. Department of the interior, Bureau of Indian Affairs to the Upper Columbia United Tribes (UCUT) to fund the operation of the UCUT Fisheries Center at Eastern Washington University (Grant No. CO02377). Ail capitol equipment for this project was supplied by the UCUT Fisheries Center. Special thanks go to Bob Austin (BPA Project Manager), Ernie Stensgar (Chairman, Coeur d'Alene Tribal Council), and Deidre Allen, (Coeur d'Alene Tribal Planner) for their assistance. The authors gratefully acknowledge and thank Cindi Abrahamson and Lori Hill for their patience and unending hours of typing.

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1.0 INTRODUCTION

In 1987, the Northwest Power Planning Council amended the Columbia River Basin Fish and Wildlife Program to include: "a *baseline stream survey of tributaries located on the Coeur d'Alene Indian Reservation to compile information on improving spawning habitat, rearing habitat, and access to spawning tributaries for cutthroat and Dolly Varden (bull trout) and to evaluate the existing fish stocks. If justified by the results of the survey, fund the design, construction and operation of a cutthroat and Dolly Varden (bull trout) hatchery on the Coeur d'Alene Reservation; necessary habitat improvement projects: and a three-year monitoring program to evaluate the effectiveness of the hatchery and habitat improvement projects. If the baseline survey indicates a better alternative than construction of a fish hatchery, the Coeur d'Alene Tribe will submit an alternative plan for consideration in program amendment proceedings."* [Section 903 (g)(l)(B)]. The Five Year Action Plan of the Council stated that Bonneville Power Administration (BPA) should commence funding a stream survey; the design, construction, operation, and maintenance of a cutthroat and bull trout hatchery on the Coeur d'Alene Reservation; habitat improvement projects: and a three-year monitoring program [Section 1400 (7.7)]. In 1990, BPA contracted the Coeur d'Alene Tribe to conduct this study. The three-phase study is designed to:

1. Compile information on improving spawning and rearing habitat and accessibility to spawning tributaries for cutthroat and bull trout.

2. Fund the design, construction and operation of a cutthroat and bull trout hatchery and necessary habitat improvement projects.

3. Conduct a three-year monitoring program' to evaluate the effectiveness of the hatchery and habitat improvement projects.

1.1 FISHERIES MANAGEMENT HISTORY OF THE COEUR D'ALENE BASIN

Historically, native species of fish that were abundant in Coeur d'Alene Lake and its tributaries included: westslope cutthroat trout *(Oncorhynchus clarki lewisi)*, bull trout *(Salvelinus confluentus),* mountain whitefish *(Prosopium williamsoni)*, yellow perch *(Perca flavescens)*, suckers *(Catostomus sp.),* redside shiner *(Richardsonius balteatus)*, dace *(Rhinichthys sp.),* northern squawfish *(Ptychocheilus oregonensis),* and sculpins *(Cottus sp.)* (Jeppson 1960; Mallet 1969; Rankel 1971; Mauser 1972 a, b).

Other fish species introduced into Coeur d'Alene Indian Reservation waters include: kokanee salmon *(Oncorhynchus nerka),* chinook salmon *(Oncorhynchus tshawytscha),* rainbow trout *(Oncorhynchus mykiss)*, brook trout *(Salvelinus fontinalis),* northern pike *(Esox lucius)*, peamouth *(Mylocheilus caurinus),* tench *(Tinca tinca)*, black bullhead *(Ictalurus me/as),* brown bullhead *(Ictalurus nebulosus)*, pumpkinseed *(Lepomis gibbosus),* largemouth bass *(Micropterus salmoides),* black crappie *(Pomokis nigromaculatus)* (Simpson and Wallace 1982; Rieman 1984).

Lake Coeur d'Alene was an extremely important resident fishing site to the Coeur d'Alene tribe. Fishing from canoes often yielded catches of cutthroat trout, bull trout and whitefish (Walker 1977). A winter ice fishery for whitefish and cutthroat trout was also established on the lake (Peltier 1975). Cutthroat trout were collected in traps during spring spawning from the tributaries. Bull trout, weighing 20-30 pounds, were frequently caught from canoes in winter and early spring in Coeur d'Alene Lake (Scott 1968).

The Coeur d'Alenes and Catholic Priests from Sacred Heart Mission built fish traps at Mission Point on the St. Joe River. During the spring spawning run "they caught thousands of trout and whitefish and dried them for later consumption" (Scott 1968). The trap was operated for over fifty years, supplying fish for the Indians and priests until it was inundated by the construction of Post Falls Dam in 1903.

There are three distinct westslope cutthroat stocks present in the Coeur d'Alene drainage (Thurow and Bjornn 1978; Liknes and Graham 1988; Rieman and Apperson 1989):

1. An adfluvial-lacustrine stock that spends one to three years in the tributaries and then migrates to the open waters of the lake. Once in the lake, feeding occurs on limnetic zooplankton until age four to six years, at which time they migrate back to the tributaries to spawn. This stock of cutthroat generally measures 300-350 millimeters as adults.

2. A fluvial stock which originates in the smaller tributaries, and then migrates to larger streams, such as the St. Joe and Coeur d'Alene rivers. They spend four to six years in the river and return to the smaller tributaries to spawn. As adults, these cutthroat normally measure between 250-350 millimeters.

3. A resident stock that spends its entire life cycle within the smaller tributaries. Adults range between 180-250 millimeters in size.

Cutthroat trout were once the most abundant trout species in the Coeur d'Alene system. Since 1932, the cutthroat population has declined significantly. This population decline has been attributed to heavy metal pollution which originated from mining and processing of silver ore (Ellis 1932), habitat degradation caused by grazing, agriculture and logging (Mallet 1969), overharvest of fish (Rankel 1971), and lake elevation changes that occurred during construction and subsequent operation of Post Falls Dam (Benker 1 987). By 1967, Mallet (1968) reported that cutthroat trout comprised only 4 percent of the catch.

The Coeur d'Alene River has been the site of extensive mine pollution since 1885. At that time, the Bunker Hill strike occurred, which resulted in mining and milling wastes being discharged into the South Fork of the Coeur d'Alene River (Ellis 1932). Aquatic life was virtually eliminated on both the South Fork and entire mainstem of the Coeur d'Alene River, extending to the delta at Harrison, Idaho where the river enters Coeur d'Alene Lake. After cessation of mining operation in 1980, conditions in the mainstem of the Coeur d'Alene River have gradually improved, and cutthroat trout have been reported to migrate throughout the drainage (Apperson *et. al.* 1988).

The southwest corner of Coeur d'Alene Lake, including a large portion of the Coeur d'Alene Indian Reservation, is characterized by rich palouse soils. Intensive farming has occurred around most of the streams, which enter Coeur d'Alene Lake on the west shoreline. Heavy sedimentation, high water temperatures and rapid water runoff have attributed to a substantial decrease in water quality (Mallet 1969). Many of the stream outlets have become settling basins, filled with large quantities of sediment.

Streams that have not incurred habitat degradation, as a result of heavy land-use practices, apparently have healthier fish. Oien (1957) performed a pre-logging fisheries survey on four streams in northern Idaho. He found that two tributaries of the St. Joe River, Gold and Simmons creeks, contained extremely healthy native cutthroat trout. In Gold Creek, only cutthroat trout were caught, with the exception of one bull trout caught in the main fork of the St. Joe River. The average condition factor of cutthroat trout in Gold and Simmons creeks was 1.76 and 1.61, respectively. Condition factor is derived from the ratio of weight to length. The higher the weight relative to length, the healthier the fish and the higher the condition number. A trout that exhibits a condition factor of 1 .O-1.3 is considered normal; condition of fish in Gold and Simmons creeks far exceeded the average. Therefore, Oien (1957) concluded that high condition factors could possibly be attributed to the lack of uncontrolled logging and siltation along these creeks.

The construction and operation of Post Falls Dam seriously altered available cutthroat habitat. Tribal fisheries for whitefish, cutthroat and bull trout at Mission Point on the St. Joe River were eliminated when Post Falls Dam went into operation. Raising and lowering the water levels of Coeur d'Alene Lake potentially exposed substrate that was used by spawning trout and prohibited spawning access to tributaries as a result of dewatering.

Rankel (1971) stated that overfishing probably caused the recent decline in the number and size of cutthroat trout harvested from the St. Joe River. In recent years, abundance, size, annual survival rate and proportion of mature females have decreased. Scholz *et a/.* (1985) estimated that historically the Coeur d'Alene Indian Tribe harvested approximately 42,000 cutthroat per year. In 1967, Mallet (1968) reported that 3,329 cutthroat were harvested from the St. Joe River, and a catch of 887 was reported from Coeur d'Alene Lake (Mallet 1969). This catch is far below the 42,000 fish per year the tribe harvested. Based on this comparison and since cutthroat populations declined in all parts of the lake, not just in areas on intensive fishing pressure, overfishing was probably not the primary cause of declining cutthroat stocks. However, overfishing may have contributed to the decline of cutthroat trout, especially where land-use practices had previously impacted and reduced spawning and rearing areas.

The overall cumulative impacts of mining and processing ore, grazing, farming, logging, overfishing, and constructing Post Falls Dam with the resultant dewatering have resulted in the decline of westslope cutthroat population of the Coeur d'Alene drainage.

1.2 STUDY OBJECTIVES

This study will provide baseline data to determine which tributary streams on the Coeur d'Alene Indian Reservation are suitable for rehabilitation and stocking of cutthroat and bull trout, and to provide baseline data to assess the effectiveness of potential habitat restoration and hatchery stocking measures. The objectives of this study were to:

1. Identify tributaries located on the Coeur d'Alene Indian Reservation that could be altered to improve cutthroat and bull trout spawning and rearing habitat.

2. Evaluate the cutthroat and bull trout fisheries of selected tributaries, and estimate available habitat for cutthroat and bull trout in these tributaries.

3. Assess the water quality and benthic macroinvertebrate community of selected tributaries and determine if fisheries and habitat enhancement measures would be profitable.

4. Identify factors limiting cutthroat and bull trout production in each selected tributary; and

5. Suggest habitat modifications to improve spawning and rearing habitat, and accessibility to streams for cutthroat and bull trout migrations.

The objectives of this report included:

1. Development of criteria for ranking nineteen tributaries based on potential for cutthroat and bull trout -habitat enhancement. This was accomplished by a literature review of cutthroat and bull trout habitat requirements, an aerial survey, and an assessment of biological and nonbiological parameters, including road access, gradient, barriers, potential for enhancement and location relative to the reservation.

2. Performance of an aerial survey on nineteen tributaries located on the Coeur d'Alene Indian Reservation. All potential barriers to fish migration were listed, and stream reaches from mouth to upper limit of suitable fish habitat were determined.

3. Determination of ten tributaries for further study by using the above ranking criteria.

2.0 MATERIALS AND METHODS

2.1 DESCRIPTION OF STUDY AREA

The Coeur d'Alene drainage basin is located in the Idaho panhandle and drains approximately 9583.0 square kilometers (3700 mi^2) (Benker 1987). It is divided into two subbasins, which includes the Coeur d'Alene River and the St. Joe River basins. The Coeur d'Alene River basin, located east and north of the lake, drains approximately 3859 square kilometers (1490 mi^2); the St. Joe River basin, located east and south of Coeur d'Alene Lake, drains approximately 4895.1 square kilometers (1890 mi^2) (Figure 2.1). The remaining 9 percent of the drainage basin consists of creeks that flow into Wolf Lodge Bay and Corbin Bay on the east side of the lake, and Windy, Rockford, Mica and Cougar bays on the west side of the lake.

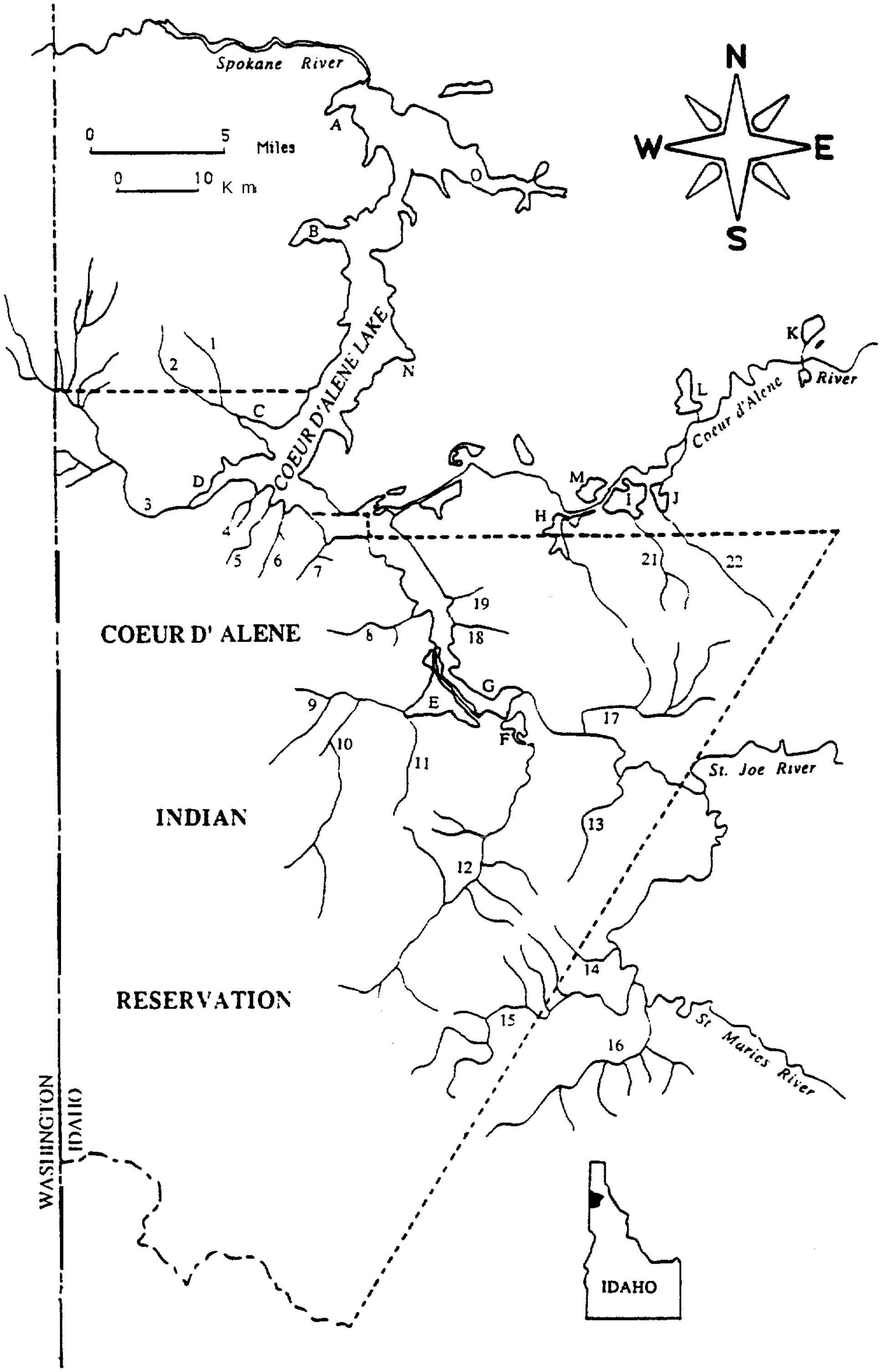
The study area covers nineteen tributaries located within the Coeur d'Alene drainage basin, including: Bellgrove, Fighting, Lake, Cottonwood Bay, Squaw, Plummer, Little Plummer, Pedee, Benewah, Cherry, Alder, John, Little John, Hell's Gulch, O'Gara Bay, Shingle Bay, Black, Willow and Evans creeks, and the St. Joe River.

Bellgrove and Fighting creeks are located on the west shoreline of Coeur d'Alene Lake. These creeks are fourth order tributaries of 4.8 kilometers (3.0 mi) and 8.1 kilometers (5.0 mi) in length, respectively. Bellgrove Creek merges with Fighting Creek at river kilometer 0.8 (RMi 0.5) and empties into Coeur d'Alene Lake (Figure 2.2).

Lake Creek, a second order tributary, is located on the west shoreline of Coeur d'Alene Lake and is approximately 20.4 kilometers (12.7 mi) long. Lake Creek receives most of its flow from the north and west forks of Lake Creek and Bozard Creek (Figure 2.3).

Cottonwood Bay Creek is located in the southeastern corner of Coeur d'Alene Lake. It is a third order stream and drains approximately 4.2 kilometers (2.6 mi) (Figure 2.4).

Squaw Creek is located in the southeastern portion of Coeur d'Alene Lake. It is a second order stream and is approximately 7.6 kilometers (4.7 mi) in length (Figure 2.5).



Bays and Lakes

A. Cougar Bay
B. Mica Bay
C. Rockford Bay
D. Windy Bay
E. Chatcolet Lake
F. Benewah Lake
G. Round Lake
H. Black Lake
I. Cave Lake
J. Medicine Lake
K. Rose Lake
L. Killarney Lake
M. Blue Lake
N. Carlin Bay
O. Wolf Lodge Bay

Streams

1. Bellgrove Ck.
2. Fighting Ck.
3. Lake Ck.
4. Cave Bay Ck.
5. Unnamed Ck. on Cave Bay
6. Aberdeen Lodge Bay Ck.
7. Cottonwood Ck.
8. Squaw Ck.
9. Plummer Ck.
10. Little Plummer Ck
11. Pedee Ck
12. Benewah Ck.
13. Cherry Ck
14. Carlin Ck.
15. Alder Ck
16. John Ck
17. Hells Gulch
18. O'Gara Bay Ck
19. Shingle Bay Ck
20. Black Ck
21. Willow Ck
22. Evans Ck.

Figure 2.1. **Map of the Coeur d'Alene drainage basin.**

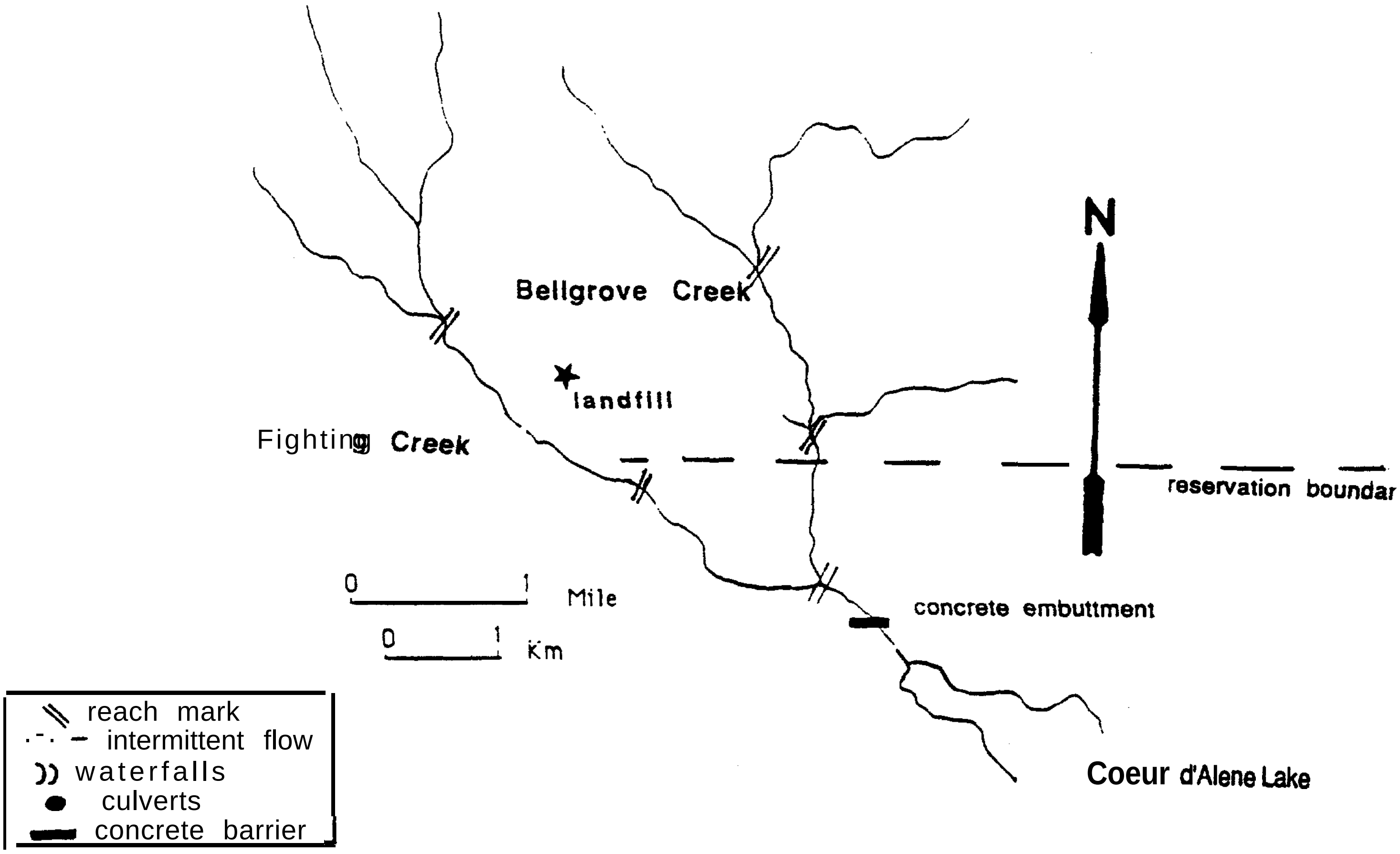


Figure 2.2. **Map of Bellgrove and Fighting Creeks showing barriers and perennial versus intermittent reaches of the streams.**

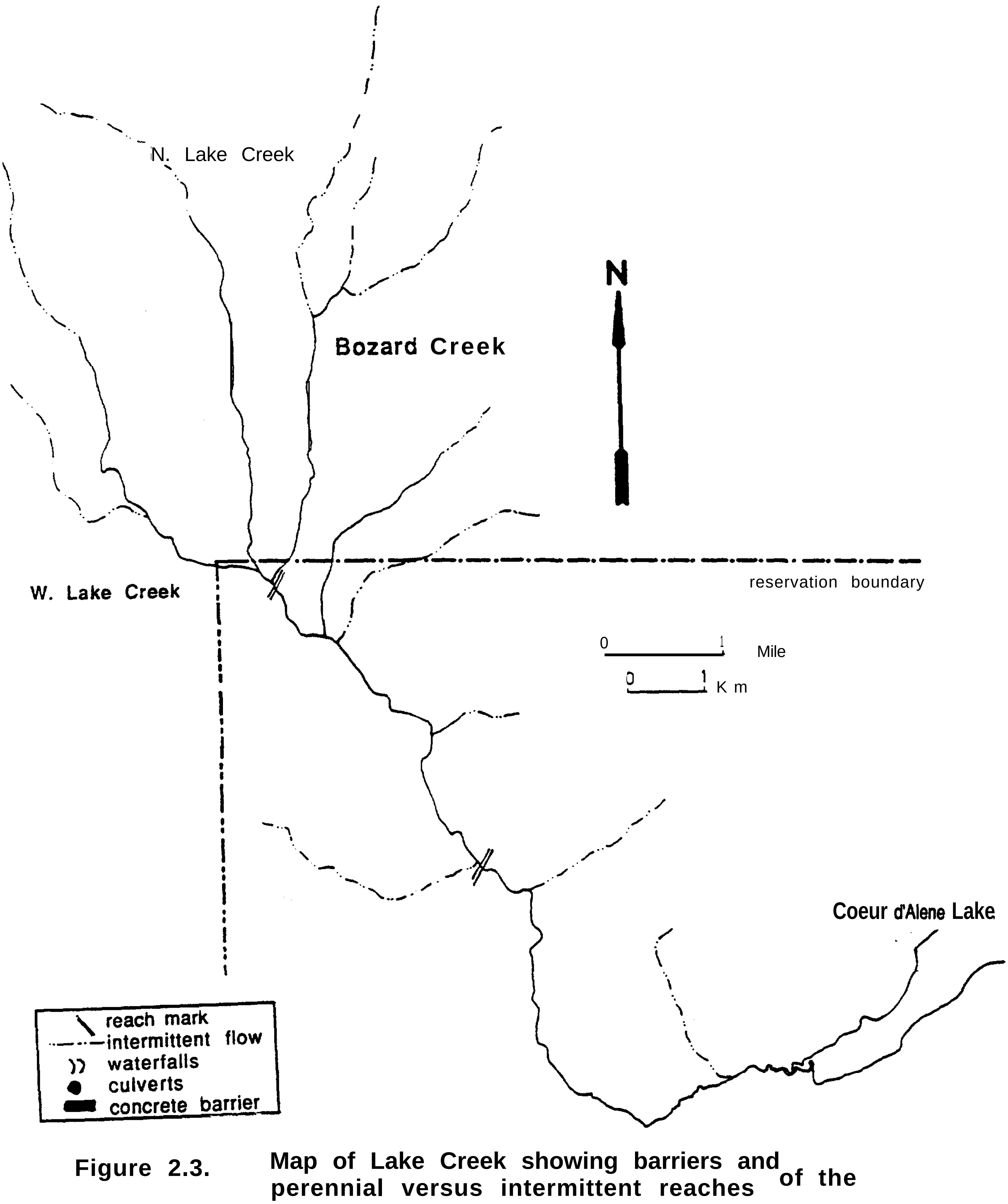


Figure 2.3. **Map of Lake Creek showing barriers and perennial versus intermittent reaches of the stream.**

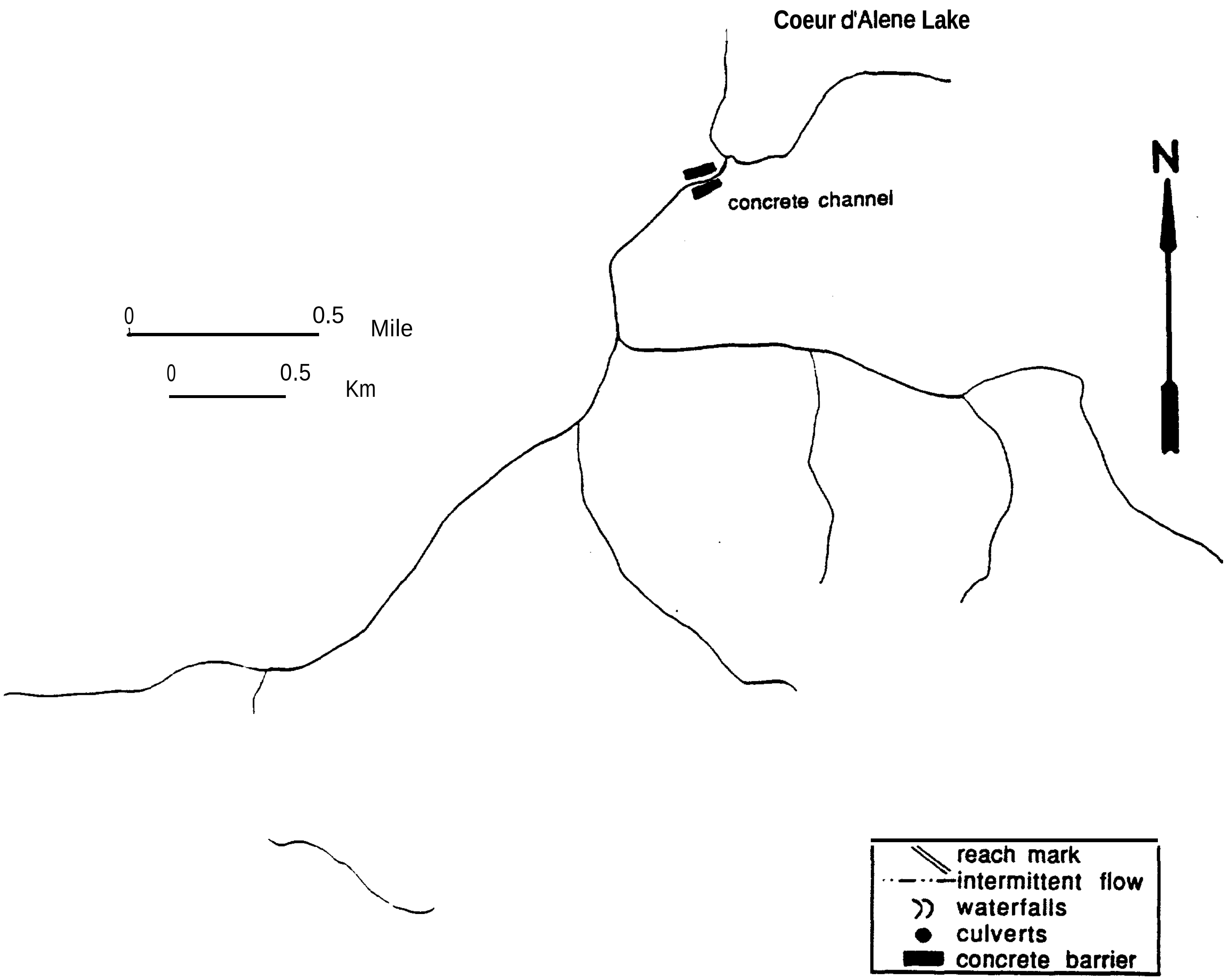


Figure 2.4. **Map of Cottonwood Bay Creek showing barriers and perennial versus intermittent reaches of the stream.**

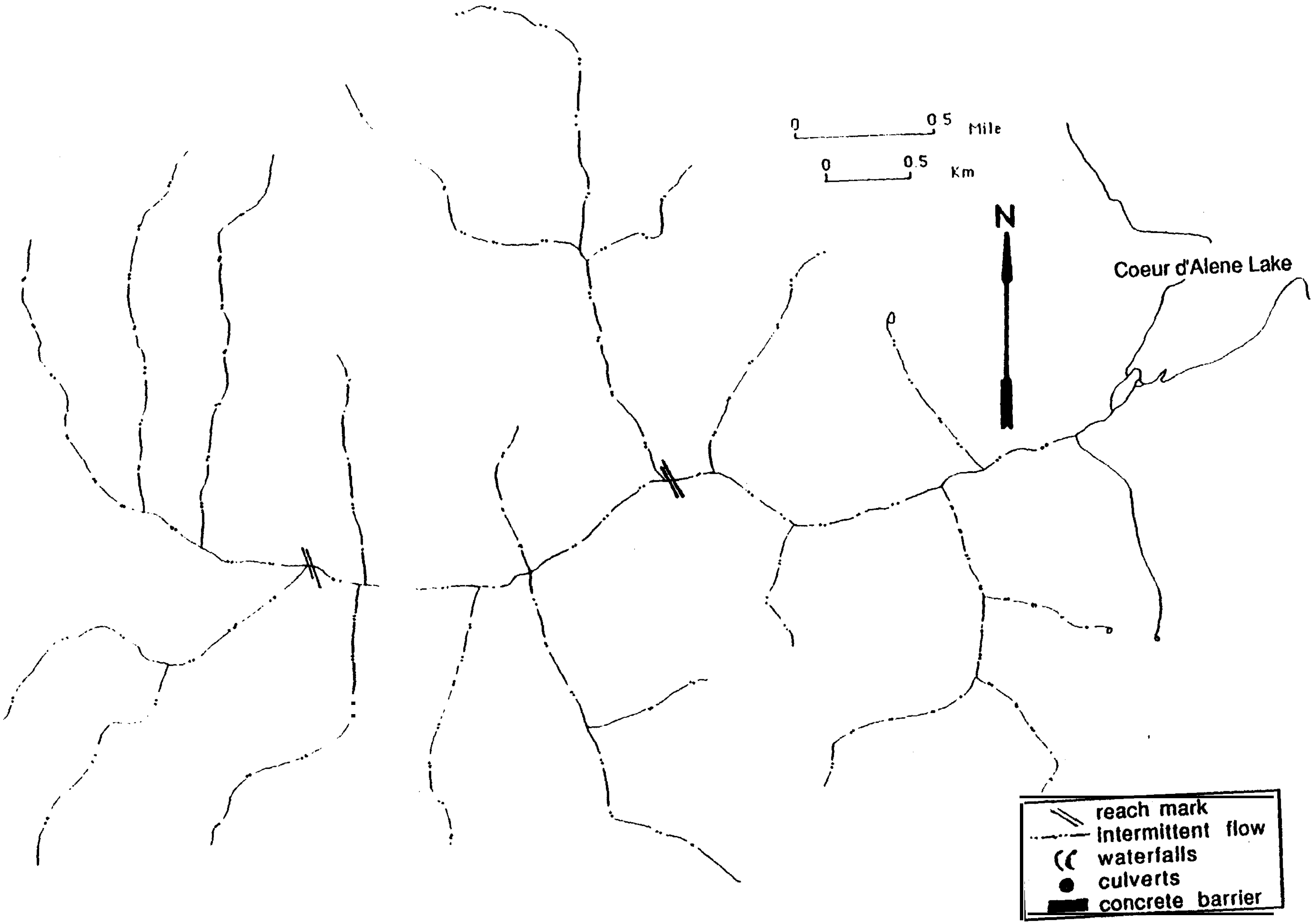


Figure 2.5 Map of Squaw Creek showing barriers and perennial versus intermittent reaches of the stream.

Plummer and Little Plummer creeks are located in the southern portion of the Coeur d'Alene basin and drain into Lake Chatcolet (Figure 2.6). Plummer Creek is a fourth order stream of approximately 6.4 kilometers (4.0 mi) in length. Little Plummer Creek is also a fourth order tributary and is approximately 14.5 kilometers (9.0 mi) long.

Pedee Creek also empties into Lake Chatcolet, and is a third order stream of approximately 4.8 kilometers (3.0 mi) in length (Figure 2.7)

Benewah Creek, a fourth order stream of approximately 24.1 kilometers (15.0 mi), discharges into Benewah Lake, which is also located in the southern portion of the Coeur d'Alene drainage basin (Figure 2.8).

Cherry Creek is located in the St. Joe River basin and is a tributary of the St. Joe River. Cherry Creek is a third order tributary of approximately 6.0 kilometers (3.7 mi) in length (Figure 2.9).

Alder Creek, located in the St. Joe River basin, is a fourth order tributary to the St. Maries River and is approximately 20.1 kilometers (12.5 mi) in length (Figure 2.10).

John and Little John creeks are located within the St. Joe River basin and is a tributary to the St. Marie's River. John Creek drains approximately 17.1 kilometers (10.6 mi) as a fourth order stream (Figure 2.11).

Hell's Gulch Creek, a third order tributary, is located in the northern section of the St. Joe River basin and is approximately 10.5 kilometers (6.5 mi) in length (Figure 2.12).

O'Gara Bay Creek, a third order tributary, is located on the east side of Coeur d'Alene Lake and is approximately 3.2 kilometers (2.0 mi) long (Figure 2.13).

Shingle Bay Creek, located on the east side of the lake, is a third order tributary that is approximately 1.6 kilometers (1 .O mi) in length (Figure 2.14).

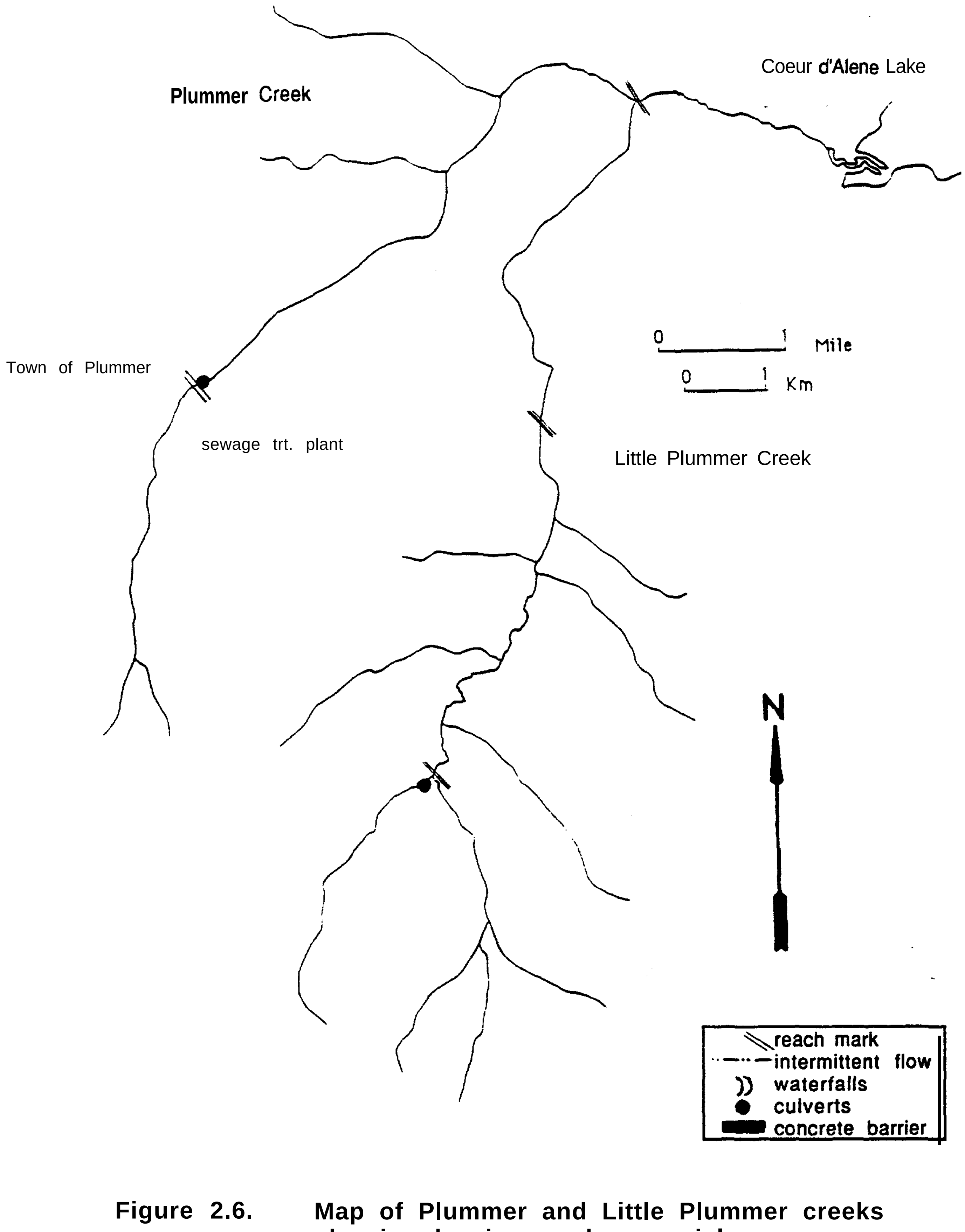


Figure 2.6. **Map of Plummer and Little Plummer creeks showing barriers and perennial versus intermittent reaches of the stream.**

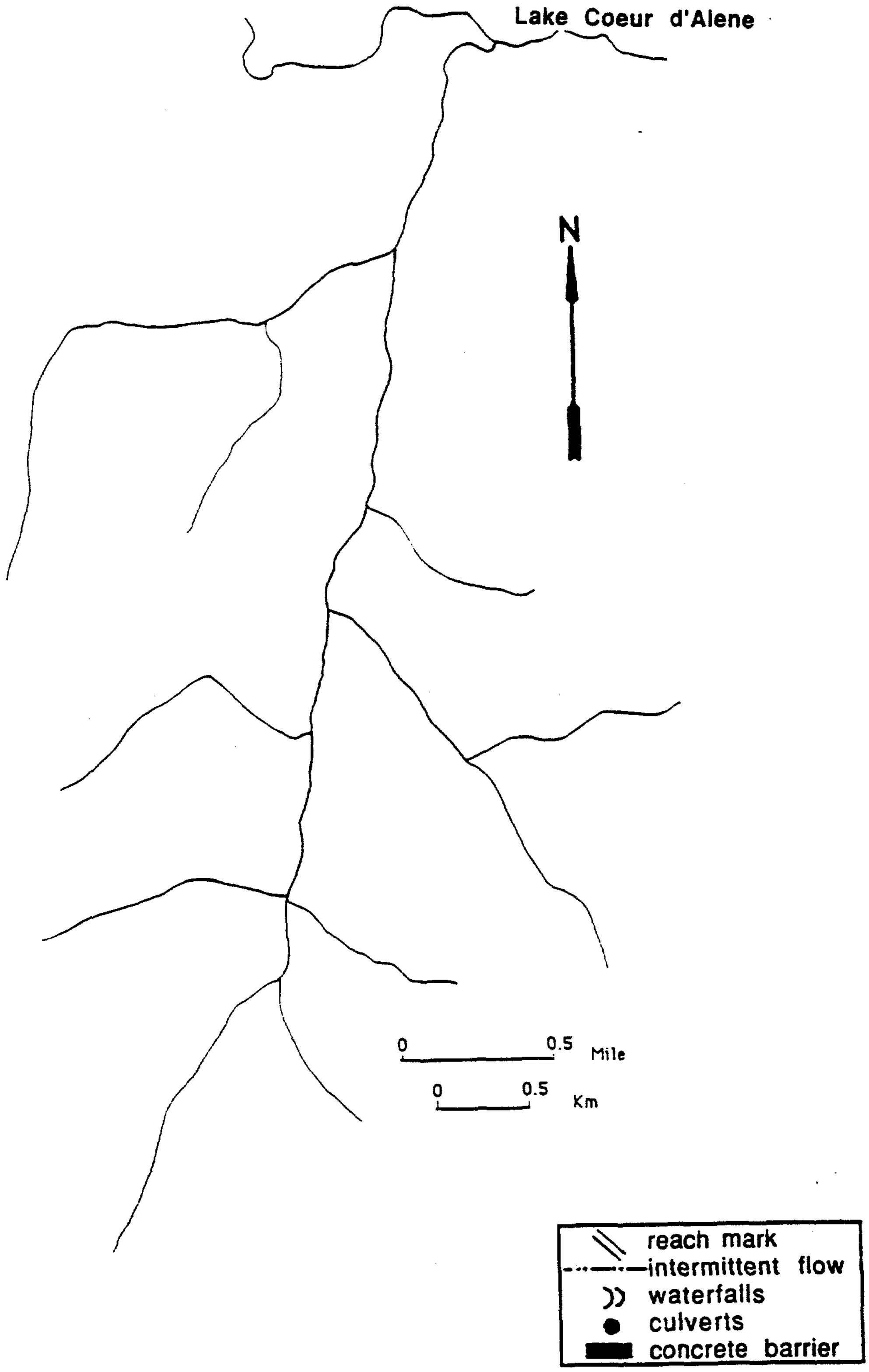


Figure 2.7. Map of Pedee Creek showing barriers and perennial versus intermittent reaches of the stream.

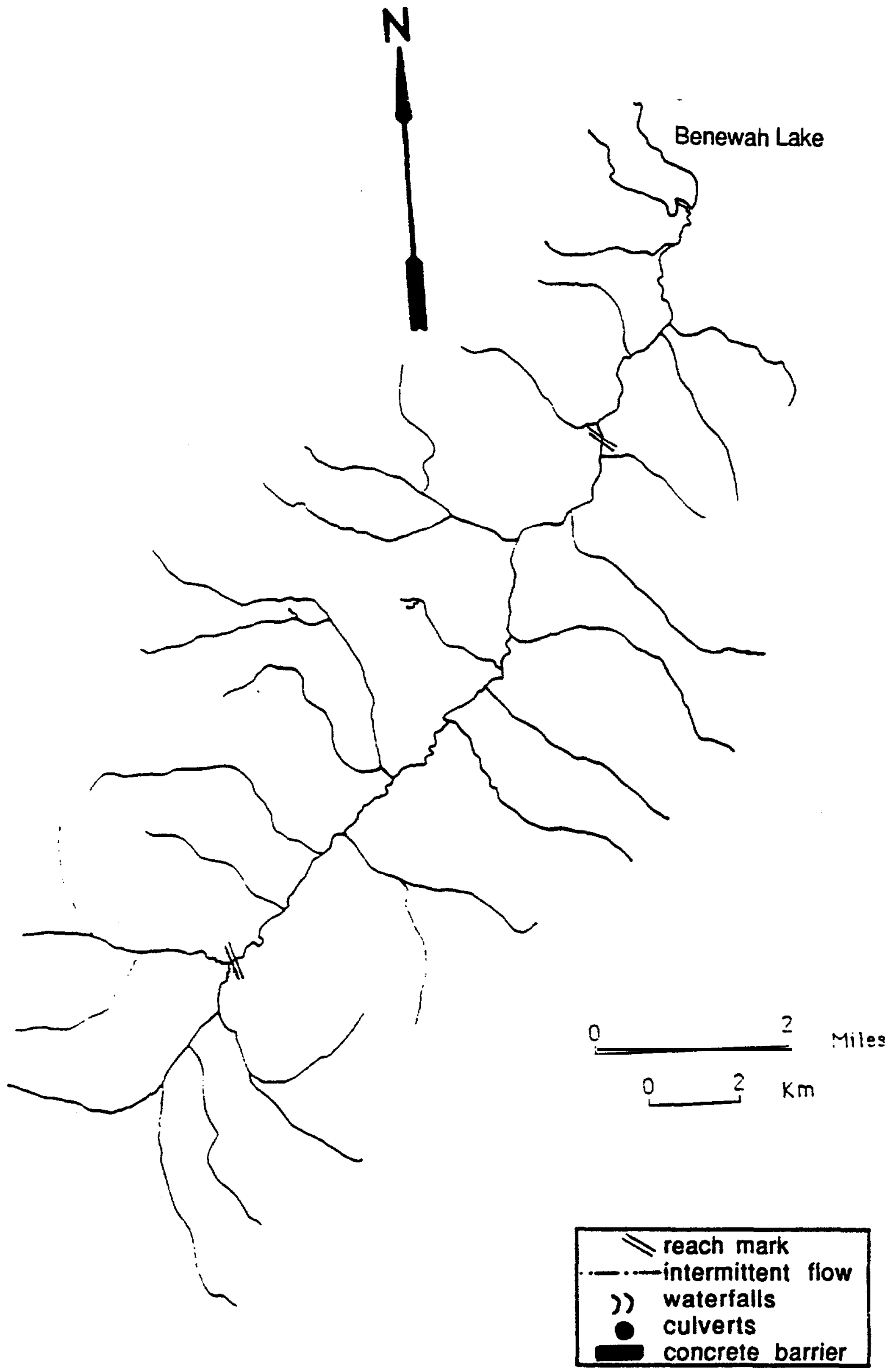


Figure 2.8. **Map of Benewah Creek relative to Benewah Lake showing barriers and perennial versus intermittent reaches of the stream.**

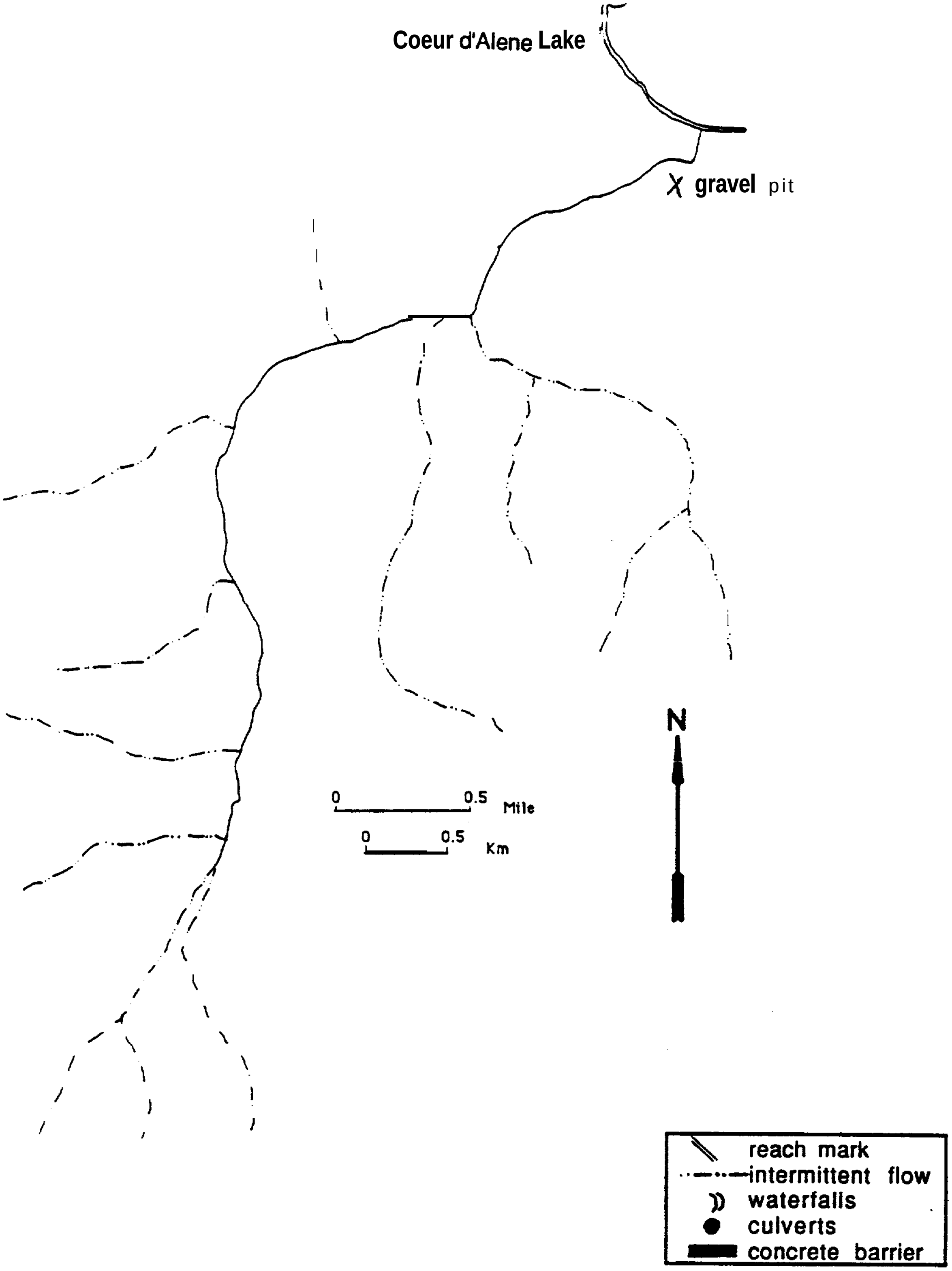


Figure 2.9. Map of Cherry Creek showing barriers and perennial versus intermittent reaches of the stream.

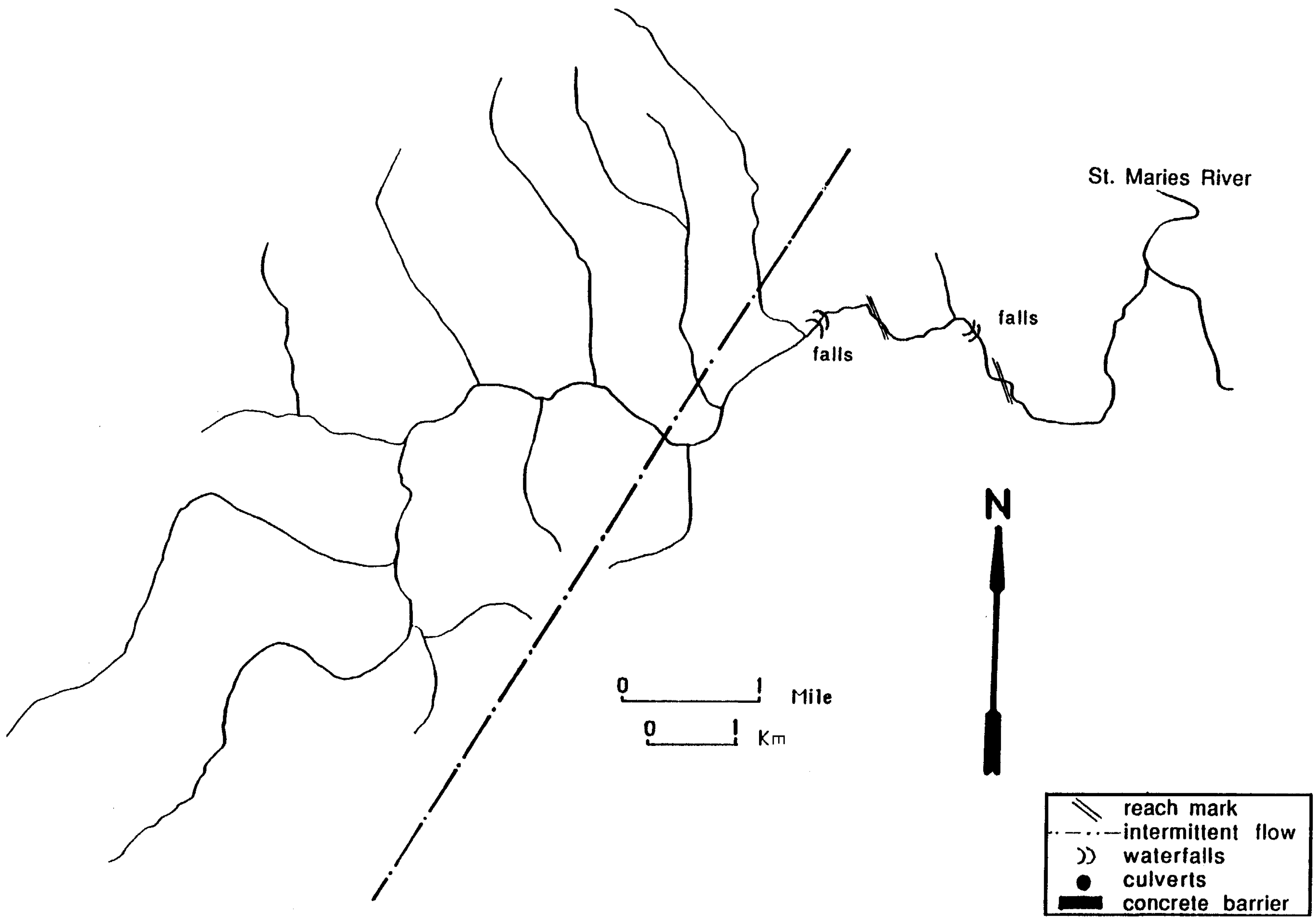


Figure 2.10. **Map of Alder Creek showing barriers and perennial versus intermittent reaches of the stream.**

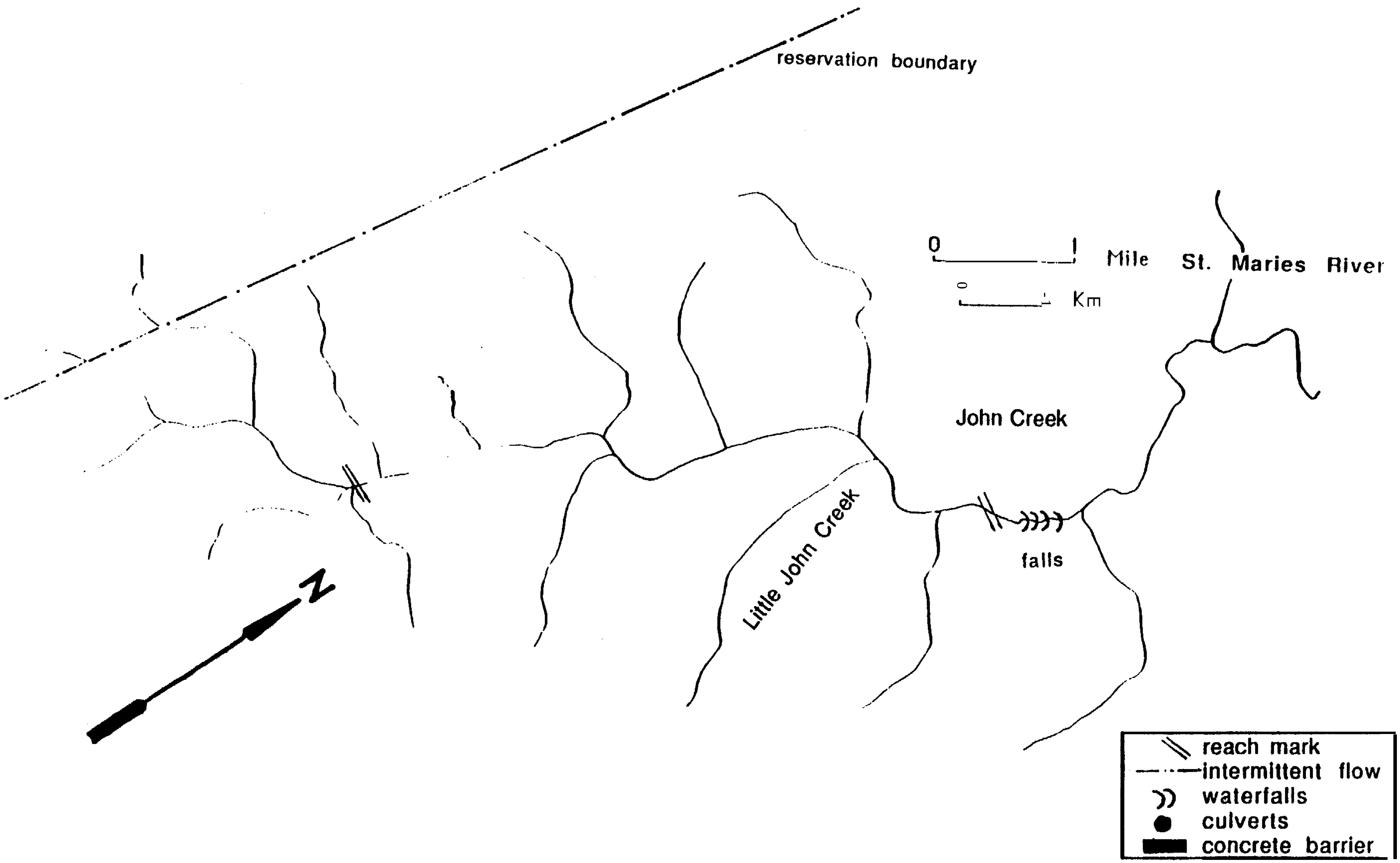


Figure 2.11. Map of John and Little John creeks showing barriers and perennial versus intermittent reaches of the stream.

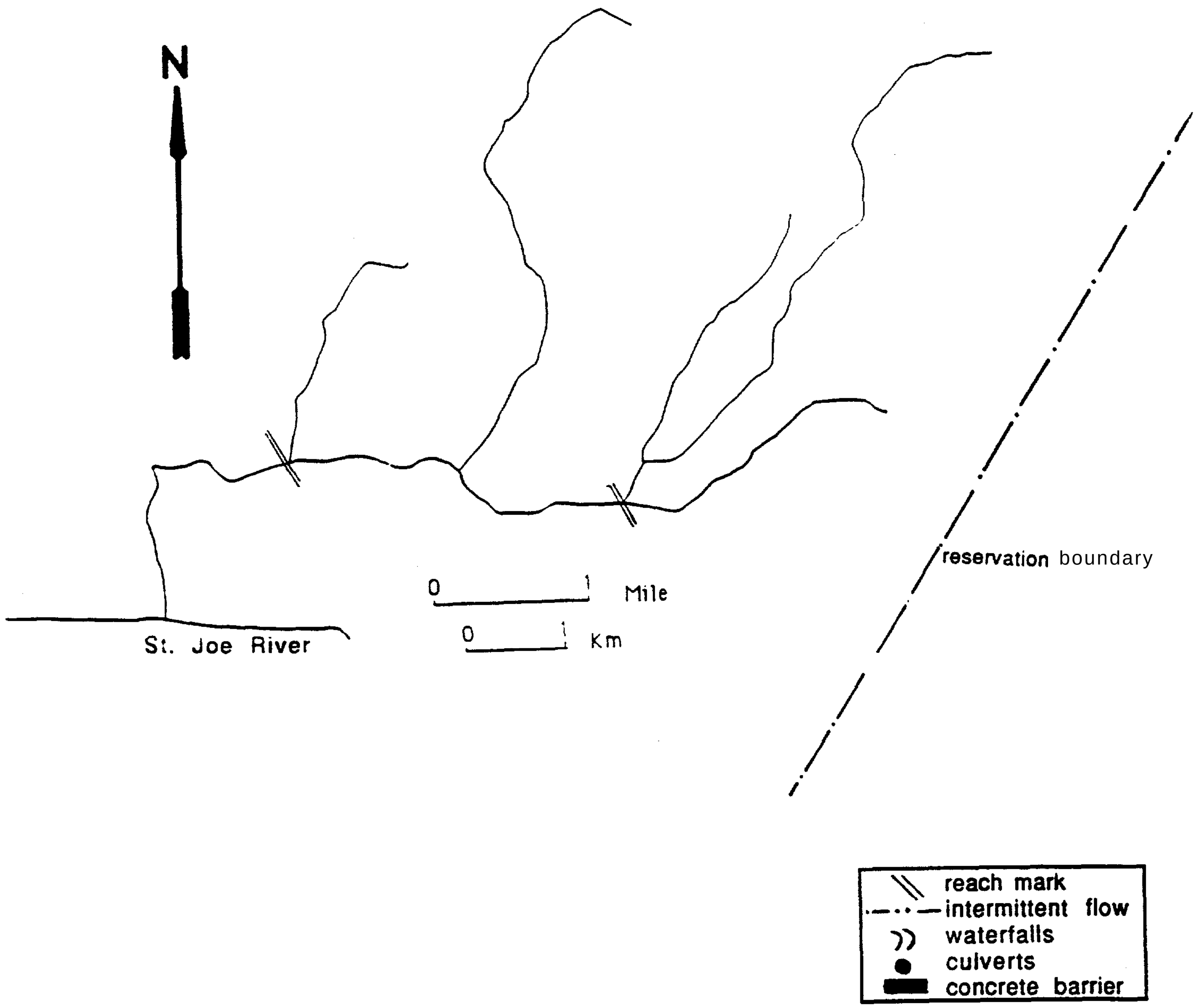


Figure 2.12. Map of Hell's Gulch Creek showing barriers and perennial versus intermittent reaches of the stream.

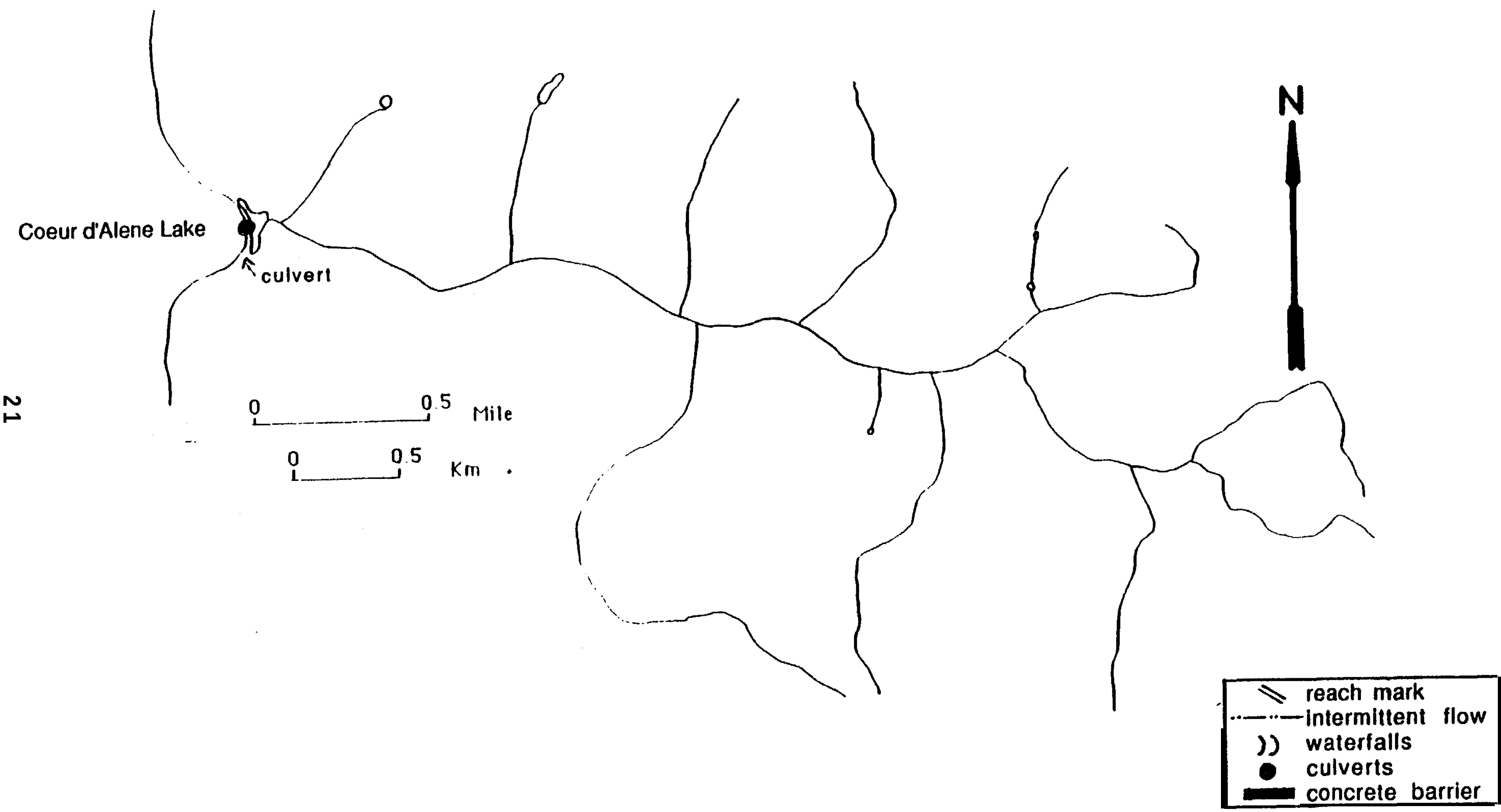


Figure 2.13. **Map of O'Gara Bay Creek showing barriers and perennial versus intermittent reaches of the stream.**

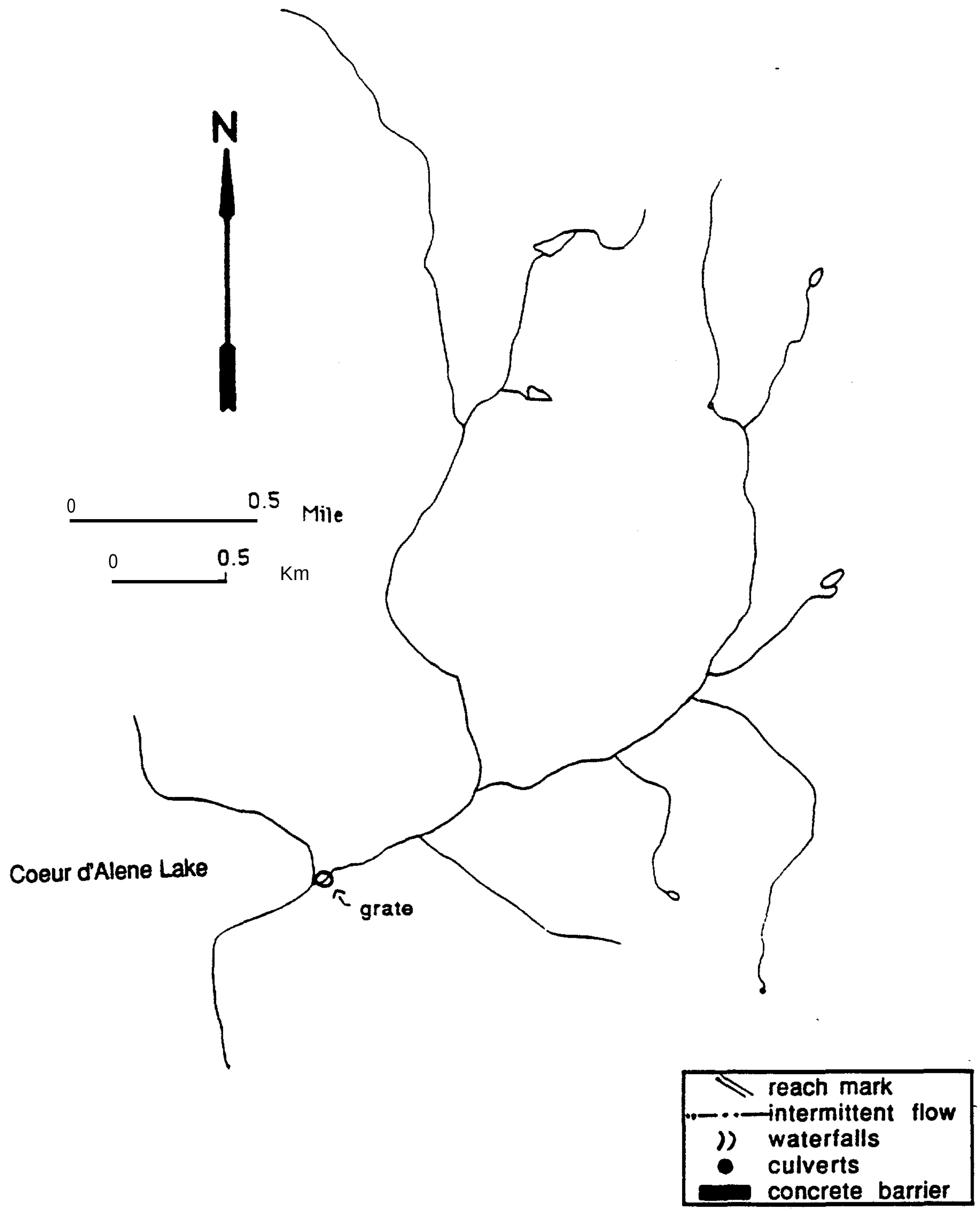


Figure 2.14. Map of Shingle Bay Creek showing barriers and perennial versus intermittent reaches of the stream.

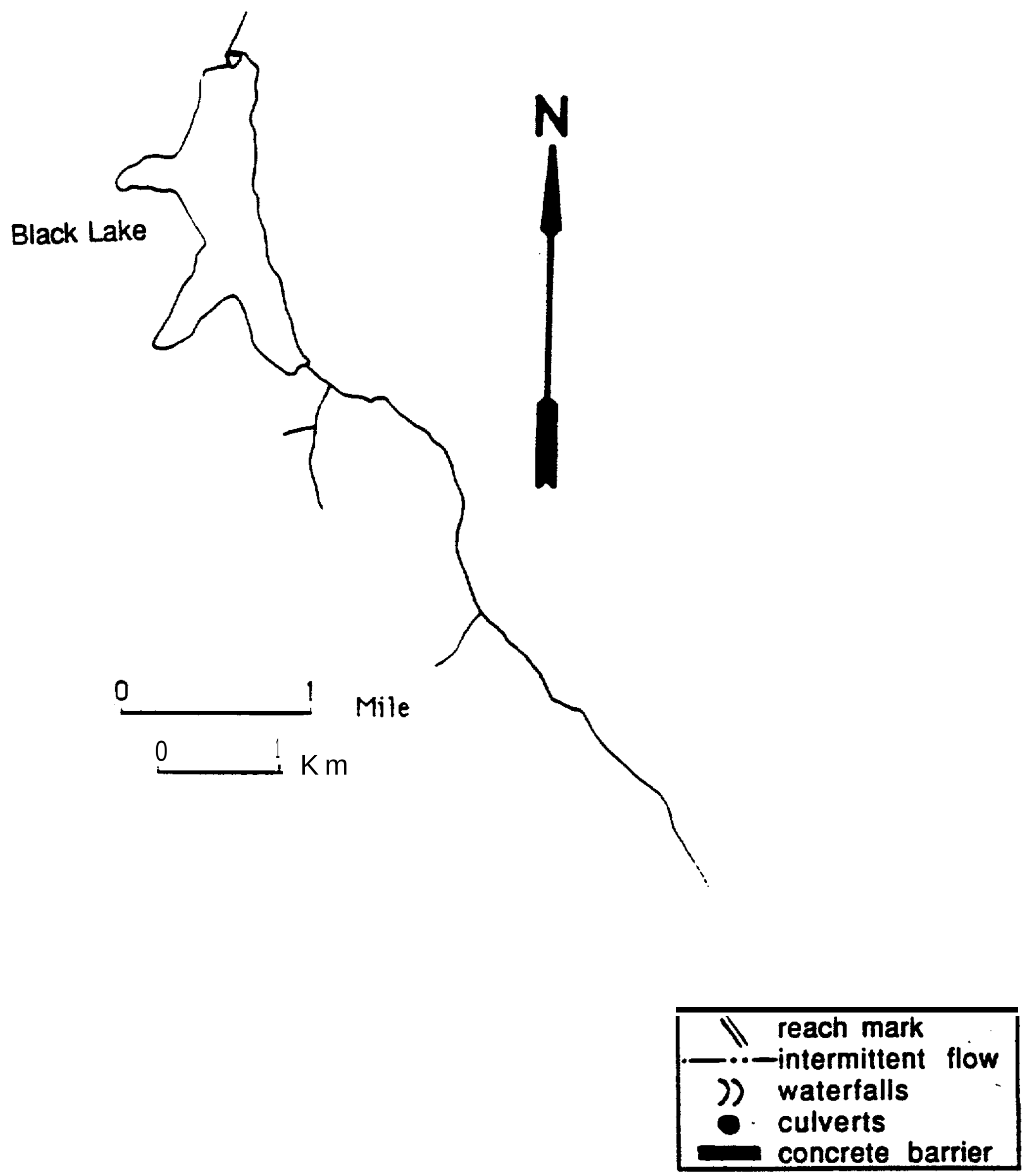


Figure 2.15. Map of Black Creek reiative to Black Lake showing barriers and perennial versus intermittent reaches of the stream.

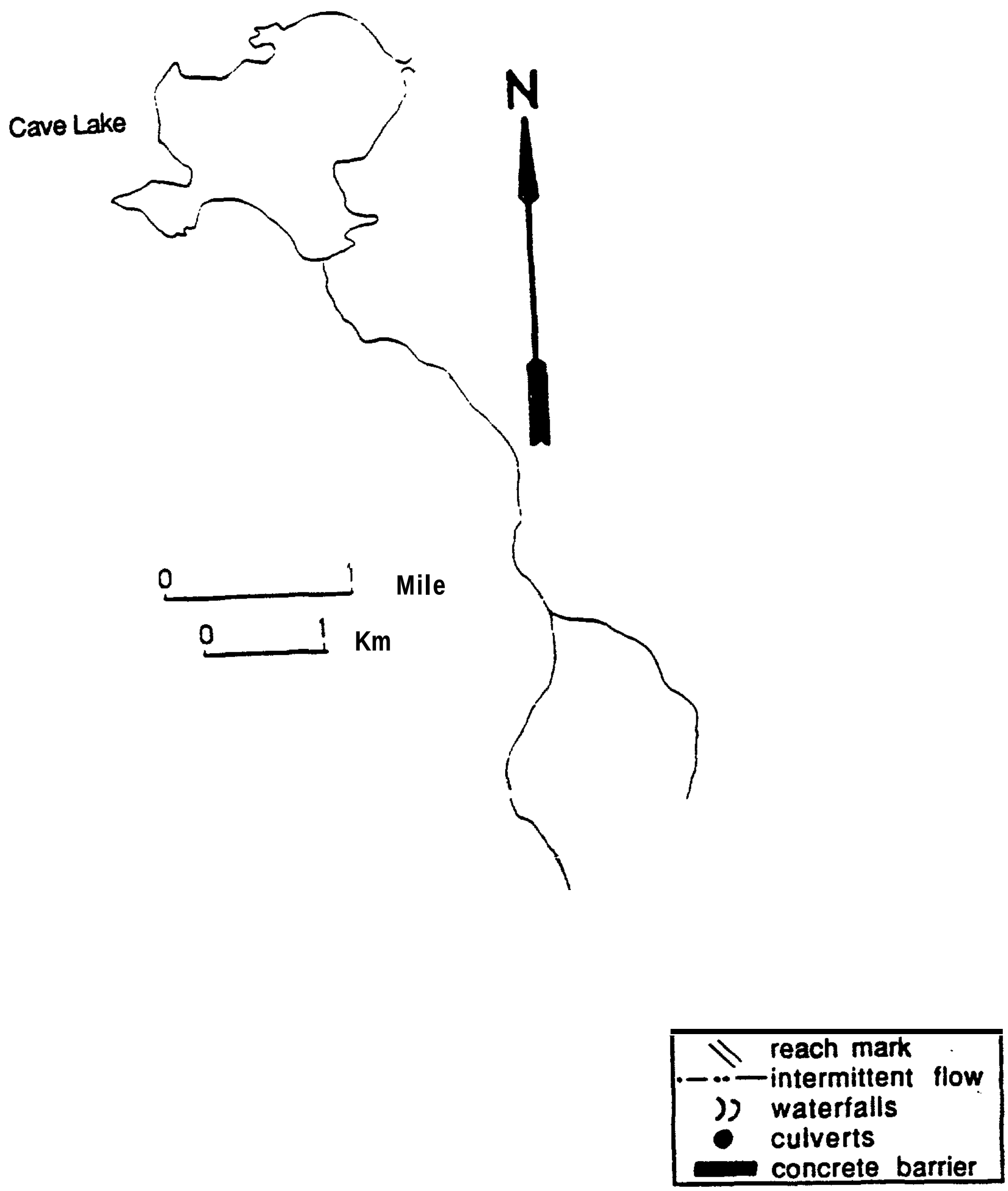


Figure 2.16. Map of Willow Creek relative to Cave Lake showing barriers and perennial versus intermittent reaches of the stream.

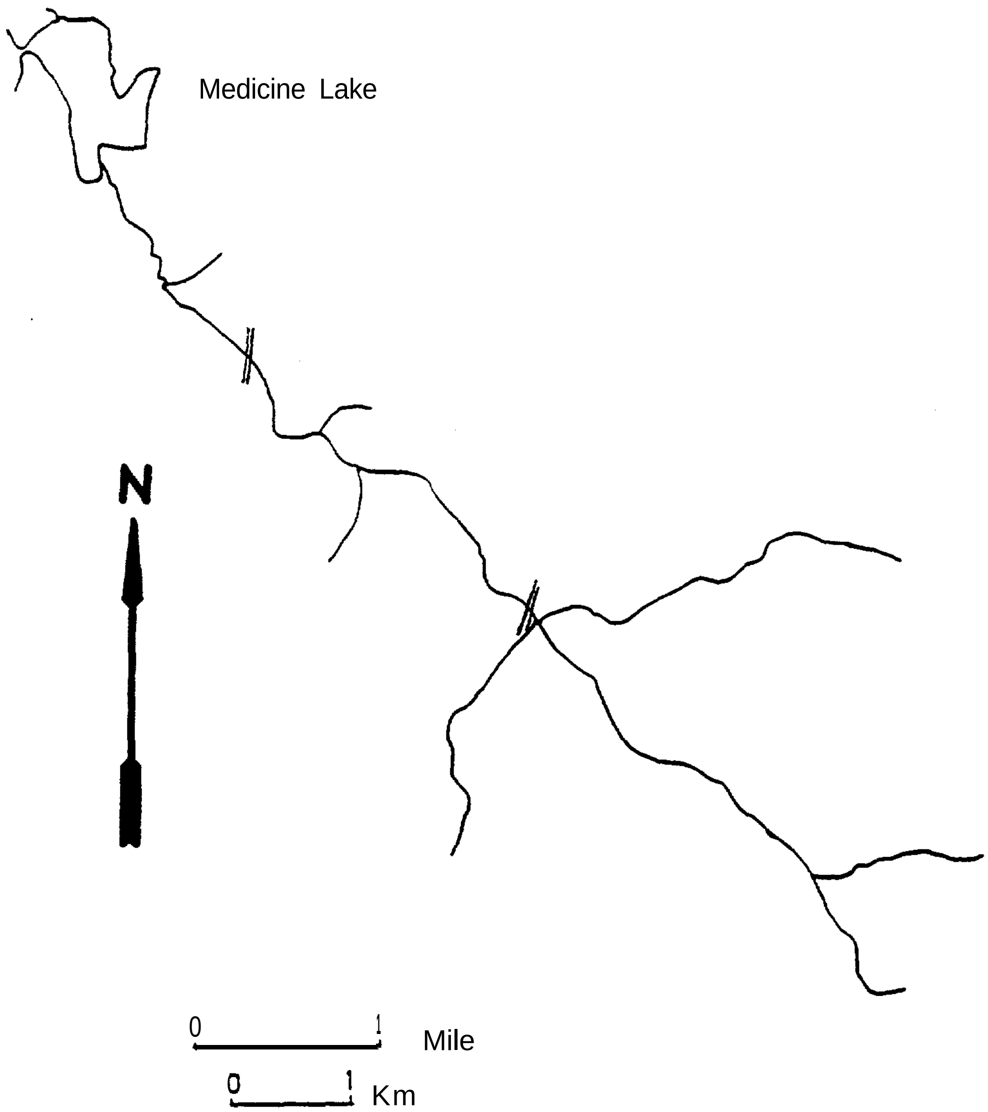


Figure 2.77. **Map of Evans Creek relative to Medicine Lake showing barriers and perennial versus intermittent reaches of the stream.**

Black Creek is located in the Coeur d'Alene River basin and ends at Black Lake, a lateral lake to the Coeur d'Alene River. Black Creek is a third order tributary of approximately 6.4 kilometers (4.0 mi) in length (Figure 2.15).

Willow Creek is a second order tributary that discharges into Cave Lake, one of the lateral lakes of the Coeur d'Alene River. Willow Creek is approximately 6.4 kilometers (4.0 mi) long (Figure **2.16).**

Evans Creek is a second order tributary that discharges into Rose Lake, a lateral lake of the Coeur d'Alene River. Evans Creek is approximately 8.1 kilometers (5.0 mi) long (Figure 2.17).

St. Joe River was too expansive for the scope of this project, therefore, no data was compiled for this body of water.

2.2 DETERMINATION OF NINETEEN STREAMS FOR AERIAL SURVEY.

To select nineteen tributaries located within the boundaries of the Coeur d'Alene Indian Reservation, a ranking criteria was developed. Selection of the nineteen tributaries was based on geographic location relative to tribal jurisdiction and stream geomorphological features.

Most of the tributaries in the northern section of Coeur d'Alene Lake were located only partially on the reservation and were eliminated. Geomorphological parameters were then determined for the remaining tributaries located within reservation boundaries.

2.2.1 Stream Geomorphology

Stream geomorphological features were examined to determine if the stream had the potential to support fish, specifically bull and cutthroat trout. Physical stream parameters examined included: stream length, gradient, elevation and order, basin area and relief ratio, drainage density and sinuosity.

Stream length, gradient and order were determined in order to quantify the stream for potential fish habitat. Since stream length and order are indicators of stream size, these parameters were used to evaluate if the stream was large enough to support a bull and cutthroat trout fishery. Gradient determines the water velocity of a stream; bull and cutthroat trout have specific habitat requirements relative to these parameters.

Elevation, drainage density, basin area and relief provide an estimate of the timing, potential discharge, base and peak stream flows and sediment yields of a stream. This information can help in determining when freshest conditions will occur. Freshets have the potential to cause habitat damage to the stream, as well as, flush juvenile trout downstream. Branson et al. (1981) found that high basin relief, greater channel slope and increased drainage density were negatively related to trout standing stock. Sinuosity is an indicator of the straightness of a stream channel and can be correlated to stream gradient.

Stream length was measured with a map measurer by following the longest perennial watercourse on a 1:24,000 scale topographic map.

Gradient was determined using a 1:24,000 scale topographic map, in which elevation was determined directly from the map and divided by the stream distance. Stream distance was calculated by using a map measurer and proportional divider.

Highest headwater elevation of each stream was determined by directly reading a 1:24,000 scale topographic map.

Stream order was determined by counting stream channels directly from 1:24,000 scale topographical maps (Horton 1945).

Basin area was determined by using the highest elevation on the headwater divide and subtracting the elevation at the confluence with the river of lake (Schumm 1956).

Relief ratio was determined by dividing all the stream channels in a drainage basin by the drainage area (Horton 1945).

Sinuosity was measured from 1:24,000 scale topographical maps and calculated as stream length divided by valley length.

2.3 AERIAL SURVEY

An aerial survey was conducted in December 1990 by applying methods of Montana Department of Fish and Wildlife and Parks (1983) and Platts et *al.* (1983). Parameters observed during the aerial survey included: observed flow, gradient changes, land-use practices, stream barriers, potential spawning areas for bull trout and cutthroat trout, riffle:pool ratio, channel debris, road accessibility, and potential water quality problem sites. These parameters were compared to the habitat requirements specific to cutthroat and bull trout.

2.4 RANKING CRITERIA

Based on biological and nonbiological parameters, ranking criteria were established, which evaluated the nineteen tributaries that were observed during the aerial survey. The nineteen tributaries were narrowed to ten streams for further study by ranking each stream according to the established criteria.

The nineteen tributaries were ranked according to five major areas that included: geographic location relative to tribal jurisdiction, road access, barriers to fish migration, channel gradient, degree of habitat degradation, and potential of enhancement for cutthroat and bull trout.

Geographic location relative to tribal jurisdiction was determined by assessing how much of the stream was located within reservation boundaries. The distance of the stream within tribal jurisdiction was important for establishing control of water rights. Since tribal control exists for waters located completely on the reservation, a rating of 1 .O was given to those streams. Secondary priority, or rating of 2.0, was given to those tributaries partially located on reservation property. Those tributaries located completely off the reservation were given a priority rating of 3.0, since tribal jurisdiction did not exist for these waters.

Road accessibility was determined to be of high priority. Since the final product is to enhance the fishery of the streams, stream access was important for conducting enhancement work and for future angler use. Road access was determined from data collected in the aerial survey and from 7.5 USGS topographic maps. A ranking of 1 .0 was given to those tributaries that seemed to have good access. A ranking of 2.0 was given to those tributaries that had limited access, and a ranking of 3.0 was given to those tributaries that lacked access.

The third category was to assess barriers that affect fish migration. Barriers observed during the aerial survey were divided into two classes: natural barriers and man-made barriers. Those streams with natural obstructions, such as waterfalls, historically would not have had native adfluvial or fluvial, but only resident, cutthroat and bull trout populations above them. Waterfalls that were observed had limited upstream habitat; gradients were steep and unusable by fish populations. Natural barriers, such as extensive gradient cascades, would be quite expensive to correct. Streams with man-made barriers could, historically, have had adfluvial and fluvial populations above the barriers and would be more cost-effective to enhance. The highest rating of 1 .O was given to those streams that lacked barriers to fish migration. Streams with man-made barriers were given the rank of 2.0, because these barriers probably had populations of adfluvial, fluvial, as well as, resident fish above them and would be easier to correct. Streams with natural barriers were given a rating of 3.0. They would be more costly to enhance, and migratory populations did not previously exist upstream: in most cases, suitable habitat was not available above the obstruction.

The fourth parameter examined the extent of habitat degradation, as a result of land-use practices, and potential for rehabilitation based on biological requirements of trout. Streams were ranked favorable or unfavorable “trout habitat”, instead of specifically for cutthroat and/or bull trout, because only general information could be obtained from the aerial survey. The biological requirements of trout, clean substrate, good water quality, proper type and amount of instream cover and food, were compared to factors that would adversely affect these habitat essentials, such as sewage treatment facilities, land fills, logging activities, mining activities, quarries, and other land-use practices. Aerial observations of each tributary were tabulated and rated according to quantity and quality of trout habitat and cumulative extent of degradation. Since enhancement of fisheries is the ultimate goal, a rating of 1 .O was given to streams that had slightly degraded trout habitat, but restoration appeared cost-effective. A rating of 2.0 was given to streams that aiready had good habitat and needed little, if any, restoration work. These streams were given second priority, because trout habitat was currently available, and stocks of cutthroat and bull trout were probably already present. A rating of 3.0 was assigned to those tributaries that had severely degraded trout habitat and expense of enhancement would be considerable.

The fifth parameter considered was gradient, because cutthroat and bull trout have specific. requirements relative to channel slope. Stream gradient indirectly affects velocity of water, ratio of pools to riffles, and amount of cover; these criteria ultimately influence fish populations and distribution. A rating of 1 .O was given to creeks that apparently had suitable gradient for fish habitat. A rank of 2.0 was applied to streams of questionable gradient, and 3.0 was given to creeks with obviously unsuitable channel slope.

Ratings of the first five categories were summed. Those streams receiving the lowest total scores were the top ten choices.

A final category was applied to the top ten scores, which eliminated those streams that had special circumstances associated with them. If the stream were completely frozen or dry in the winter when peak flows should be evident, the stream was eliminated from consideration, because it also would be dry in the summer.

3.0 RESULTS

Data recorded during the aerial survey, along with some of the parameters used to established the ranking criteria, were based on habitat conditions specific to westslope cutthroat and bull trout. Specific habitat requirements were obtained from an extensive literature search of these species. Findings from the literature review of cutthroat and bull trout are summarized in Tables 3.1 and 3.2, respectively. For more comprehensive life history information on cutthroat and bull trout, refer to Appendix A for cutthroat trout and Appendix B for bull trout; this information will be useful in Phase 2 and Phase 3 of this project. A condensed synopsis of each species is provided below.

3.1 LITERATURE REVIEW FOR CUTTHROAT TROUT

3.1.1 General Information

Westslope cutthroat display three distinct life forms. They are:

1. Resident, which inhabit small, unproductive headwater streams and do not migrate.
2. Fluvial, which inhabit larger streams and main rivers, and may show extensive migration between rivers, streams and small tributaries.
3. Adfluvial, which inhabit large lakes and migrate to spawn in tributary streams. Adfluvial stocks generally dominate tributaries to lower reaches of the drainage or small streams directly connected to the lake; they rear in tributaries for two to four years and then migrate to a lake to mature.

3.1.2 Life History

In Idaho, westslope cutthroat deposit their eggs into substrate gravel of streams from March to May. As a result of temperature and differing spawning times, fry emergence can begin between April-June, but may be as late or later than August in coldest waters.

Juvenile cutthroat remain in natal streams for two to four years, then during June-August migrate to rivers or lakes to mature.

Table 3.1 **Acceptable and optimal habitat conditions for various life stages of cutthroat trout.**

		Egg/Alevin	Frv	Juvenile	Adult	Spawner
Temperature (°C)	maximum range	3-16°C	6-I 2°C	6-12°C	6-12°C	5-11°C March-June
	optimal	7-I 1.5°C	11-15.5°C	11-15.5°C	11-15.5°C	8-10°C
Dissolved oxygen (mg/l)	minimum range	4.5-7.3 (≤15°C) 6.0-9.0 (>1 5°C)	4.5-7.3 (≤15°C) 6.0-9.0 (>15°C)	4.5-7.3 (≤15°C) 6.0-9.0 (>15°C)	4.5-7.3 (≤15°C) 6.0-9.0 (>15°C)	4.5-7.3 (≤15°C) 6.0-9.0 (>15°C)
	optimal	7.3(≤15°C) 9.0(>15°C)	7.3(≤15°C) 9.0(>15°C)	7.3(≤15°C) 9.0(>15°C)	7.3(≤15°C) 9.0(>15°C)	7.3(≤15°C) 9.0(>15°C)
pH	range	5.9-9.0	5.9-9.0	5.9-9.0	5.9-9.0	5.9-9.0
	optimal	6.5-8.0	6.5-8.0	6.5-8.0	6.5-8.0	6.5-8.0
Velocity (cm/sec	range	20.0-80.0	O-30.0	9.1-10.3	2.8-29.3	11 .o-92.0
	optimal	30.0-65.0	<8.0	13.1-16.0	10.0-14.0	25.0-70.0
Gradient	range	0.7-10.0	0.7-10.0	0.7-10.0	0.7-10.0	0.7-10.0
	optimal	2.4-5.2	2.4-5.2	2.4-5.2	2.4-5.2	2.4-5.2
Substrate		2.0-6.0 cm gravel <2% fines (5 3mm)	gravel-cobble boulder	gravel-rubble boulder	80-95% rubble (7.6-30.1 cm) and 5-15% coarse gravel (2.5-7.6 cm) w/occ. boulders and fame woody debris	2.0-6.0 cm gravel: <2% line (≤ 3mm
Summer Cover			protected stream edges, lateral habitats, back-waters, deep backwater pools, glides, low-gradient riffles: 34% gravel-cobble-boulder, 24 % shade overhang, 24% fine debris, 17 % woody debris in fess 200m2 or 100m3	deep lateral scour and plunge pools, protected stream edges. lateral habitats with 16% cover, protected lov gradient riffles: 34% gravel-cobble boulder, 24% shade overhand, 24% fine debris. 17% 17% woody debris in less 200m2 or 100m3	1030% pools with 30% bottom obscure with low-velocity (<15 cm/sec) restinc for several adults: ≥1.5m deep in streams ≤5.0m wide or >2.0m deep in >5.0m wide. Alternate: moderate velocity (>15cm/sec runs w/80% large organic cover. Low velocity runs and boulders.	small, ephemeral or permanent 1st or 2nd order streams with moderate velocities and low-to high-gradients
Winter and Escape cover		2.0-6.0 cm gravel, <2% fines (≤3mm)	burrow in 10% substrate (10-40cm) at <8°C	burrow in 10% substrate (10-40cm) al <8°C	burrow in 85-95% rubble (7.6-30.1cm) and 515% coarse gravel (2.5-7.6 cm) w/occ. boulders and large woody debris; hide under debris jams. root wads, fogs, boulders, or in negative-velocity pools	boulders: logs; debris.
Diet		yolk sac	large zooplankton, small aquatic insects	small-medium aquatic insects	92% drift insects: Diitera. Trichoptera. Pfecoptera Ephemeroptera; 6-8% allochthonous terrestrial insects: 0-2% fish	very little: eggs. aquatic insects

Males mature one year earlier than females, males reach maturity at age 3-4+, and females mature at age 4-5+.

Size at maturity depends upon environmental conditions and abundance of food. Consequently, adfluvial cutthroat stocks are substantially larger than fluvial stocks, which inhabit the same drainage and are the same age.

Cutthroat return to natal tributaries to spawn. Initiation of spawning is dependent on water temperature, runoff, ice melt, elevation and latitude. Westslope cutthroat may spawn as early as February, or in colder waters as late as August. Most spawn just before and during high-water of April and May in the lower tributaries and from April to June in middle and upper tributaries.

Spawning populations tend to have a higher ratio of females to males, averaging 2.6 females per male. Fecundity of females is similar to other salmonids; number of eggs per female increases with length of fish.

Natural mortality ranges from 30-54 percent for adfluvial and fluvial populations. During early stages of life, it is estimated that 95 percent mortality occurs from emergence to age 1+ fingerlings. Amount of fine sediment (< 3.0 mm) in incubation gravels is a major factor that determines egg to swim-up fry mortality. Optimal percent fines in spawning areas during average summer flows is two percent or less.

3.1.3 **Water Quality**

3.1.3.1 Temperature

Average maximum daily water temperatures have a greater effect on trout growth and survival than minimum temperatures. During embryo development, average maximum water temperature range is 3.0°-16.0°C, with 7.0°-11.5°C as optimum (Table 3.1). Highest average temperature range during warmest period of the year for juvenile to adult is 6.0-21.0°C, with 11 .0-15.5°C representing optimal conditions.

3.1.3.2 Dissolved Oxygen

For all ages of cutthroat trout, the average minimum dissolved oxygen concentrations during late season, low water period are 4.5-7.3 mg/l for water temperatures up to 15°C. Minimum dissolved oxygen concentrations during late season, low water period are 4.5-7.3 mg/l for water temperatures up to 15°C and 6.0-9.0 mg/l in water above 15°C. Optimal concentrations of dissolved oxygen are 7.3 mg/l in water up to 15°C and 9.0 mg/l in water exceeding 15°C (Table 3.1).

3.1.3.3 Other Water Quality Parameters

Annual pH range for cutthroat trout is 5.9-9.0, with optimal conditions at 6.5-8.0 pH (Table 3.1). Neither pH or total dissolved solids appear to have any influence on limiting distribution of cutthroat trout. Little information is available on total alkalinity and total hardness requirements.

Turbidity is an optical property of water wherein suspended and dissolved materials cause light to be scattered and absorbed rather than transmitted in straight lines. Low turbidities near 10-26 nephelometric turbidity units (NTU) and suspended concentrations near 35 mg/l have deleterious effects on fish and macroinvertebrates. In Idaho, numerical turbidity standard for protection of fish and aquatic habitats is 5 NTU/JTU (Jackson turbidity units) above normal.

3.1.4 Gradient and Velocity

Streambed gradient effects trout populations by influencing stream velocity. Stream velocity effects the quality and quantity of bottom organisms and has a direct influence on fish populations by restricting and influencing the delivery of oxygen-saturated water.

Velocities for spawners range from 11.0-92.0 cm/sec (Table 3.1). During spawning, cutthroat trout are typically found in small, ephemeral or perennial, first and second order streams with moderate velocities and low to high gradients.

Average velocities during embryo development range from 20.0-80.0 cm/sec, with optimal velocities at 30.0-65-O cm/sec.

Fry (age 0+) prefer protected habitats with velocities ranging from O-30.0 cm/sec, optimally with flows less than 8.0 cm/sec. Since fry survival decreases with increased velocity above- optimum, preferred rearing areas are protected stream edges, lateral habitats, backwaters, deep backwater pools, glides, and low gradient riffles.

Juvenile cutthroat of ages 1+ and 2+ use similar habitats with optimal velocity increasing with age. For age 1+ juveniles, preferred velocities are 9.1-10.3 cm/sec, and 13.1-l 6.0 cm/sec are chosen by age 2+ fish. Juveniles choose deep lateral scour and plunge pools, protected stream edges, lateral habitats with optimally 16 percent cover, and protected low-velocity riffles.

Adult cutthroat trout desire velocities of 10.0-14.0 cm/sec, but can be found in areas of 2.8-29.3 cm/sec. They choose habitats with 10-30 percent deep, class-l pools during lowest flow period, but favor areas of 30 percent class-l pools, where low-velocity resting (< 15 cm/sec) for several adult trout, is possible. Deep, class-l pools have greater than 30 percent of bottom obscure due to depth, surface turbulence, presence of structures (e.g., logs, debris piles, boulders), or overhanging banks and vegetation. Depth of class-l pools should be 1.5 meters or greater in streams that are 5.0 meters wide or less, or should exceed 2.0 meters deep in streams greater than 5.0 meters wide. During low water period of summer, 35-65 percent of entire stream should consist of low-velocity pools in some form. Alternate habitat for adults is moderate velocity runs with 80 percent large organic cover.

The lowest flows of late summer to winter, or base flows, are the most critical periods for trout. A base flow of 25-50 percent is acceptable. A base flow of greater than 50 percent of average annual daily flow is optimal for quality trout habitat; anything less than 25 percent is unacceptable. High base flows (≥ 50%) and low flow variability results in optimal habitat (Table 3.1).

Overall gradient for all ages and life stages of cutthroat trout ranges from 0.7-10-O percent, with desired range of 2.4-5.2 percent.

3.1.5 Substrate

Bottom type influences the quantity and quality of macro-invertebrates and is of prime importance in determining the natural production in a stream. In riffle-run areas of food production, optimal substrate consists of 50 percent or greater rubble, small boulders or aquatic vegetation in spring areas, with limited amounts of gravel, large boulders or bedrock.

For successful reproduction, the average optimal substrate is 2.0-6.0 centimeters in diameter, with less than two percent fines (ı 3 mm) in riffle-run spawning areas. Approximately 85 percent mortality of eggs and alevins will occur if 15-20 percent of interstices of substrate is filled with sediment.

Fry (age 0+) are more consistently associated with gravel-cobble-boulder substrate, and juveniles (age 1+ - 2+) favor gravel-rubble-boulder mix. Since small fish move into substrate as temperature drops below 8°C, optimal winter and escape cover for fry and juveniles is a substrate where ten percent ranges between 10-40 centimeters in diameter (Table 3.1).

Subadults and adults prefer substrates of 85-95 percent rubble (7.6-30.1 cm) and 5-15 percent coarse gravel (2.5-7.6 cm), interspersed with boulders and large woody debris.

3.1.6 Cover

Instream cover is recognized as a critical component of stream habitat affecting trout densities. Cover consists of water depth, surface turbulence, loose substrate, large rocks and other submerged obstructions, undercut banks, aquatic and overhanging terrestrial vegetation, downed snags and other debris lodged in the channel, and anything else that allows trout to avoid impacts of elements and enemies.

There are two types of cover that limit trout densities--summer and winter cover. The main use of instream summer cover is for predator avoidance, resting and feeding stations. Summer cover of protected stream edges and backwater pools for fry and juveniles, and deep class-l pools or protected runs for adults has been discussed relative to gradient and velocity in Section 3.1.4. Apportionment of summer cover for fry and juvenile is 34 percent gravel-cobble-boulder mix, 24 percent shade overhang, 24 percent fine debris, and 17 percent woody debris, which occur along pool edges and in habitat units less than 200 m^2 or $100 m^3$. Adults prefer protected pools and low-velocity runs, or boulders (Table 3.1).

In winter, fish inhabit near freezing water temperatures and have lower metabolism, reduced food requirements and less available energy. The resultant hiding **response** is **a means** of avoiding predation, mass ice movements and flooding, and of reducing downstream displacement during freshets to conserve energy. Fry and juvenile cutthroat trout move into the substrate as temperature drops below 8°C. Subadults and adults often display the same behavior or seek shelter under debris jams, root wads, logs, boulders, or in sheltered negative-velocity pools.

Another form of cover is canopy cover. Canopy cover and streamside vegetation are important in providing temperature control, in contributing to the energy budget and allochthouous input to the stream, in controlling watershed erosion, and maintaining streambank integrity. Approximately 15-90 percent of stream area should be shaded from 1100-1400 hours. For streams less than 50 meters in width, 50-75 percent of stream area was necessary to be shaded at midday for optimal habitat conditions.

3.1.7 Diet

Cutthroat trout are very opportunistic and their diet consists mainly of insects. As fish grow larger, diversity of food items increases and includes terrestrial insects and sometimes small fish.

Fry (< 110 mm) often prefer a diet of larger zooplankton and small aquatic insects. Juvenile trout increasingly consume larger insects. Subadults and adults feed 92 percent (75-100%) on drift organisms. The four principal orders of aquatic insects consumed are Diptera (midges and flies), Trichoptera (caddisfiies), Plecoptera (stoneflies) and Ephemeroptera (mayflies) in decreasing order of importance (Table 3.1).

3.2 LITERATURE REVIEW FOR BULL TROUT

3.2.1 General Information

Bull trout display three distinct life history patterns. They are:

1. Resident, which inhabit headwater streams, do not migrate, and are normally isolated by a physical barrier.

2. **Fluvial,** which inhabit large streams and mainrivers, and migrate from main river to natal stream to spawn and rear.

3. Adfluvial, which inhabit large lakes and reservoirs and migrate back to nursery stream to spawn. They rear l-6 years in nursery tributary and mature 2-3 years in lake, before returning to spawn.

3.2.2 Life History

Life history of bull trout can be categorized by advanced age of maturity, increased size, alternate-year spawning, extensive migrations, and separation of juvenile and adult populations. Average age of maturity for bull trout is age 4-7+. Length at maturity is dependent upon environmental productivity, water temperature and life history pattern of stock.

Spawning usually occurs between September and October. Bull trout enter tributaries approximately one month prior to spawning. Upstream migration has been found to coincide with maximum water temperatures (1 O-l 2°C) and minimum flows in O-76-0.80 meter deep water (Table 3.2).

Initiation of spawning appears to be related to declining water temperatures, photoperiod, and possibly stream flow. Most spawning occurs at night, when water temperatures fall below 9°C (av. 5-6°C). Bull trout pairs remain over the nest for one to six days: after spawning, they move downstream within a month.

Fertiliztion rate is estimated to be approximately 90 percent. Fecundity (#eggs/female) is lower than or equal to other charrs of comparable size. Egg retention is 2-5 percent. Sex ratio averages 1 .1 female per male. In the Flathead River system, each redd averaged 3.2 spawners.

Incubation continues throughout winter, with peak hatch occurring by mid-January. Peak emergence of fry generally takes place by 1 May. After l-3 years of rearing in tributary streams, bull trout smolts out-migrate to main rivers (fluvial) or lakes and reservoirs (adfluvial).

Table 3.2 Acceptable and optimal habitat conditions for various life stages of bull trout.

		Egg/Alevin	Frv	Juvenile	Adult	Spawner
Temperature (°C	maximum range		5-15°C	5-l 5°C	9-1 5°C (resident/fluvial) 7.2-l 4.0°C (adfluvial)	5-9°C
	optimal	2-4°C	5-8°C	5-8°C	9-1 0.0°C (resident/fluvial) 8.0-l 2.8°C (adfluvial)	5-6°C Sept. - Oct.
Velocity (cm/sec	range	fast	low	low- moderate	moderate - fast	moderate - fast
	optimal		8-10	8-16		
Gradient	range		low	low	10-20%	
	optimal	<3%				<3%
Substrate		i0% unembedded |ravel, !3% cobble, 7% boulder; ю fines ≤ 6.4 mm,	sand/gravel ɡravel-cobble-rubble	unembedded, stacked rubble-cobble-boulder with large interstitial spaces between particles	deep pools w/ boulder-rubble substrate	i0% unembedded ɉravel, !3% cobble, I7% boulder: ю fines ≤ 6.4 mm
Cover		Substrate	sidechannels; backwaters: lateral stream margins; pools with submerged debris: substrate: unconsolidated woody debris: submerged and large instream structures.	side-channels; backwaters: lateral habitats: pools with submerged debris substrate: unconsolidated woody debris: submerged and instream structures.	closed-forest canopy shade: overhanging banks and vegetation: woody debris and jams; large deep pool: water depth.	:losed-forest :anopy shade: ›verhanging ›anks and regetation; voody debris ınd jams; arge deep pools: vater depth.
Diet		ʼolk sac	1. aquatic insects 2. eggs	1. aquatic insects 2. salmon eggs 3. increasingly piscivorous	1. piscivorous: 2. whitefish 3. kokanee 4. sculpins 5. squawfish 6. chubs 7. suckers 8. yellow perch 9. aquatic and terrestrial insects: Mysis shrimp.	rery little, f anything eggs, insects)

Most fluvial and adfluvial young remain in nursery streams for 1-6 years, generally 2-3 years of age. Time of migration varies depending on age and size of fish, and amount of available habitat. Out-migration occurs in the spring (May-August) to areas where water velocities are lower.

3.2.3 Water Quality

3.2.3.1 Temperature

All life history stages of bull trout are strongly influenced by temperature (Table 3.2). Bull trout are seldom associated with tributaries where summer temperatures exceed 15°C and are normally associated with cold perennial springs or groundwater influence, and a closed-forest canopy.

Spawning migration coincides with water temperatures around 1 O-l 2°C. During embryo development, optimal incubation temperture is 2-4°C. Highest average temperature range during warmest period of year for fry and juvenile bull trout' is 5-15°C, with optimal range of 5-8°C for fry and 5-12°C for juveniles. For resident and fluvial adult bull trout, the average maximum temperature range is 9-15°C, with 9-10°C as optimum. Adfluvial adults prefer 7.2-l 4.0°C temperatures; 8.0-l 2.8°C range is optimum.

3.2.3.2 Other Water Quality Parameters

No conclusive information exists on chemical parameters, such as dissolved oxygen, pH, alkalinity, hardness, total dissolved solids or turbidity.

3.2.4 Substrate

Unembedded gravel-cobble-boulder composition (60-23-l 7%) substrate with low compaction, low gradient and no fines below 6.4 millimeters are selected as bull trout spawning sites; these areas have the highest frequency of redds and success of emergent fry (Table 3.2).

Young fry show a preference for sand and gravel, whereas highest density of juveniles will be found in stream segments dominated by clean unembedded, stacked rubble-cobble-boulder substrate with large interstitial spaces between particles.

Adult bull trout are bottom dwellers and prefer deep, cold water pools with boulder-rubble substrates; this type of habitat ensures good winter survival and adequate summer protection.

3.2.5 Velocity and Gradient

Low channel gradient has been significantly correlated with high redd frequency of bull trout; frequency is highest where gradient is less than three percent in a high order stream with groundwater influence (Table 3.2).

Juveniles distribute themselves along the stream bottom, seeking low velocites (10 cm/sec) in association with submerged cover. Since low optimal velocities are found only in small pockets of the stream, it has been found that describing mean velocities by conventional methods has not provided information on available rearing habitat. Extremely high flows reduce survival by flushing fry out of tributaries into mainstem, where predation rates are higher. Conversely, low flows reduce wetted area and reduce amount of space available for rearing fry and juvenile.

Adult bull trout select streams with 10-20 percent gradients and moderate to fast velocity flow.

3.2.6 Cover

Upon emergence, bull trout fry migrate to low-velocity areas that are separated from adults, such as side channels, backwaters, lateral stream margins, and pools (Table 3.2). Fry and juvenile find protection and rest near submerged debris over gravel-cobble-rubble substrate or by burrowing into the interstices of unembedded substrate cobble.

Streams can be manipulated to enhance rearing capacity for juvenile bull trout (40-200 mm). A single piece of submerged debris along the stream margin or a large jam of unconsolidated woody debris can mitigate for rearing capacity; water should flow through the debris jam or root wad, not necessarily over it into a plunge pool. Submerged cover along stream bottoms can create small pockets of slow (10 cm/sec) water, advantageous to fry and juveniles. As juveniles increase in size, they become less dependent on instream cover.

Adults and spawners rely upon closed-forest canopy shade, overhanging banks and vegetation, and woody debris as cover; higher redd frequency is associated with this type of cover. Resident and fluvial adults require large deep pools for cover in summer and winter. Adfluvial bull trout in lakes use depth as cover.

3.2.7 Diet

Bull trout are voracious predators and have been described as opportunistic and adaptive in feeding habits (Table 3.2).

Bull trout larvae remain in gravel until yolk sac absorption is nearly complete. Bull trout begin feeding at emergence and select aquatic insects from the entire water column.

Bull trout fry (< 100 mm) feed exclusively on aquatic insects, however, salmon eggs are important components of juvenile diets. As juveniles reach 11 O-l 14 millimeters, they become increasingly piscivorous. Growth and condition improve after bull trout begin feeding on fish. Sub-adults (< 300 mm) consume small individuals of sculpins, whitefish, kokanee, and incidentally yellow perch, squawfish, peamouth chubs and suckers, and Mysis shrimp, if opportunely available.

Fluvial adults (≥ 400 mm) eat primarily fish and insects. Adult resident trout feed exclusively on insects. Food preferences are Diptera (midges and flies), Trichoptera (caddisflies), Ephemeroptera (mayflies), and Plecoptera (stoneflies), in decreasing order of importance.

Adfluvial populations are highly piscivorous and reach the largest size of all stocks. Preference is for kokanee and whitefish: however, diet preference is altered by availability of prey and season.

Spawning adults eat very little, if at all.

For hatchery produced bull trout, it is difficult to provide a suitable diet; these fish demonstrate clear preferences for certain flavors. Since bull trout feed exclusevely on the bottom, finding palatable sinking food has been difficult, and diseases (gill infections) have been much more difficult to control than in aquaculture of other species.

3.2.8 **Species interactions**

Interactions between bull trout and northern squawfish, cutthroat, rainbow, and lake trout have been recognized.

Both northern squawfish and bull trout shift to a piscivorous diet at 200-300 millimeters and compete for the same food source, if cohabiting together.

Rainbow and bull trout do not compete for food resources or living space, but bull trout and juvenile rainbow trout partition the habitat; rainbow trout choose areas of higher velocity.

Habitat partitioning occurs between juvenile bull and cutthroat trout. Also, in areas of high cutthroat density, bull trout have been repeatedly found, which suggests that cutthroat fry serve as prey for adult and subadult bull trout.

Fluvial populations of bull and brook trout, that cohabitate in the same stream, share the same habitat during at least one stage of their life. Hybridization of the two species is common and extensive. It has been hypothesized that the introduction of brook trout and competition with brown trout have led to the decline of bull trout populations.

Decline of adfluvial bull trout stocks has been attributed to flood damage of spawning and rearing habitat and competition with introduced lake trout.

3.3 GEOMORPHOLOGICAL PARAMETERS

Geomorphological data from 19 streams, which are tributary to Coeur d'Alene Lake, are listed in Table 3.3. Parameters listed include: stream length, stream order, channel gradient, elevation, basin area, basin relief, drainage density and sinuosity. Stream lengths ranged from 1.9 kilometers (1.2 mi) for Shingle Bay Creek to 23.7 kilometers (14.7 mi) for Benewah Creek. The study streams ranged from second to fourth order with gradients ranging from 1.5-6.4 percent. Elevation of streams ranged from approximately 823-1463 meters (2700 to 4800 ft). Area of stream basins ranged from 9.6-135.9 square kilometers (3.7 to 52.5 mi^2). Figure 3.1 shows the gradient based on stream distance versus elevation of each of the nineteen tributaries.

Table 3.3 Results* of geomorphometric data calculated from the tributaries of Coeur d'Alene Lake.

Stream	Length mi (km)	Stream order	Channel gradient	Stream elevation ft (m)	Basin area mi^2 (km^2)	Basin relief ft (m)	Drainage density mi (km)	Sinuosity
Bellgrove	3.0 (4.8)	4	2.5	4001 (1219.5)	4.7 (12.3)	624 (190.2)	2.6 (4.2)	1.10
Fighting	4.9 (7.9)	4	2.6	4004 (1220.4)	6.1 (15.7)	813 (247.8)	3.1 (5.0)	1.12
Lake	12.7 (20.4)	3	1.8	4793 (1460.9)	12.7 (32.8)	462 (140.8)	3.9 (6.3)	1.12
Cottonwood Bay	2.6 (4.2)	3	5.8	2921 (890.3)	5.6 (14.5)	884 (269.4)	1.3 (2.0)	1.01
Squaw	4.7 (7.6)	2	3.4	3903 (1189.6)	12.6 (32.7)	884 (269.4)	1.9 (3.0)	1.01
Plummer	6.8 (10.9)	3	1.5	3395 (1034.8)	21.1 (54.6)	1274 (388.3)	3.0 (4.8)	1.31
Little Plummer	8.8 (14.2)	4	1.6	3603 (1098.2)	21.9 (56.7)	1716 (523.0)	2.0 (3.2)	1.19
Pedee	2.8 (4.5)	3	4.4	3640 (1109.5)	6.9 (17.8)	1599 (487.4)	1.8 (2.9)	1.02
Benewah	14.7 (23.7)	4	1.7	4095 (1248.2)	52.5 (136.0)	2509 (764.7)	3.0 (4.9)	1.17
Cherry	3.7 (6.0)	3	4.9	4000 (1219.2)	8.4 (21.7)	2743 (836.1)	1.8 (2.9)	1.20
Alder	12.6 (20.3)	4	4.5	4295 (1309.1)	26.9 (69.6)	2662 (811.4)	2.3 (3.6)	1.18
John & Little John	10.6 (17.1)	4	2.2	3690 (1124.7)	25.9 (67.1)	1853 (564.8)	2.8 (4.5)	1.09
Hell's Gulch	6.5 (10.5)	3	4.6	4436 (1352.1)	14.8 (38.4)	2704 (824.2)	2.6 (4.2)	1.01
O'Gara Bay	1.8 (2.9)	3	3.7	3058 (932.1)	4.7 (12.3)	657 (200.3)	2.3 (3.6)	1.01
Shingle Bay	1.2 (1.9)	3	6.4	2980 (908.3)	5.6 (14.5)	637 (194.2)	1.5 (2.4)	1.06
Black	3.7 (6.0)	3	3.4	3400 (1036.3)	7.0 (18.1)	1274 (388.3)	2.6 (4.1)	1.03
Willow	4.0 (6.4)	2	5.8	3910 (1191.8)	5.7 (14.7)	2704 (824.2)	1.6 (2.6)	1.01
Evans	5.2 (8.4)	3	4.5	4589 (1398.7)	12.8 (33.2)	3256 (992.4)	1.9 (3.1)	1.03

* Rounded to nearest tenth.

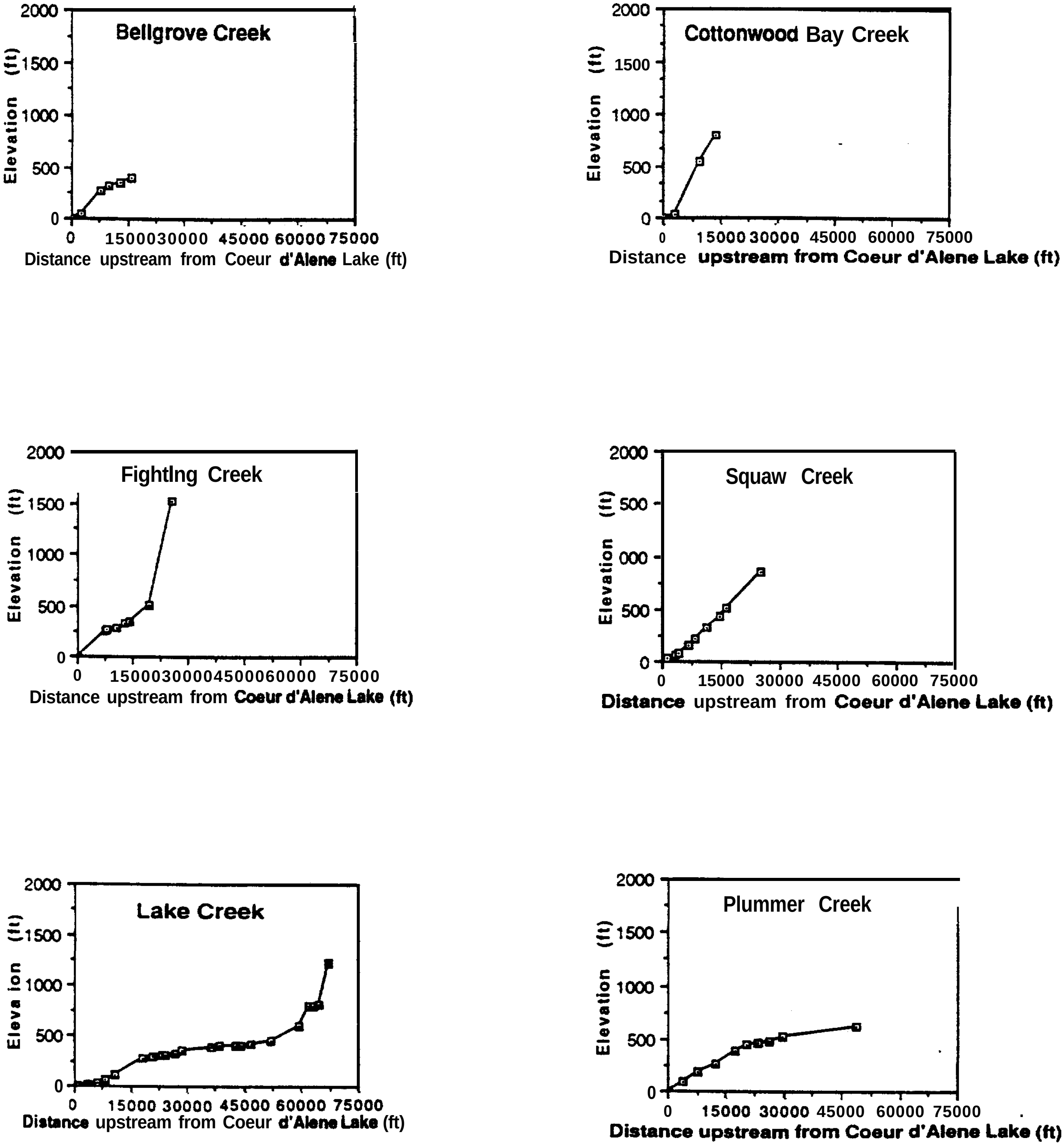


Figure 3.1. Stream gradient profiles for tributaries on the Coeur d'Alene Indian Reservation (no graph for Little John Creek).

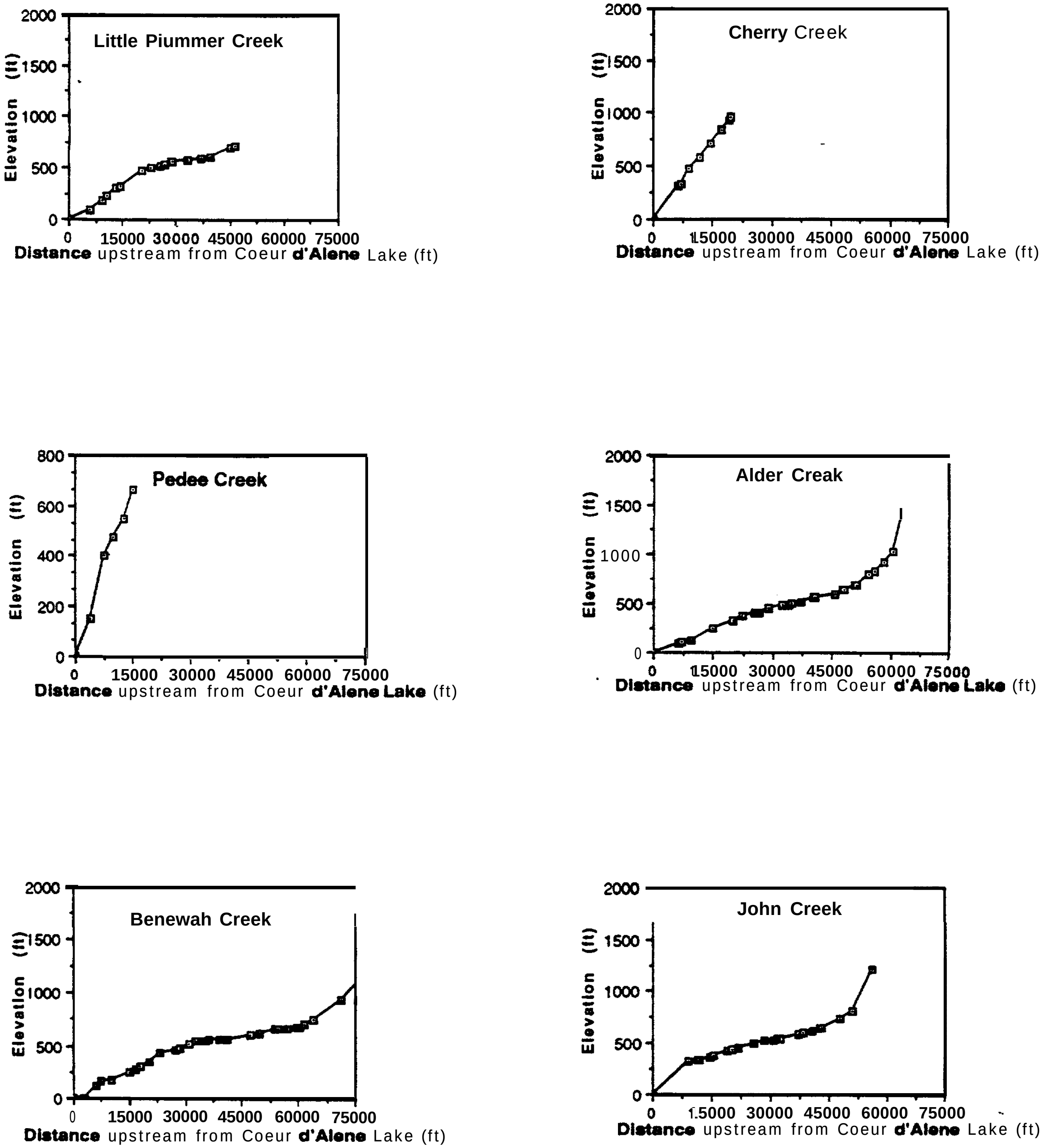


Figure 3.1. (cont.).

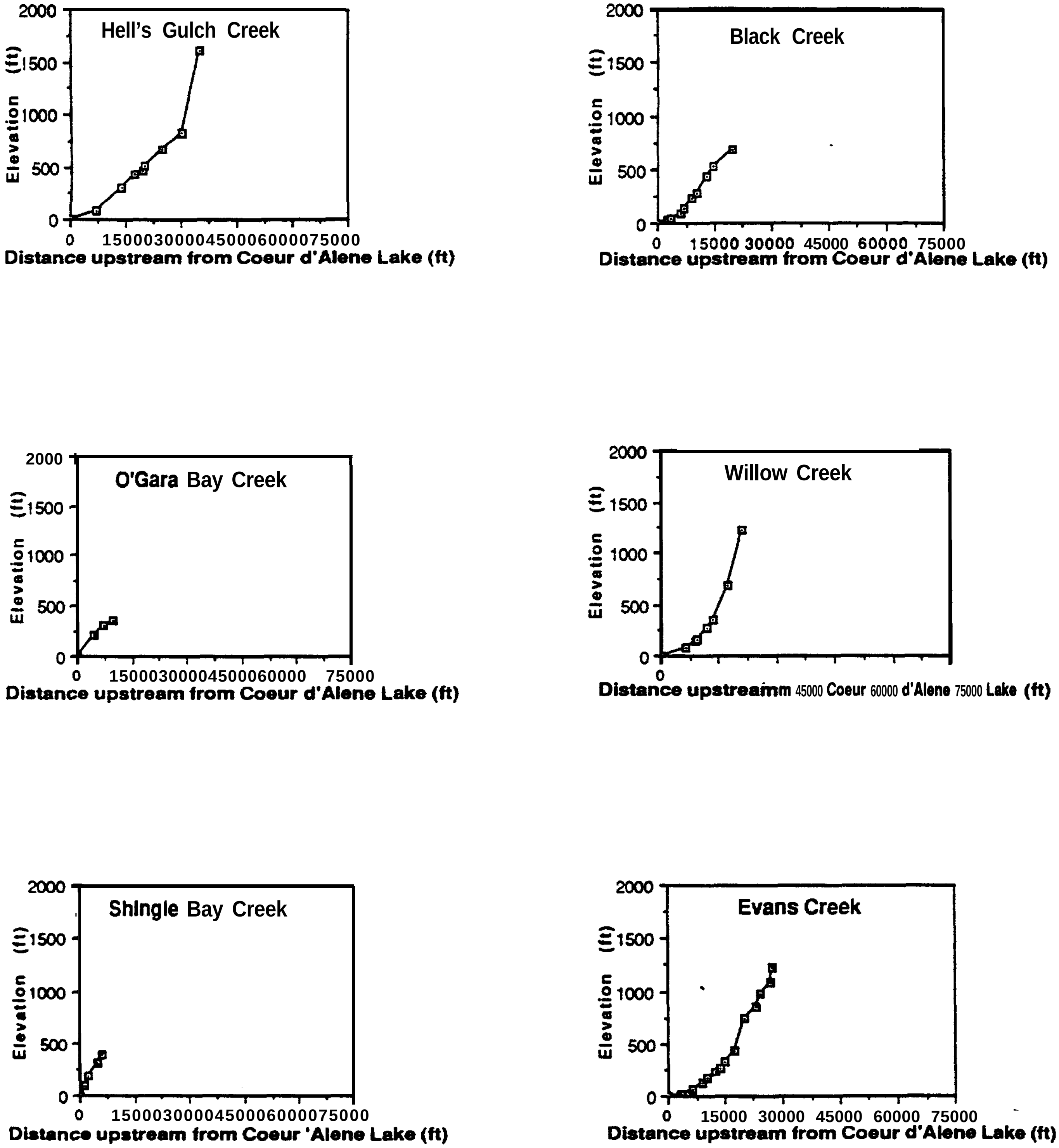


Figure 3.1. (cont.).

3.4 AERIAL SURVEY

Comparison of results observed during the aerial survey for lower, middle and upper reaches of the 19 tributaries are provided in Table 3.4. Summary of each stream is provided below.

3.4.1 Bellgrove Creek

Recreational, residential, agricultural, grazing and timber land-use practices were observed adjacent to Bellgrove Creek. Road access appeared good, especially in the lower reaches where 50 percent was residential. Stream width ranged from approximately 0.6 meters (2.0 ft) in the upper reach to 9.1 meters (30.0 ft) at the mouth. Gradient was steep for most of the stream. Minimal flows were observed during December, indicating summer flow would probably be intermittent. Lack of a riparian zone, along with unstable and wasting banks, allowed meandering of the stream channel throughout the lower valley floor. The instability of the stream channel can be attributed to agricultural, logging and grazing practices adjacent to and within the stream channel. Large woody debris was observed in the stream. A heavy silt load from logging and grazing posed a potential water quality problem. Observed barriers included a concrete embuttment and numerous culverts. At the confluence with Coeur d'Alene Lake, a solid concrete embuttment was observed under the bridge that appeared to be a barrier to fish migration. Numerous improperly graded culverts were noted within the channel. Cumulative land-use impacts were noted along entire length of the stream. At the mouth, heavy recreational use was noted.

3.4.2 Fighting Creek

Land-use practices adjacent to Fighting Creek included recreation, residential, agricultural, grazing, and timber harvest. Road **access was** good. The stream channel was an irregular meander, in which the riparian zone and stream banks were significantly damaged. A moderate gradient, capable of sustaining a fishery, was observed in the middle reach. No vegetative streamside cover remained along the stream channel, except for a few isolated alder groves. The gradient appeared steep with rapids and boulders prevalent in the upper reach, which suggests that this area is not conducive to a bull and cutthroat trout fishery. Observed barriers

Table 3.4. Summary of information recorded during aerial survey for lower, middle and upper reaches of the nineteen tributaries under study (St. Joe River excluded).

Stream & Section		Land-Use	Road Access	Gradient	Flow	Substrate-Riffle:Pool	Soils & Bank Stability	Riparian	Channel	Cover & Woody Debris	Water Quality	Barriers
Bellgrove	Lower	agriculture grazing	good	moderate	low	silted	highly erodible;	none		good	marginal-poor	cement embuttiment
	Middle	logging-timber	good	moderate	low		wasted & unstable	none	unstable	good	heavy silt	culverts;
	Upper	recreational residential	good	moderate-high	rapids			none	meander	good	load	cumulative impacts.
Fighting	Lower	agriculture grazing	good	moderate	moderate	silted	highly	damaged	unstable	-	poor	cement embuttment
	Middle	logging & timber	good	moderate	moderate	silted	erodible	to none	meander	-	poor	water quality;
	Upper	recreational residential	good	very high	rapids	boulders				-	poor	cumulative impacts.
Lake	Lower	agriculture grazing	none	gradual/low	moderate	silted substrate	highly erodible;	site-specific	unstable	-	silted;	none
	Middle	logging-timber	limited	moderate/low	moderate	50/50 r:p-high riffle	wasted and	protected	meander;	-	moderate-poor	none
	Upper		good	moderate	moderate-rapids	high riffle	undercut	limited	unstable braided	-		none
Cottonwood Bay	Lower	-	good		none	-	-	-	dry	-	none	concreet channel;
	Middle	-	good	very	none	-	-	-	dry	-	none	no
	Upper	-	good	high	none	-	-	-	dry	-	none	water
Squaw	Lower	agriculture grazing	good	moderate	-	gravel	stable	undamaged			good	none (potential
	Middle	logging-timber	good	moderate	-	50/50 riffle:pool	stable	undamaged	unstable	good;	good	for log jams and intermittent
	Upper		good	moderate	-		stable	none	meander	logs and debris	good	flow in upper)
Plummer	Lower	logging-timber	good	moderate			highly	damaged		good		upper: Town of Plummer;
	Middle	residential	good	moderate	moderate-	50/50 riffle:	erodible;	with	stable	good	muddy-	culverts; sewage ponds + storm
	Upper		good	low-moderate	high	pool	stable	residual snags	meander	good	poor	drain effluent; water quality
Little Plummer	Lower	agriculture grazing	good	low					stable	good	good	gravel pit;
	Middle	gravel mining	good	gradual/moderate	moderate-	gravel	erodible;	undamaged;	stable	good	good	numerous culverts;
	Upper		good	moderate	high	50/50 riffle:pool	stable	stable	stable	good	good	possible log jams
Pedee	Lower	-	good	very high	none	-	-	-	dry	-	none	frozen in
	Middle	-	good	very high	none	-	-	-	dry	-	none	winter;
	Upper	-	good	very high	none	-	-	-	dry	-	none	gradient
Benewah	Lower	agriculture grazing	excellent	low	moderate			site-specific:disturbed	stable	good	good	
	Middle	logging	excellent	gradual/moderate	moderate	50/50 riffle:	erodible;	stable, protected.	stable	good	good	improperly graded culverts;
	Upper		excellent	moderate-very high	moderate rapids	pool	stable	limited	stable	good	good	headwaters: steep gradinet rapids
Cherry	Lower	-	good	very high	none	-	-	-	dry	-	-	no
	Middle	-	good	very high	none	-	-	-	dry	-	-	water;
	Upper	-	good	very high	none	-	-	-	dry	-	-	gradient
Alder	Lower	logging	good	moderate	moderate	high riffle:	stable		stable	good	good	upper: waterfalls;
	Middle		good	moderate	moderate-slightly high	low pool	stable	stable;	stable	good	good	steep gradient;
	Upper		good	high	rapids	cascades	stable	undamaged	stable	good	good	rapid cascades

Table 3.4. (cont.).

Stream & Section		Land-Use	Road Access	Gradient	Flow	Substrate Riffle: Pool	Soils & Bank Stability	Riparian	Channel	Cover & Woody Debris	Water Quality	Barriers
	Lower	logging	good	high	moderate	50/50 riffle:	stable	stable	stable meander;	good;	good	waterfalls
John	Middle	grazing	good	low-moderate	moderate	pool;	stable	stable	sidepools	upstream potential	good	-
	Upper		good	high	moderate-high	good	erodible; unstable	stable	unstable	for downstream scour	good	gradient, flow, woody debris
	Lower	-	limited	high	rapids	poor	unstable	-	-	-	poor	flow
Little John	Middle	-	limited	high	rapids	high riffle	unstable	-	-	-	poor	
	Upper	-	limited	high	rapids		unstable	-	-	-	poor	gradient
	Lower	agriculture	good:	moderate-high		silted poor;		damaged-none;	highly erodible;	poor	poor:silted	water quality;
Hell's Gulch	Middle	logging-timber	south side	moderate-high	low flow	high riffle	erodible; unstable	damaged-none;	mass wasting;	poor	poor:silted	gradient; culverts;
	Upper	gravel mining		very high				forested	unstable;	good	clean	debris jams
	Lower	timber	goods	high	minimal	-	-	one side	-	-	-	culvert at mouth;
O'Gara Bay	Middle		goods	high	minimal	-	-	wooded;	-	-	-	gradient;
	Upper		goods	high	minimal	-	-	other=none	-	-	-	flow
	Lower	-	good	high	disappeared underground	-	-	-	dry	-	none	stream disappeared
Shingle Bay	Middle	-	good	high	into grate at	-	-	-	dry	-	none	into grate;
	Upper	-	good	high	mouths ; no flow	-	-	-	dry	-	none	no flow
	Lower	agriculture	poor	moderate	low	silted poor	stable		stable	-	poor	none
Black	Middle	logging	poor	high	low	50/50 riffle;:pool	stable	very degraded;	stable	-	poor	none
	Upper	+ timber	limited	very high	low-intermittent	high riffle	stable	stable	stable	-	poor	none
	Lower	agriculture; grazing;	good	moderate	moderate	silted	erodible;	none	highly	good	poor	culverts;
Willow	Middle		good	moderate-high	moderate	silted	unstable	none	erodible;	good	poor	water quality;
	Upper	logging -timber	good	high	moderate	riffles		none	meander	good	poor	upper gradient
	Lower	agriculture	good	moderate	low	heavily silted;	unstable;	slightly	unstable meander;	good	silted	none
Evans	Middle		good	moderate-high	moderate	gravel;	erodible	degraded	stable;	good	silted	none
	Upper		good	high	rapids + cascades	boulders			steep		silted	none; possible gradient

included a concrete embuttment, extensive water quality problems, and a landfill site located along the stream.

At the confluence with Bellgrove Creek, a solid concrete under-bridge embuttment was observed that appeared to limit fish access to the creek. Also, extensive water quality problems were possible, as a result of grazing adjacent to and within the stream channel, agricultural land-use practices, and seepage from the landfill site. These water quality problems could pose as a migration barrier to trout.

3.4.3 Lake Creek

At the mouth of Lake Creek, the width was approximately 9.1-10.7 meters (30-35 ft). No road access existed along the lower reaches of Lake Creek. The gradient was gradual. Highly erodible soils allowed the stream channel to meander through the valley, where severely undercut banks, exposed tree roots, and mass wasting were evident. Site-specific damage to the riparian zone was noticed. Heavy sediment loads were observed at the mouth of Lake Creek.

Land-use practices adjacent to the middle reach of Lake Creek, included selective and partial logging with a protected riparian zone. The gradient was gradual with a high riffle:low pool ratio, gradually changing to an equal riffle:pool ratio.

The upper reach of Lake Creek was agricultural, and a limited riparian zone remained. Agricultural and grazing practices allowed for an unstable, braided stream channel, carrying a heavy silt bedload.

3.4.4 Cottonwood Bay Creek

The gradient of Cottonwood Bay Creek was very steep, and no water was observed in the stream channel during the aerial survey. The mouth of Cottonwood Bay Creek had been channelized with concrete.

3.4.5 Squaw Creek

Land-use practices adjacent to Squaw Creek included clear-cut logging, grazing and agriculture. Road access to Squaw Creek was good. At the confluence with Coeur d'Alene Lake, a meandering stream channel was present, resulting in an unstable stream channel. Factors conducive to a trout fishery included a moderate gradient, good gravel deposition, stable streambanks, large- organic debris within the stream channel for cover and pools, and a relatively undamaged riparian area. Site-specific damage to the riparian area was observed in the upper reach of Squaw Creek, where clear-cut logging had taken place. Logging on a 30 percent, south slope increased the possibility of significant sediment loads to the stream. A log jam in the upper portion of the middle reach could result in a blockage to fish migration.

3.4.6 Plummer Creek

Land-use practices adjacent to Plummer Creek included timber, logging and residential. Road access was good. At confluence with Coeur d'Alene Lake, the stream was approximately 12.2 meters (40 ft) wide. The stream meandered throughout the valley floor. Although the soil was highly erodible, the stream integrity appeared relatively stable, as a result of gradual slope and vegetation. Substantial flow was observed, but water was very muddy. The riparian area was damaged, however, it contained a few residual snags for future input of large woody debris to the stream. Large woody debris occurred in the floodplain but was marginal within the creek. The gradient, flow, riffle:pool ratio and instream/overhang cover was conducive to good trout habitat. Barriers associated with Plummer Creek include the town of Plummer, culverts, and the sewage treatment facility.

The upper reach of Plummer Creek has been impacted by the city of Plummer. Two sewage ponds and a city storm drain discharged into the stream, indicating a potential water quality problem. Two huge culverts prohibited upstream fish migration past the sewage treatment plant, which were south of the city of Plummer.

3.4.7 Little Plummer Creek

Little Plummer Creek is a tributary to Plummer Creek with gravel mining, agricultural, and grazing land-use practices. Road access was good. Factors conducive to a trout fishery included sufficient spawning gravel, good riffle:pool ratio, streamside cover, stable riparian areas, moderate flow, gradual gradient, and no downstream barriers. Some grazing was noted adjacent to and within the stream channel, causing site-specific erosion and water quality problems. Barriers observed in Little Plummer Creek included culverts and potential log jams.

An out-of-channel culvert located in the upper reach of Little Plummer created a blockage to fish migration.. Numerous other culverts were located in the middle and upper reaches of Little Plummer Creek, possibly causing barriers to fish passage. Potential log jams were also observed.

3.4.8 **Pedee Creek**

In December, Pedee Creek was covered with ice. Maximum length for Pedee Creek was approximately 6.4 kilometers (4.0 mi), and a steep gradient was not acceptable for fish habitat.

3.4.9 Benewah Creek

Land-use practices adjacent to Benewah Creek included agriculture, grazing and logging. Road access to the entire length of the stream appeared excellent. A gradual gradient, adequate stream width and flow, substrate size and **riffle:pool** ratio flavored a fishery in all reaches, except the headwater area. Potential for the installation of fish traps was noted for the majority of Benewah Creek. Damage to the riparian zone was observed occasionally due to logging and grazing, however, it appeared that enough of the riparian zone was left intact to offer shade and erosion control. Large woody debris input to the stream from the riparian area was also noticed. The only barriers observed along the length of the stream included the possibly of improperly graded culverts, and a steep gradient in the headwater region.

A dense stand of alder **was** located near the mouth of the creek; management of the alder grove might enhance the level of water of the slough. Numerous culverts were noted in the upper section of the stream. In the headwater area, a steep gradient and rapids predominated; limited riparian vegetation remained to protect the stream, as a result of grazing.

3.4.10 Cherry Creek

The gradient associated with Cherry Creek appeared steep, and no water was observed in the stream channel during the aerial survey.

3.4.11 Alder Creek

The land adjacent to Alder Creek was heavily forested with no prior evidence of timber harvest. Good road access existed along a portion of the stream; new logging roads suggested future timber harvest. The gradient appeared moderate, and riffles were the predominate habitat type. The streambank and riparian zone were stable and undamaged. The presence of large woody debris and instream/overhang cover was noted. Water quality appeared silt-free and clean. Waterfalls were evident in the middle and upper reaches of the stream. A waterfall located in the middle reach appeared not to prohibit fish passage, however a waterfall located in the upper reach was a possible barrier to fish migration. A steep gradient and step-pool cascades were observed above the upper falls.

3.4.12 John Creek

Land-use practices observed adjacent to John Creek included logging and grazing. Road access existed along the entire length of John Creek. Four to five waterfalls were observed approximately two miles upstream, however whether they posed as barriers to fish migration was undetermined. The gradient, flow, and riffle:pool ratio observed in the middle reach of John Creek appeared conducive to a trout fishery. Large woody debris in the stream channel was sufficient to provide instream cover and pool habitat. The presence of meandering, grass-covered side channels provided potential rearing habitat. The middle reach **was** the limit of fish habitat. In the upper reach, the gradient was relatively steep, and stream banks were unstable. Large instream woody debris suggested potential downstream scouring. Grazing activity was noted within the stream channel.

3.4.13 Little John Creek

The observed flow, substrate, and gradient of Little John Creek was unsuitable for fish habitat.

3.4.14 Hell's Gulch Creek

Agriculture, logging, gravel mining, and timber were the predominate land-use practices adjacent to Hell's Gulch Creek. Logging roads provided access on the south side of creek. The lower reach was affected by agriculture, and no riparian zone remained. The substrate **was** heavily silted, and no gravel **was** visibly evident. Gradient was gradual only temporarily, and then steepened significantly. The middle reach was characterized by logging and gravel mining. Mid-reach gradient was steep with a high **riffle:low** pool ratio. Stream banks were highly erodible and suggested possible water quality problems. Improperly placed culverts and debris jams associated with the culverts were also observed. In the upper reach, heavily forested 2.4-3.0 meter (8-10 ft.) stream banks, located on 30-40 percent slopes, were observed. Water quality appeared clean with large amounts of woody debris located in the floodplain.

3.4.15 O'Gara Bay Creek

A culvert at the mouth of O'Gara Bay Creek prevented any upstream migration of fish. The observed stream flow was minimal with a steep gradient. One side of creek was heavily wooded, and road access was good.

3.4.16 Shingle Bay Creek

The gradient of Shingle Bay Creek appeared steep. The stream disappeared into a grate under the road, and no water was observed in the stream channel.

3.4.17 Black Creek

Agriculture, logging and timber were the land-use practices associated with Black Creek. Stream was accessible by road only in the upper reach. In all reaches, stream width **was** narrow, and flow was limited, which suggested intermittent conditions in summer. Substrate was heavily silted. Although stream banks were stable, riparian areas along most of the creek were degraded. Gradient appeared steep; high **riffle:low** pool ratio was observed.

3.4.18 Willow Creek

Land-use practices adjacent to Willow Creek included agriculture, grazing and logging. Road access was good. The lower reach of Willow Creek had a moderate gradient. Highly erodible stream banks contributed to the meander of the channel and to the poor water quality of the valley. In the upper reach, a steep gradient with riffles was the predominate habitat type. No riparian area remained along the stream, as a result of logging and grazing. Large organic debris was present adjacent to and within the stream channel. Barriers to fish migration were culverts.

3.4.19 Evans Creek

Agriculture was the primary land-use along Evans Creek. Good road access was observed. The lower reach of Evans Creek had unstable banks and meandered throughout the valley floor. A heavily silted substrate was observed. Sufficient flow existed in this portion of the stream to allow a possible migratory corridor for fish, however, it was not conducive to a resident trout fishery. The middle reach of Evans Creek was very short; the gradient, flow, width (15 ft), depth, gravel, woody debris cover and riffle:pool ratio appeared to favor a cutthroat, and possibly a bull trout, fishery. The middle reach was the limit of favorable fish habitat. The upper reach of Evans Creek had a steep gradient, and step pool cascades were the predominant habitat type. Along the entire creek, it was noted that vehicular traffic crossed the stream in numerous places.

3.4.20 St. Joe River

Land-use practices adjacent to the St. Joe River included agriculture, grazing, industrial, logging, mining, recreation, residential, and timber. Road access was good. Although gradient was suitable for fish habitat, water quality was good, and no barriers existed to prevent fish migration, the St. Joe River was eliminated from study during the aerial survey. This decision was made because jurisdictionally the river was located only partially on the Coeur d'Alene Indian Reservation, and the study area was too expansive for the scope of this project.

3.5 RATINGS BASED ON THE RANKING CRITERIA

Results of the ranking system that established the top ten tributaries for further study are listed in Table 3.5. Those tributaries selected as future study sites included: Bellgrove, Fighting, Lake, Squaw, Plummer, Little Plummer, Benewah, Alder, Hell's Gulch, and Evans creek.

The St. Joe River ranked low enough to be included as a study site, however it was eliminated. Jurisdictionally, only a small portion of the river was located on the reservation, and the study area was too extensive for the scope of this project.

Those tributaries located completely on the reservation included: Benewah, Black, Cherry, Cottonwood, Hell's Gulch, Little Plummer, Lake, O'Gara Bay, Pedee, Plummer, Shingle Bay and Squaw creeks. Those tributaries located partially on the reservation included: Alder, Bellgrove, Evans, Fighting, and Willow creeks and the St. Joe River. Those tributaries located completely off the reservation included John and Little John creeks.

Road access was acceptable for all the tributaries in question, except for Black and Lake creeks, which were determined to have limited access.

No barriers were apparent on Black, Evans, Lake and Squaw creeks. Natural barriers existed on Alder, Cherry, Cottonwood Bay, John, Little John and Pedee creeks. The remainder of the tributaries had man-made barriers located on some portion of the stream.

Potential for enhancement was established by identifying the level of habitat degradation apparent from the aerial survey. This parameter rated the biological characteristics that could be determined from the aerial survey, such as observed flow, sediment loads, gradient, and ranked them according to how they met the requirements for cutthroat and bull trout habitat. This was a subjective method, that quantified the available habitat for cutthroat and bull trout and determined if restoration would improve the amount and quality of habitat for each species.

The tributaries that had marginal habitat included: Alder, Benewah, Evans, John, Lake, Little Plummer, Plummer and Squaw

Table 3.5. Summary of selected parameters and ratings used in ranking criteria to establish ten tributaries for further study.

Stream	Location to Reservation	Road Access	Barriers	Potential for Enhancement	Gradient	Total Score	Recommended Streams
Bellgrove	2	1	2	3	1	9	+
Fighting	2	1	2	3	1	9	+
lake	1	2	1	1	1	6	+
Cottonwood Bay	1	1	3	3	3	11	
squaw	1	1	1	1	1	5	+
Plummer	1	1	2	1	1	6	+
Little Plummer	1	1	2	1	1	6	+
Pedee	1	1	3	3	3	11	
Benewah	1	1	2	1	1	6	+
Cherry	1	1	3	3	3	11	-
Alder	2	1	3	1	2	9	+
John	3	1	3	1	3	11	-
Little John	3	1	3	3	3	13	-
Hell's Gulch	1	1	2	3	2	9	+
O'Gara Bay	1	1	2	3	3	10	-
Shingle Bay	1	1	2	3	3	10	-
Black	1	3	1	3	3	11	-
Willow	2	1	2	3	2	10	-
Evans	2	1	1	1	2	7	+
St. Joe River	2	1	1	3	1	8	-

Location:
1. Completely on reservation.
2. Partially on reservation
3. Competely off reservation

Road Access:
1. Good accessibility
2. Limited accessibility
3. Poor accessibility

Barriers:
1. No barriers
2. Man-made barriers
3. Natural barriers

Potential for enhancement:
1. Slightly degraded habitat
2. Good habitat
3. Severely degraded habitat

Gradient:
1. Suitable for fish habitat
2. Questionable for fish habitat
3. Not suitable for fish habitat

creeks. The remainder had severely degraded habitat for cutthroat and bull trout.

Stream gradients that were unsuitable for fish habitat included: Black, Cherry, Cottonwood Bay, John, Little John, O'Gara, Pedee, and Shingle Bay creeks. Questionable gradient for fish habitat was present on Alder, Evans, Hell's Gulch, and Willow creeks. The remainder had adequate gradients to support bull and cutthroat trout habitat.

4.0 DISCUSSION

In determining the ten tributaries for further study, priority was given to those streams under tribal jurisdiction based on geographic location. Those streams located partly on, or completely off the reservation have potential for jurisdictional conflicts or resource allocation problems. Therefore, the most favorable rating was given to those streams that were completely on the reservation. Those streams located completely off the reservation were removed from consideration.

Streams displaying the highest potential for improvement and enhancement were ranked higher than those streams showing severe degradation or no need of improvement.

The most favorable ratings were awarded to streams that had good road access, no barriers to fish migration, and a gradient acceptable to cutthroat and bull trout habitation. The following tributaries were chosen for continued study based on the aerial survey, cutthroat and bull trout habitat requirements and the ranking system discussed above:

Bellgrove Creek was only partially located on the Coeur d'Alene Indian Reservation. The headwaters of the creek fell outside the boundaries of the reservation. Road access along entire stream was good. Prior to the confluence of Bellgrove and Fighting creeks, a solid, concrete embuttment under a bridge was observed that spanned the stream; it appeared to be a blockage to fish migration. Degradation of habitat was due to excessive, cumulative land-use practices along the creek. Heavy recreational- and residential-use was noted in the lower 50 percent of the stream, however most habitat could be restored with public education and cooperation. Primary damage to the stream, (ie., poor water quality, heavily silted substrate and wasting unstable riparian zone) was caused by improper agriculture, grazing and clearcut-logging practices. Streambanks were severely damaged by livestock, and the resulting' erosion created a substantial water quality problem. Miles of streamside fencing and revegetation would be necessary to restore the riparian areas and control erosion. In December, the flow was minimal, which indicated summer flow would be minimal or intermittent. Gradient was moderate for majority of the stream, however, conditions appeared unsuitable for bull trout and was questionable for all age-classes of cutthroat trout.

Fighting Creek was located only partially on the Coeur d'Alene Indian Reservation. Headwaters of creek fell outside of boundaries of the reservation. Road access along entire creek was good. Prior to the confluence of Bellgrove and Fighting creeks, a solid concrete embuttment under a bridge created a possible barrier to fish migration. Similar to Bellgrove Creek, habitat degradation of Fighting Creek resulted from cumulative impacts by recreational, residential, logging, grazing and agricultural land-use practices. Riparian vegetation and stream banks were severely damaged, causing water quality problems and wasting streambanks. The gradients in the lower and middle reaches appeared favorable to trout, however gradient in the upper reach was steep. Gradient, boulders, and rapids in the upper reach were unsuitable for fish.

Lake Creek was located completely within reservation boundaries. Road access to lower reach was poor, while road access to middle and upper reaches was adequate. The lower reach was the longest portion of Lake Creek and was very favorable trout habitat. This section had low human influence, protected riparian vegetation and 50 percent pool habitat above and below high riffle-drift production segments. Since a partially open-canopy above riffle segments of a stream supports a greater abundance of macroinvertebrates, Lake Creek could possibly produce a 40 percent drift production.

In the middle reach, the gradient was moderate, and the channel was braided and pooled by beaver dams in grassy farmland fields. This type of habitat is favored in the summer by adult cutthroat trout and by juveniles when stream edges are protected by grass overhang.

In the middle and upper reaches, farming and grazing to stream edge, loss of streamside vegetation and highly erodible soils have caused water quality problems downstream. Landowner education, fences and biotechnical slope and erosion control techniques in the upper reaches would significantly enhance this stream for fish. If erosion were controlled, lateral habitats of undercut banks and exposed tree roots and gradual-low gradients would provide very favorable rearing habitat for cutthroat, and possibly bull trout. Lake Creek has the potential to support a sizable population of fish, especially if the upstream contribution of agricultural silt were rectified.

Squaw Creek was located within reservation boundaries. Logging roads provided road access along entire creek. The habitat was slightly degraded, therefore, potential for improvement was good. Farming in the headwaters and logging along the banks of the middle and lower reaches posed cumulative, but correctable, water quality problems. In the upper portion of the middle reach, a debris jam appeared to be a barrier to fish migration. The headwaters had been clear-cut. Planting riparian vegetation would help to maintain acceptable downstream temperatures and to provide erosion control.

Parameters favorable to cutthroat and bull trout habitat outweighed areas of concern. Gradient was gradual: gravel deposition and riffle:pool ratio appeared suitable for trout habitat. Large organic debris and logs scattered in the creek from logging provided good summer and winter cover and created resting and rearing pools. Riffle-pool-run ratio showed possibility of enhancement by creating more pools within the run ratio. Hawkins *et. al.* (1982, 1983) found that riffles represent feeding stations to drift feeding trout. Macroinvertebrates are most productive in streams with open-canopy riffles. Evidence of logging, adjacent to at least 30 percent of the riffle areas, indicated that sufficient macroinvertebrate production possibly existed. Riparian vegetation with stable bank integrity in the middle reach protected Squaw Creek from severe degradation that might result from logging and farming practices in the headwaters.

Plummer Creek was also located completely within reservation boundaries. Road access extended to all three reaches. Width and apparent depth of the lower reach appeared favorable for bull and cutthroat trout habitat. In some areas, adequate streamside vegetation and gentle slope of adjacent terrain should have aided in controlling erosion, runoff and water temperature. Water quality problems were evident, however, as indicated by the unstable meander of the stream channel and the brown, sediment-laden color of the water.

The middle reach of Plummer Creek was heavily forested with limited degradation of the riparian management zone. A few residual snags and large woody debris were present for future recruitment of cover, food and rearing areas for fish. A gentle stream gradient, 50/50 riffle:pool ratio, adequate aquatic vegetation and overhang cover appeared conducive to good trout habitat. Substrate, however, could not be observed due to the muddiness of the water from adjacent agriculture. If the point source of pollution could be identified and controlled, this creek would increase as a potential fishery stream.

The upper reach of Plummer Creek was heavily impacted by the city of Plummer; structural barriers to fish migration existed. Two huge culverts prohibited fish migration past the sewage treatment plant, located south of the city of Plummer. Two sewage ponds and a city drain discharged directly into the creek; this caused potential water quality problems not only from toxic substances and nutrient loading, but also from fecal coliform (human waste) and fecal streptococci (animal waste) bacteria. Idaho Department of Health and Welfare - Division of Environmental Quality *et. al. (1990)* reported that the water quality standard for secondary contact recreation (< 800 fecal coliform bacteria/l00 ml sample) was exceeded along the mainstem of Plummer Creek. Waste, leaching into the stream from a hog farm, was the major source of animal bacteria. They concluded that the higher counts of fecal coliform and streptococci bacteria were cause for concern and should be corrected (IDHW *et.* al. 1990). Plummer Creek was not removed from consideration as a favorable trout stream; habitat does exist, if the major water quality problems were identified and corrected.

Little Plummer Creek was located completely within reservation boundaries and was a tributary to Plummer Creek. The lower reach began at the confluence of Plummer Creek and ended at the highway, where an out-of-channel culvert had been placed. Factors favoring trout habitat included: sufficient amount and size of spawning gravel for both cutthroat and bull trout, favorable riffle:pool ratio, adequate overhang cover, protected riparian areas, moderate flow and gradient, and lack of any downstream barriers. Due to all these factors, Little Plummer Creek appeared suitable habitat for bull and cutthroat trout.

The middle reach of Little Plummer Creek began past the highway and was characterized by gravel pits, culverts, agriculture, and streamside grazing. This reach of Little Plummer had severely degraded habitat, however, most factors have the potential to be corrected.

A culvert, located in the upper reach, limited any migration of fish past this barrier. This reach was characterized by several intermittent, type 5 streams that drained through farmlands and grazing areas of highly erodible soil. The upper reach did not eliminate Little Plummer Creek as a potential enhancement stream; cutthroat and bull trout do not need to ascent to the headwaters of a tributary to spawn. Adequate spawning and rearing areas were present downstream.

Benewah Creek was located completely on the Coeur d'Alene Indian Reservation. Road access was good along the entire length of the creek. At the mouth of Benewah Creek, alder trees had overtaken the stream bed. The meandering slough was highly silted and unstable. Proper alder management techniques would provide bank reinforcement, help stabilize the channel, control siltation, and yet allow critical shading to control temperatures in the lower portion of the stream. In all stream reaches, culverts that could limit or prevent upstream fish migration, were areas that possibly needed improvement. In the upper reach of Benewah Creek, instream vehicular traffic was of special concern. Driving within the stream channel is damaging to spawning beds and bank integrity; it has the potential to get petroleum products in the water, which are lethal to aquatic life. Logging and grazing in the riparian management zone of the headwater region had potential for downstream water quality problems; fences, riparian vegetation, erosion control and education are possible restorative measures.

The middle reach was the most substantial reach of this stream. The moderate gradient had the potential for good cutthroat and bull trout habitat. Approximately 19.3 kilometers (12 mi) from the mouth the gradient steepened, favoring fluvial and resident cutthroat populations. Width of stream and gravel-rubble substrate created the possibility of installing temporary fry traps. Instream woody debris and standing snags from selectively logged forest ensured recruitment of cover for future generations of the fishery. Stream width, discharge and velocity, large woody debris, cover, bank stability, riffle:pool ratio, spawning gravel, and shade appeared conducive to both cutthroat and possibly a bull trout fishery.

Approximately 60-65 percent of Alder Creek was located on the Coeur d'Alene Indian Reservation; this included the headwater and middle reaches. Road access was adjacent to the stream. Gradient appeared moderate but slightly steep, since the predominate habitat type was riffles. Although riffles provide limited cover and resting areas for trout, this problem has the potential to be corrected. Natural waterfalls were located in the middle and upper reaches. In the middle reach, the fall appeared small and migration may occur past this barrier. The upper fall was substantial and a possible barrier to fish migration. In terms of enhancement, the middle fall appears feasible to bypass and substantial habitat exists above the barrier; the falls, steep gradient, and step-pool cascades in the upper reach prohibit the establishment of favorable trout habitat.

Factors conducive to trout habitat in Alder Creek included a protected riparian management zone for erosion and temperature control, large organic and woody instream debris for cover, resting pools and feeding stations for all ages of trout, and good water quality with moderate flow.

Hell's Gulch Creek was located completely within reservation boundaries and had good road access. The lower reach of Hell's Gulch had been severely impacted by human alteration. No riparian management zone was left along the creek, offering the stream no thermal protection or sediment buffer. Temperatures in excess of optimal range can interfere with reproduction, embryo development or prevent trout habitation completely. With the absence of riparian vegetation acting as a sediment buffer, rain-on-snow winter thaw, and heavy spring rains flowing over highly erodible soil, could reduce egg survival and macroinvertebrate abundance substantially. No spawning gravel was evident, since the substrate was covered in silt. In the lower reach, large debris jams and numerous culverts posed potential barriers to fish migration.

The middle reach of Hell's Gulch Creek was characterized by a moderately steep gradient and predominantly riffle habitat. Since trout require regularly spaced resting areas within a steep channel gradient, the length of riffle habitat would determine if fish could transverse through this reach or if passage would be prohibited. The . middle reach was also braided with bridges, culverts and debris jams that could pose migrational barriers to fish.

The upper reach of Hell's Gulch Creek was heavily forested with 30-40 percent slopes, which made road access a problem. The upper reach appeared favorable for a population of resident cutthroat. There was ample debris within the channel to create cover, resting pools, and feeding stations. Forest canopy was sufficiently open to enhance the macro-invertebrate population for drift-feeding cutthroat trout. Due to barrier problems in the lower reaches, adfluvial and fluvial cutthroat and bull trout could be prohibited from reaching the upper segment of this stream. Since the above mentioned barriers were all man-made and potentially correctable, restoration that is cumulatively cost-effective would have to be considered for the entire creek.

Evans Creek was located only partially within reservation boundaries. Road access was provided along entire length of creek. One area of concern, which should be addressed, was that roads and vehicular traffic transversed the stream in numerous places throughout the drainage. In the lower reach, heavily silted substrate showed evidence of surrounding agricultural land-use and the resulting erosion. Although the middle reach was very short, all habitat parameters appeared to favor both species of trout. Apperson et. *al.* (1988) reported migratory cutthroat trout production in Evans Creek and documented that Idaho Department of Fish and Game used this stream as a source of broodstock between 1970-l 979. Gradient of the upper reach appeared to prohibit fish migration: however, step-pool cascades in upper reach may possibly have a population of resident headwater cutthroat trout.

The following tributaries were removed from consideration based on results obtained from the aerial survey, cutthroat and bull trout habitat requirements and the ranking system discussed above:

John Creek was eliminated based on the premise that those tributaries located within reservation boundaries received priority. John Creek was located completely off the reservation and, therefore, was eliminated.

Shingle Bay Creek was eliminated because the stream flowed into a grate and disappeared underground. No water was present in the stream channel, and the gradient was very steep.

O'Gara Bay Creek was eliminated because of severely low flow in December. The assumption was made that the stream channel would be dry in summer. A culvert at the mouth of the creek limited any fish migration. The gradient was quite steep and not conducive to trout habitat.

Pedee Creek was located completely within reservation boundaries. The creek was covered with ice in December, suggesting minimal depth and flow in winter and no flow in the summer. Pedee Creek was eliminated from consideration, because steep gradient was not acceptable for fish habitat.

Cherry Creek was located completely within reservation boundaries. During the aerial survey, no flow was observed in December, which suggested intermittent or dry conditions in the summer. Also, a steep gradient was not acceptable for fish habitat.

Cottonwood Bay Creek was located completely within reservation boundaries. Access by road was good. This stream was removed from consideration primarily because gradient was very steep, and mouth had been channelized with concrete. Secondary reasons were that the width was less that 1.5 meters (5 ft), and flow was almost non-existent.

Black Creek was located within reservation boundaries. Although there were no barriers to fish migration, and streambanks and stream channel were stable, Black Creek was removed from consideration. Road access was poor. Stream gradient was steep, and flow was low to intermittent. A silted substrate and poor water quality, in addition to the above conditions, eliminated this creek from further study.

Willow Creek was located only partially within reservation boundaries. Although road access was good, habitat was considered severely degraded. Land-use practices were occurring within channel boundaries; numerous culverts transversed the stream. Grazing, farming and logging on highly erodible soil created an evident water quality problem. Severity of channel slope, velocity of water and high riffle:low pool ratio excluded the possibility of a fishery.

The St. Joe River was also eliminated as a future study site. Study of the river would be beyond the limits of this project, and only a portion of the river was located on the reservation.

Ranking criteria were developed to rate 19 tributaries for potential of westslope cutthroat and bull trout habitat enhancement. Cutthroat and bull trout habitat requirements derived from an extensive literature review of each species, were compared to the physical and biological parameters of each stream observed during the aerial survey. Ten tributaries were selected for further study, using the ranking criteria that were derived. The most favorable ratings were awarded to streams that were located completely on the reservation, displayed highest potential for improvement and enhancement, had no barriers to fish migration, good road access, and a gradient acceptable to cutthroat and bull trout habitation. The ten streams selected for study were Bellgrove, Fighting, Lake, Squaw, Plummer, Little Plummer, Benewah, Alder, Hell’s Gulch, and Evans creeks.

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APPENDIX A

LITERATURE REVIEW

FOR

CUTTHROAT TROUT

APPENDIX A

A.1. Literature Review for Cutthroat Trout

A.I.I. General Information

The historic range of westslope cutthroat trout (*Oncorhynchus clarki lewisi*) included western Montana, a portion of Wyoming and central and northern Idaho. The range extended into Canada throughout the headwaters on the eastern side of the Continental Divide. In Idaho, it is believed that the historic distribution included all of the Kootenai River drainage above barrier falls and all of the Pend Oreille and Spokane river drainages. Westslope cutthroat were present in upper Clearwater drainage, and Salmon River above and including the South Fork. Westslope cutthroat are currently located in Cpeur d'Alene, St. Joe, Salmon, Cleat-water, Kootenai, and Pend Oreille river drainages in Idaho and in the Spokane River above Spokane Falls in Washington (Behnke 1972, 1979; Behnke and Wallace 1979; Trotter 1987; Liknes and Graham 1988; Rieman and Apperson 1989).

Biologist believe that cutthroat moving into headwaters of the Columbia River were isolated by geologic diversions and ice dams: this resulted in distinct differentiation from the other cutthroat. As many as 16 subspecies, with eight major subspecies, are now recognized (Behnke 1979; Trotter 1987; Allendorf and Leary 1988). Available data from electrophoretic studies suggested that westslope cutthroat trout were phenotypically and genetically more similar to rainbow trout and coastal cutthroat, than they were to the Yellowstone, Snake River, Green River and Colorado cutthroat subspecies (Loudenslager and Thorgaard 1979; Behnke 1979; Loudenslager and Gall 1980; Allendorf and Leary 1988). Allendorf and Leary (1988) believe differences were significant enough to consider westslope cutthroat as a separate species.

Westslope cutthroat exhibit three distinct life history forms based on their behavioral patterns (Averett 1962; Averett and McPhee 1971; Bjornn 1975; Thurow and Bjornn 1978; Liknes and Graham 1988; Rieman and Apperson 1989). They are:

1. Resident, which inhabit small headwater streams and do not migrate. Resident populations occur throughout Idaho.

2. Fluvial, which inhabit larger streams and main rivers, and may show extensive migration between rivers, streams and small tributaries. Fluvial populations represent the dominant form and primarily support current fisheries in Idaho.

3. Adfluvial, which inhabit large lakes and migrate to spawn in tributary streams. Adfluvial stocks generally dominate tributaries to lower reaches of the drainage or small streams directly connected to the lake: they rear in tributaries for two to four years and then migrate to a lake to mature.

All three life history forms often occur in one drainage system.

A.I.2. Life History

In Idaho, westslope cutthroat trout deposit eggs into substrate gravel of streams from March to May. Incubation time of eggs and alevins varies inversely with temperature. Alevins remain in the gravel for 13-16 days after hatching and emerge as fry (Scott and Crossman 1979). With different spawning times, fry emergence can begin between April - June; in very cold waters, emergence can be delayed until August (Scott and Crossman 1979).

Cutthroat trout in northern Idaho remain in natal streams for two to four years, then migrate to rivers or lakes to mature. Shepard et. *al.* (1984) determined that juveniles, primarily of age 2+ and age 3+, emigrated throughout summer, but out-migration peaked in early July.

Once sexually mature, these trout return to natal tributaries to spawn. Generally, cutthroat begin maturing in their third year, with all of the population spawning for the first time by the sixth year. Males usually mature one year earlier than females (Brown 1971; Johnston and Mercer 1977; Mauser 1972a, 1988). In Idaho, male cutthroat trout matured at age 3-4+, and females matured at age 4-5+ in the St. Joe River (Rankel 1971) and in Coeur d'Alene Lake (Lukens 1978).

Size at maturity depends on environmental conditions and abundance of available food. Cutthroat trout matured at a smaller size in cold, unproductive headwater streams (Rankel 1971; Behnke and Zarn 1976; Hickman and Raleigh 1982; Rieman and Apperson 1989). Slow growing resident cutthroat matured at a similar age but at a much smaller size than faster growing fluvial and adfluvial stocks in the same drainage (Mauser 1972a, b; Thurow and Bjornn 1978). Rankel (1971) stated that cutthroat trout grew slower in the St. Joe River than other western streams, probably because of the shorter growing season.

Cutthroat may spawn in consecutive, but generally spawn in alternate, years (Calhoun 1944; Scott and Crossman 1979; Liknes and Graham 1988). In Montana, Huston (1972, 1973) documented the contribution of second time spawners to an annual run and found the range varied between 0.7 to 24.0 percent.

Initiation of spawning is dependent upon water temperature, run-off, ice melt, elevation and latitude (Behnke and Zarn 1976). Adfluvial adults moved into tributary streams during high stream flows and spawned as early as February (Behnke 1979; Roscoe 1974) or as late as August in colder areas where temperatures were near 10°C (Scott and Crossman 1979). In lower tributaries to the St. Joe River, Averett (1963) reported that most cutthroat spawned just before or during high water of April and May. In middle and upper tributaries to the St. Joe River, Rankel (1971) found that spawning occurred just before or during high water of May and June.

Spawning populations of cutthroat trout tend to have a higher ratio of females to males. From one Idaho and three Montana streams, sex ratio was 3.4:1 (Huston et. *al.* 1984; Shepard et. *al.* 1984). Lukens (1978) reported females to male ratios ranging from approximately 2:1.3 to 5:1 for six adfluvial populations; females averaged 2.6 per one male. Bjornn (1957) determined that 64 percent of fish examined in creel surveys were females. Huston *et. al.* (1984) found the higher. female:male ratio persisted even in older age classes.

Fecundity and reproductive effort in westslope cutthroat appear similar to other salmonids; number of eggs per female increases with length of fish. In an extensive synopsis of westslope data, Rieman and Apperson (1989) could find no data demonstrating variability nor differences in fecundity between or within stocks.

Documented fecundities for this subspecies ranged from 200 to about 2000 eggs per female (Averett 1962; Johnson 1963; Smith et. al. 1983). Roscoe (1974) found fecundity to be slightly higher for westslope subspecies, ranging from 1000-1500 eggs for females with a mean length of 355 millimeters.

Estimated growth of westslope cutthroat varies considerably. Comparing resident, fluvial and adfluvial populations, growth estimates were highest among adfluvial populations (Lukens 1978; Pratt 1985). Lukens (1978) found as fish migrated from relatively small, unproductive rearing streams to larger, more productive rivers and lakes, growth increased substantially, and size at maturity was larger. Growth of resident fish from headwater streams was slower, and size at maturity was smaller (Thurow and Bjornn 1978).

Limited data exists to estimate natural mortality. Estimates of natural mortality ranged from 30-54 percent for adfluvial and fluvial populations (Bjornn et. *al.* 1977; Apperson et. *al. 1988;* Mauser 1988). Mortality was not documented from resident cutthroat. During early stages of life, Bjornn and Johnson (1977) estimated 95 percent mortality from emergence to age 1+ fingerlings. Depending upon the amount of fine sediment in incubation gravels, Irving and Bjornn (1984) showed that mortality from egg to swim-up fry was 5.0-99.6 percent.

A.1.3 Water Quality

A.l.3.1. Temperature

Average maximal daily water temperatures have a greater effect on trout growth and survival than minimal temperatures. During embryo development, average maximum water temperature range is 3-16°C, with 7-11.5°C as optimum. Highest average temperature range during the warmest period of the year for juvenile to adult is 6-21 °C, with 1 l-l 5.5°C representing optimal conditions (Table A.l). Most authors found that their study streams fell within these ranges (Oien 1957; Binns and Eiserman 1979; Woodward et. *al.* 1989; Graham et. *al.* 1980; Pratt 1984; Scarnecchia and Bergersen 1986; Baltz et. *al.* 1987).

In studies with an incubation temperature of 10°C, eggs hatched in 28-40 days (Snyder and Tanner 1960; Bell 1973) or

TABLE A.I. **Acceptable and optimal habitat conditions for riverine cutthroat using Habitat Suitability Index criteria***

	Range of Habitat Conditions	Optimal Habitat Conditions
Avg maximum water temp (°C) during warmest period of year (fry - adult)	6° - 21°C	11° - 15.5° c
Avg maximum water temp (°C) during embryo development	3° - 16° C	7° - 11.5° c
Avg minimum dissolved oxygen (mg/l) during late growing season, low water period, and during embryo development (embryo - adult)	4.5 - 7.3 (≤15° C) 6.0 - 9.0 (> 15" C)	7.3 9.0
Annual maximal or minimal pH	5.9 - 9.0	6.5 - 8.0
Avg thalweg depth (cm) during late growing season low water period (sw = stream width)	15 - 30 (≤ 5m wide) 30 - 45 (> 5m wide)	30 45
Avg velocity (cm/sec) over spawning areas during embryo development	25 - 75	30 - 65
Percent cover during late growing season, low water periods at depths > 15cm and velocities < 15cm/sec.	3 - 16 (juvenile) 8 - 24 (adult)	16% 24%
Avg sire of substrate (cm) between 0.3 - 8.0cm diameter in spawning areas	0.5 - 7.5	2.0 - 6.0
Percent substrate size class (10-40 cm) used for winter and escape cover by fry and small juveniles	5 - 10	10%
Dominant (≥ 50%) substrate type in riffle-run areas for food production	A - 0	A
A = rubble or small boulders or aquatic vegetation in spring areas dominant with limited amounts of gravel, large boulders or bedrock.		
B = rubble, gravel, boulders and fines occur in approximately equal amounts or gravel is dominant. Aquatic vegetation may or may not be present.		
C = Fines, bedrock, large boulders are dominanl and rubble and gravel insignihcant (< 25%)		
Percent pools during late growing season bw water period (100-%riffles)	10 - 99	35 - 65%
Avg percent vegetation (trees, shrubs. grass-forb) along streambank during summer for allochthonous input. Veg index = 2(% shrubs) + 1.5 (% grasses) +1(%trees) +0 (% bare ground). (For streams ≤50m wide)	75 - 150	150%
Avg percent root vegetation and stable rocky ground cover along the streambank during summer (erosion control)	40-80	80%
Avg annual base how regime during late summer or winter low lbw period as percentage of average annual daily flow	25 -50	50%
Percent lines (< 3mm) in rime-run and in spawning areas during average summer flows	2 - 15 (spawning) 15 - 35 (riffle-run)	2% 15%

	Acceptable Habitat Conditions	Optimal Habitat Conditions
Percent of stream area shaded between 1000 and 1400 hours (≤ 50m wide). Not for use on cold (< 18°C) unproductive streams.	15 - 90	50 - 75%
Pool class rating during late growing season bw flow period. Rating based on percent of area containing pools of 3 classes described below.	A - 0	A
A ≥ 30% of area comprised of lst-class pools. 1st-class pool: large and deep. Pod depth and size sufffcffnt for low velocity resting for several adult trout. >30% pool bottom obscure due to depth, surface turbulence, or presence of structures: e.g. fogs, debris piles, boulders, or overhanging banks and vegetation. Or greatest pool depth is ≥ 1.5 m in streams ≤ 5m wide or ≥ 2m deep in streams > 5m wide.		
B ≥ 10% - < 30% 1st-class pools or ≥ 50% 2nd-class pools		
cc 10% 1st-class pools and < 50% 2nd-class pools		

· From Hickman 8 Raleigh (1982): Persons & Buckley (1984).

required 310 temperature units to hatch (Shepard et. *al.* 1984). Calhoun (1966) reported normal development of embryos at approximately 12°C and increased mortalities below 7°C. For juveniles and adults, Binns and Eiserman (1979) reported a maximum temperature range of 12.6-18.6°C to be optimal cutthroat habitat in summer. Summer temperatures of less than 6°C or greater than 26.4°C were considered inadequate to support viable cutthroat trout populations (Scarnecchia and Bergersen 1982). In studying temperature and microhabitat choices of fish, Baltz et. *al.* (1987) concluded that fish choose microhabitat conditions where the temperature gradient favors maximum growth. Hartman (1965, 1968) and Bustard and Naver (1975a) determined that lowering temperatures below 8°C induced a hiding response; at these temperatures, no fish were found active or more than one meter from cover.

A.I.3.2. Dissolved Oxygen

For all ages of cutthroat trout, the average minimum dissolved oxygen concentrations during late season, low water period are 4.5-7.3 mg/l for water temperatures up to 15°C and 6.0-9-O mg/l in water above 15°C. Optimal concentrations of dissolved oxygen are 7.3 mg/l in water up to 15°C and 9.0 mg/l in water exceeding 15°C (Table A.1). At least 5.0 mg/l of dissolved oxygen is required to maintain favorable conditions for cold water fish (Oien 1957; Trojnar 1972). As temperature increases, dissolved oxygen saturation level decreases, while the dissolved oxygen concentration requirement for fish increases. Doudoroff and Shumway (1970) demonstrated that swimming speed and growth rates for salmonids declined with decreasing dissolved oxygen levels. Lantz (1971) showed no food energy was available for growth until all other functional requirements of fish had been met; optimal dissolved oxygen concentration was a major requirement. Oien (1957) reported that decaying bark and slash following logging removed oxygen from streams, thus impacting microhabitats of embryos, fry, adult fish and aquatic invertebrates.

A.I.3.3. Other Water Quality Parameters

Annual pH range for cutthroat trout is 5.9-9.0, with optimal conditions at 6.5-8.0 pH (Table A.1). Hartman and Gill (1968) sampled 66 streams in British Columbia and reported that those streams containing cutthroat trout had pH values of 6.0-8.8. Similar results were obtained in studies by Platts (1979), Petrosky and Bjornn (1988), Oien (1957), Pratt (1984), Baltz et. *al.* (1987), Scarnecchia and Bergersen (1986), and Binns and Eiserman (1979).

Hartman and Gill (1968) reported that neither pH nor total dissolved solids appeared to have any effect on limiting the distribution of cutthroat trout. Total dissolved solid values ranged from 15-192 mg/l between April and October and 15-95 mg/l from November to March. Platts (1974) analyzed three streams in Idaho and reported total dissolved solid values of 41-63 mg/l. Bjornn (1969) reported values of 298 mg/l for an Idaho drainage, and Binns (1977) studied 13 Wyoming streams containing cutthroat trout and reported 38-544 mg/l total dissolved solids.

Little information was available on total alkalinity and total hardness requirements for cutthroat trout. Total alkalinity values in waters in which cutthroat trout were found ranged from 19-544 mg $CaCO_3$/l (Oien 1957; Binns 1977; Pratt 1984). No optimal range for total alkalinity and hardness has been established for cutthroat trout.

Turbidity is an optical property of water wherein suspended and dissolved materials, such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms, cause light to be scattered and absorbed rather than transmitted in straight lines (APHA *et al.* 1980). Suspended solids facilitate the transport of heavy metals and other pollutants (Lloyd *et. al.* 1987). Low turbidities near IO-26 nephelometric turbidity units (NTU) and suspended concentrations near 35 mg/l have deleterious effects on fish and macroinvertebrates (Olson *et. al.* 1973; Bachman 1984; Berg and Northcote 1985). Bachman (1958) reported that at turbidities above 35 mg/l, cutthroat trout stopped feeding and moved to cover. In Idaho, numerical turbidity standard for protection of fish and wildlife aquatic habitats is 5 NTU/JTU (Jackson turbidity units) above normal (API 1980).

A.I.4. Gradient and Velocity

Streambed gradient affects trout populations by influencing stream velocity. Stream velocity, in turn, affects the quality and quantity of bottom food organisms and has a direct influence on fish populations by restricting and influencing the delivery of oxygen-saturated water. During spawning, cutthroat trout are typically found in small, ephemeral or permanent, first and second order streams with moderate velocities and low to high gradients. Velocities for spawners ranged from 1 l-92 cm/sec (Thompson 1972; Hooper 1973; Hunter 1973). Shepard *et. al.* (1984) reported spawning velocities of 30-40 cm/second.

Average velocities during embryo development range from 20-80 cm/sec, with optimal velocities at 30-65 cm/sec (Hickman and Raleigh 1982; Table A.l). Emergent fry prefer shallower water and slower velocities than other life stages (Miller 1957; Horner and Bjornn 1976). Fry were observed in protected habitats with velocities ranging from O-30 cm/sec, but preferred flows less than 8 cm/sec (Griffith 1972, 1988; Horner and Bjornn 1976; Pratt 1984). Since fry survival decreases with increased velocity above optimum (Buckley and Benson 1962; Drummond and McKinney 1965), lateral habitats, backwaters and covered pools with lower flows are preferred as rearing areas (Griffith 1970, 1988; Hanson 1977; Pratt 1984; Irving 1987; Moore and Gregory 1988 a,b). Moore and Gregory (1988 a,b) studied a headwater stream in Oregon with 8.2-10.0 percent gradient and found population size and survival of young-of-year cutthroat trout to be positively correlated with length of stream edge and area of lateral habitat. After emergence, fry established territories in low velocity (<4 cm/sec), shallow (<20 cm deep) protected stream edges.

In studying habitat utilization by salmonids during low streamflow, Bisson *et. a/.* (1981) reported that age 0+ cutthroat preferred low gradient riffles, but in the company of steelhead or coho, the cutthroat trout were displaced and switched to glides and plunge pools. Bisson *et. al.* (1981, 1988) and Glova (1987) reported underyearling cutthroat use backwater pools of 6.3 cm/sec, 194.0 centimeters deep and glides of 20.3 cm/sec, 11 .O centimeters deep.

Juvenile cutthroat of ages 1+ and 2+ were most often found in water depths of 35-65 centimeters (Cochnauer and Elms-Cockrum 1986). Velocities were 9.1-l 0.3 cm/sec for age 1+ and 13.1-l 5.4 cm/sec for age 2+ fish (Hanson 1977). Griffith (1972) reported focal point velocities for juveniles to be between 1 O-12 cm/sec, with a maximum velocity of 22 cm/sec. Pratt (1984) and Hanson (1977) reported typical facing velocities of 1 O-30 cm/sec for juvenile cutthroat. Bustard and Naver (1975a,b) and Bisson *et. al.* (1988) found age 1+ and age 2+ cutthroat trout to use similar habitats; both age groups preferred 24.3 centimeters deep lateral scour pools of 15.3 cm/sec velocity and 37.8 centimeters deep plunge pools of 16.8 cm/sec velocity with abundant cover.

For resident adult cutthroat trout, distribution appears to occur mainly in higher elevation and lower order reaches, such as headwater and mid-drainage areas (Platts 1974, 1979; Fraley and Graham 1981). Some populations of adfluvial and fluvial fish make seasonal use of entire drainages (i.e., Coeur d'Alene River). Griffith (1970, 1972) found cutthroat in higher stream gradients and reported focal point velocities in Idaho streams of 1 O-14 cm/sec, with maximum velocities between 15.6-29.3 cm/sec. Cowley (1987) studied upper Priest River cutthroat populations and reported gradients from 0.7 percent to greater than 10 percent in upper reaches to contain fish. Oien (1957) found cutthroat inhabiting 2.4-5.2 percent gradients with velocities ranging from 2.8-28.0 cm/sec.

It has been shown that abundance of macroinvertebrates and forage tactics of drift-feeding trout are related to water velocities. Foraging tactics of drift-feeding salmonids favored maximizing energy intake while minimizing the effort of maintaining a feeding position (Wilzbach 1985; Bisson *et. al.* 1988). In terms of channel hydraulics, an individual gained in fitness if it could occupy a site where current velocity was slow but where there was ready access to drifting food, the abundance of which was believed to be proportional to water velocity (Elliot 1967; Wankowski and Thorpe 1979; Wilzbach 1985; Bisson *et. al.* 1988). Griffith (1972) showed resident trout were much smaller and slower growing than the adfluvial and fluvial stocks, owing to lower abundance of prey items, colder water, limited growing season and greater expenditure of energy in higher velocity flows.

There is a definite relationship between annual flow regime and quality of trout habitat. The lowest flows of late summer to winter, or base flows, are the most critical periods. A base flow of greater than 50 percent of average annual daily flow is optimal. A base flow of 25-50 percent is acceptable, but less than 25 percent is unacceptable for quality trout habitat (Table A.l). To predict salmonid standing stock and abundance in streams, Lanka *et. al.* (1987) applied drainage basin geomorphology to trout standing stock. Their data confirmed that a small, gently sloping drainage basin produced the best trout habitat. They showed the combined effects of watershed features, such as basin slope, channel slope (gradient) and a more dendritic drainage pattern (drainage density), tended to decrease response time of discharge from rainfall. With these characteristics, sudden amounts of precipitation decreased surface and groundwater storage and lowered base flows (Viessman et. *al.* 1977). According to Binns and Eiserman (1979) low base flows and high flow variability resulted in poor quality habitat for trout. Conversely, high base flows of greater than 50 percent and low flow variability would result in optimal habitat.

A.I.5. Substrate

Bottom type influences the quantity and quality of macroinvertebrates and is of prime importance in determining the natural production in a stream. In riffle-run areas of food production, optimal substrate consisted of **≥50** percent rubble or small boulders or aquatic vegetation in spring areas (Table A.I). For successful spawning and reproduction, cutthroat trout require an adequate amount and size of clean gravel. The average optimal substrate for spawning areas is 2.0-6.0 centimeters in diameter. Abnormal flood action, scouring and siltation of spawning beds are extremely destructive forces that interfere with the standing stock of the stream. Percent fines of (13 mm) in riffle-run spawning areas during average summer flows were found to optimally be two percent (Hickman and Raleigh 1982; Persons and Buckley 1984).

Griffith (1972) and Pratt (1984) found cutthroat fry to be more consistently associated with gravel-cobble-boulder substrate, and juvenile favored a gravel-rubble-boulder mix (Thurow and Bjornn 1975; Graham *et. al.* 1980; Pratt 1984). For optimal winter and escape cover of fry and juveniles, ten percent of substrate ranged between IO-40 centimeters in diameter (Table A.I). In studies, small fish moved into substrate as temperature dropped below **8°C** (Chapman and Bjornn 1969; Everest 1969; Bustard and Naver **1975a,b;** Bjornn *et. al.* **1977),** and depending upon velocity and ice, subadults burrowed 15-30 centimeters in substrate (Everest 1969). In a prelogging inventory of four streams in northern Idaho, Oien (1957) described preferred substrates for cutthroat trout to be **85-**95 percent rubble (7.6-30.1 cm diameter) and 5-15 percent coarse gravel (2.5-7.6 cm diameter). Pratt (1984) recommended boulders placed on top of sand and pea-sized gravel as favorable substrate that may Increase habitat for cutthroat. Elser (1968) and Lanka *et.* al. (1987) observed that the transition zone between high gradient, boulder-gravel substrate and low gradient, gravel substrate contained the best quality trout habitat.

Habitat changes influence substrate composition in several ways. Fine sediments (cl mm - ≤10mm) have been negatively correlated with embryo survival (Cordone and Kelly 1961; Bjornn 1969; Platts 1974; Crouse *et. al.* 1981; Bjornn *et. a/.* 1977; Irving and Bjornn 1984). Bell (1973) reported that salmonid eggs will suffer mortality of 85 percent, when 15-20 percent of the interstices of the substrate is filled with sediment; the extent of siltation on egg development depended on type of material deposited and time of occurrence. Gibbons and Salo (1973) attributed low embryo survival to decreased gravel permeability and/or entrapment of alevins and fry, decreased oxygen supply to embryos, and accumulation of toxic metabolic wastes. Persons and Buckley (1984) documented only 2-3 percent as allowable fines for developing embryos. Tappel and Bjornn (1983) and Cederholm and Scarlett (1981) found material finer than 0.085 mm to be most detrimental.

Fine sediments reduce carrying capacity of essential pool habitat, eventually eliminating pools (Bjornn *et.* al. 1977). Fines filled interstices of spawning gravel (embeddedness), eliminated winter cover for young fish, and altered production and composition of forage benthos (Irving *et. al.* 1983). Thurow (1987) reported that total densities of trout were inversely related to gravel embeddedness in streams. Movements of fines into the stream environment resulted from logging, mining and agricultural activities, road construction, and mass wasting, following disturbance of unstable soils (Edwards and Burns 1986; Thurow 1987; Krygier and Hall 1971).

A.I.6. Cover

Instream cover is recognized as a critical component of stream habitat affecting trout densities when considered in combination with other habitat variables (Lewis 1967; Binns and Eiserman 1979; Platts 1979; Cardinal 1980; Fraley and Graham 1981). The importance of debris, substrate and undercut banks in providing fish shelter, escape cover and feeding stations is well documented (Chapman 1962; Hynes 1972; Bustard and Naver 1975a; Meham *et. al.*, 1977; Cardinal 1980; Oswood and Barber 1982).

Binns and Eiserman (1979) identified cover as consisting of water depth, surface turbulence, loose substrate, large rocks and other submerged obstructions, undercut banks, aquatic and overhanging terrestrial vegetation, downed snags and other debris lodged in the channel, and anything else that allows trout to avoid the impacts of elements or enemies. Cover and complex habitats, as described above, have been shown to have a significant effect on cutthroat numbers. Boussu (1954) increased density and biomass of trout in stream sections by adding artificial brush cover and found a marked reduction in trout numbers and biomass by experimental removal of cover and undercut banks. Fraley and Graham (1981) found overhang and instream cover to have the best correlation to trout densities. Elliot (1986) reported that the removal of large logging debris from small streams in southeast Alaska caused initial reductions of larger Dolly Varden and cutthroat trout; lower numbers resulted from habitat loss and the loss of smaller fish during subsequent November freshets. He determined that the amount of instream cover per acre was about 80 percent greater in unaltered sections, and trout abundance varied directly with the amount of cover. Lider (1985) associated the percentage of large woody debris in pools, such as root wads and logs, with the highest cutthroat densities. In studying factors that limit westslope cutthroat trout production in the Coeur d'Alene, St. Joe and St. Maries river systems, Horton and Mahan (1988) observed a direct relationship between cover components, particularly large organic debris, and high fish densities. They found that when pools or runs included large organic cover, these areas had more fish than areas where cover was absent or was provided by boulders, depth or overhanging vegetation. Horton and Mahan (1988) concluded that proper management, which included establishing organic material as cover for fish, was critical to reversing the decline in trout numbers and was essential in restoring Idaho drainage tributaries to higher production levels. Other studies have shown increased trout densities associated with the presence of organic material in stream as cover for fish (White and Brynildson 1967; Chapman and Bjornn 1969; Lestelle and Cederholm 1973; Bryant 1980; Wilzbach and Hall 1985).

Standing crop of cutthroat trout is correlated to the amount of useable cover present in a river or stream. Pools, depth and surface turbulence are forms of habitat cover. Streams that provided 30 percent or greater first-class pools were considered optimum for cutthroat trout (Hunt 1971; Horner and Bjornn 1976; Table A.l). Pool depth and size were, therefore, sufficient for low velocity resting of several adult trout (Lewis 1969; Raleigh *et. a/.* 1983). First-class pools were characterized as large and deep; depth varied depending on stream width (Hickman and Raleigh 1982). More than 30 percent of the bottom of a first-class pool is obscure due to depth, turbulence or structures, such as logs, debris piles, boulders or overhanging banks and vegetation. In areas where overhead cover was marginal, Hanson (1977) found cover for cutthroat trout to be provided by substrate, depth and surface breaks. During late season, low water periods, Boussu (1954) and Lewis (1969) reported that juvenile cutthroat trout required 3-16 percent usable pool cover in the form of depth, turbulence or instream structures, and adults required 8-24 percent; useable cover was associated with water at least 15 centimeters deep and less than 15 cm/sec velocity.

There are two types of cover that limit trout densities -- summer and winter cover. The main use of instream summer cover, as described above, is probably for predator avoidance, resting and feeding stations (Hickman and Raleigh 1982; Boussu 1954). In winter, however, fish inhabit near freezing water temperatures and have lower metabolism, reduced food requirements and less available energy (Reimers 1957; Hartman and Gill 1968), and the resultant hiding response is probably a means of avoiding predation, mass ice movement and flooding, and reducing downstream displacement during freshets to conserve energy (Hartman 1965; Everest 1969; Chapman and Bjornn 1969; Bustard and Naver 1975a). In winter, cutthroat occupied different habitat areas than in summer, and the availability of winter habitat had a strong influence on seasonal movements of westslope cutthroat trout (Bjornn and Liknes 1986; Liknes and Graham 1988; Rieman and Apperson 1989). Large autumn movements out of tributary streams with poor winter cover into larger streams with good boulder, debris and log cover or overhanging bank cover have been described by Hartman (1965), Chapman and Bjornn (1969), Bjornn (1971) and Bustard and Naver (1975a,b). Cutthroat trout were found under boulders, log jams, root wads and debris when temperatures dropped to 4°-8°C, depending on velocity (Chapman and Bjornn 1969; Bustard and Naver 1975a). Extensive migrations resulted where high quality pools were found downstream of spawning and rearing habitat (Bjornn and Liknes 1986; Liknes and Graham 1988; Peters 1988). Lewis (1969) reported cutthroat moved to deeper, first-class pools in winter. Wilson *et. al.* (1987) and Peters (1988) found large aggregations of adult and subadult cutthroat trout in pools during winter; trout densities were strongly and positively associated with pool quality (defined width, depth and escape cover) and low to negative velocities. Bjornn (1971) indicated that downstream movement did not occur if sufficient cover was locally accessible. Peters (1988) observed that cutthroat reside the entire year in reaches where both summer habitat and high quality pools are found together. Bustard and Naver (1975a,b) and Cunjak and Power (1987) reported that proximity to suitable cover areas appeared to be critical and few fish were found more than one meter from potential cover.

Gravel substrates are especially important for overwintering juvenile cutthroat trout. As winter approached and temperatures dropped, fry moved into rubble (IO-40 cm diameter) as principal cover (Hartman 1965; Everest 1969; Chapman and Bjornn 1969; Rankel 1971; Thurow and Bjornn 1975; Bjornn *et. a/.* 1977; Hanson 1977; Wilson *et. a/.* 1987), and moved in and out daily, relative to temperature (Chapman and Bjornn 1969). .Bustard and Naver (1975a) reported that substrate shifting and increase in mortality resulted when fry used smaller diameter substrate winter cover. While examining the declining cutthroat population in the St. Joe River, Rankel (1971) observed no cutthroat once temperatures dropped below 6°C in October and attributed their disappearance to downstream migration in search of cover and/or movement into rocky substrate for duration of winter. Hanson (1977) documented cutthroat entering the substrate as winter approached and water temperature dropped below 8°C. Bustard and Naver (1975a,b) and Hartman (1965) determined that juvenile cutthroat selected substrate for escape and winter cover that optimally contained ten percent, 1 O-40 centimeter diameter gravel.

Winter mortality among stream salmonids can be substantial for both young (Lindroth 1965) and older fish (Whitworth and Strange 1983; Cunjak and Power 1987). Stream management programs designed to improve species' winter habitat ultimately can increase survival (Cunjak and Power 1987; Hunt 1969; Rieman and Apperson 1989).

Survival during the period following emergence has the greatest influence on population density of cutthroat fry and is related to the amount of immediately available cover (Griffith 1972; Pratt 1984; Elliot 1985; Moore and Gregory 1988a,b). Moore and Gregory (1988 a,b) studied a headwater stream with 8.2-10.0 percent gradient and found population size and survival of young-of-year cutthroat trout to be positively correlated with length of stream edge and area of lateral habitat. They found that after emergence, fry established territories in low velocity (<4 cm/sec), shallow (<20 cm deep), protected stream edges, backwaters and pools; fry remained there for at least six weeks. They determined total biomass and abundance of age 0+ cutthroat increased 2.2 times with a 2.4 increase in lateral habitat area. By end of summer, some age 0+ fish moved laterally in direction of adjacent midchannel pools and riffles. By increasing the area of lateral habitats, Moore and Gregory (1988a, b) provided more territory for resident fish and reduced downstream displacement and emigration. Pratt (1984) and Griffith (1970, 1972) found young cutthroat fry to be consistently associated with cover, in the form of gravel-cobble-boulder mix substrate (34%), shade overhang (24%), fine debris (24%), and woody debris (17%), along pool edges and in habitat units less than $200m^2$ or $100m^3$. They also determined that cutthroat used faster, deeper water as they grew larger, and ventured farther from escape cover as they aged and grew stronger. As winter approached and water temperatures dropped, fry used rubble of IO-40 centimeters in diameter as principal cover (Hartman 1965; Chapman and Bjornn 1969; Rankel 1971; Thurow and Bjornn 1975; Bustard and Naver 1975a,b; Hanson 1977).

Lateral habitats are sensitive areas, vulnerable to natural degradation and man's influence (e.g. logging, grazing, road construction). Enhancement efforts focused on development of spawning areas and midchannel pools may be insufficient to achieve desired objectives, if lateral rearing, areas are not abundant.

Juvenile cutthroat of age 1+ and age 2+ were most often found associated with gravel-rubble-boulder substrate (Thurow and Bjornn 1975; Graham *et. al.* 1980; Pratt 1984). In small streams, larger fish occupied stream areas with larger substrate and deeper water, generally in pools (Griffith 1972; Hanson 1977). Bisson *et. al.* (1981, 1988) and Glova (1987) reported underyearling cutthroat (age 0+) use backwater pools (6.3 cm/sec, 19.4 cm deep) and glides (20.3 cm/sec, 11 .O cm deep). Age 1+ and age 2+ cutthroat used similar habitats, both age groups preferring lateral scour (15.3 cm/sec, 24.3 cm deep) and plunge (16.8 cm/sec, 37.8 cm deep) pools with abundant cover, instead of tench pools where cover was infrequent (Bustard and Naver 1975a,b; Bisson *et. al.* 1988). In studying winter cutthroat cover, Bustard and Naver (1975a) showed winter habitat is different for juveniles than summer cover. Log jams and rubble were important winter cover, as opposed to summer hiding cover of root wads, logs, debris piles, small boulders and overhanging vegetation.

Woody debris is a major component in the development of cover and pools for westslope cutthroat trout habitat (Pratt **1984a,** Lider 1985; Gamblin 1988). Removal of riparian timber has severely limited or eliminated the recruitment of large organic debris to the watershed. As old debris decomposes, is lost, and is not replenished to the system, pools and cover are lost. Large organic debris played an important role in stream stability, habitat complexity, **bedload** storage, rearing habitat protection, and macroinvertebrate densities (Bisson and Sedell 1982; Gamblin 1988).

Canopy cover and streamside vegetation are important in providing temperature control, contributing to the energy budget and allochthonous input to the stream, controlling watershed erosion, and maintaining streambank integrity (Idyll 1942; Chapman 1966; White and Brynildson 1967; Brown 1971; Lantz 1971; Hunt 1975; Moore and Gregory **1988a,** b). Too much shade can restrict primary productivity of a stream; stream temperatures can be increased or decreased by controlling the amount of shade. Hawkins et. *al.* (1982) and Martin *et. al.* (1981) demonstrated that 50-75 percent of midday (1000-I 400 hours) shade was optimal for most cutthroat streams. They showed that shading became less important as gradient and size of stream increased. For stream widths less than 50 meters, a vegetative index was computed that approximated the percentage of vegetation needed for optimal deposition of allochthonous material to the stream annually (Chapman 1966; Hunt 1975). For cutthroat trout habitat, 150 percent vegetation along stream during summer was optimal for the annual energy input of allochthonous materials, with a range of 75-I 00 percent as acceptable habitat (Idyll 1942; Chapman 1966; Hunt 1975; Table A.l). Because trout sheltering and feeding characteristics of natural channels were enhanced by low streamside plants that drape into the water, shrubs are the major contributor to computation of the vegetation index. Also, a well vegetated riparian zone helps control watershed erosion and the presence of fines in substrate. A streamside buffer of approximately 33 meters, of which 80 percent is either well-rooted and vegetated or has stable rocky streambanks, will maintain adequate erosion control and maintain undercut streambanks characteristic of favorable trout habitat (Raleigh and Duff 1981).

Studies by Brown (1970, 1971) and White and Brynildson (1967) showed removal of forest canopy allowed temperature increases and encouraged elevated algae growth. Both of these events had the potential to increase fish production, except when thermal change and algae accumulation became excessive; at this point, production was reduced (Bisson and Davis 1976). Explanation for increased carrying capacity of stream following controlled removal of riparian overstory was confirmed by Hall and Lantz (1969), Lantz (1971), Murphy *et. al.* (1981), Weber (1981), Hawkins *et. al.* (1982); their studies found higher densities of benthic macroinvertebrates in open-canopied streams. By contrast, in less heavily wooded areas where winter icing and high summer water temperatures may be the principal factors limiting cutthroat trout populations and determining overall carrying capacities, Platts and Nelson (1989) showed increased canopy cover may be beneficial to trout production. Under these conditions, cutthroat abundance was more dependent more upon stream canopy influence on water temperature extremes than on its influence on instream primary productivity (Platts and Nelson 1989). Consequently, favorable management policies should combine the benefits of a regulated riparian canopy with maintenance of adequate pools and instream cover, thus sustaining moderate instream temperatures, with the goal of enhancing all species and age-classes of fish.

A.1.7. **Diet**

Cutthroat trout are very opportunistic (Oien 1957; Griffith 1970; Rankel 1971; Schutz and Northcote 1972; Everest and Chapman 1972; Hanson 1977; Wilzbach 1985; Liknes and Graham 1988), and their diet consists mainly of aquatic insects. In studying four trout streams in northern Idaho, Oien (1 957) found that Diptera (particularly Tipulidae), Trichoptera, Plecoptera and Ephemeroptera (in decreasing order of importance) were the four principal orders of aquatic insects consumed. In studying cutthroat and brook trout interactions, Griffith (1970) found cutthroat diets averaged 92 percent (75-100%) drift organisms, and Diptera was very strongly preferred. Shepard *et. al.* (1984) documented Diptera and Ephemeroptera as the most important dietary components for cutthroat trout; Trichoptera was an important constituent for fish 110mm and larger. As fish grew larger, diversity of food items increased and included terrestrial insects and sometimes small fish (Liknes and Graham 1988; Shepard *et. a/.* 1984; Hanson 1977; Hickman 1977; Rankel 1971; Carlander 1969; McAfee 1966). In a few studies, zooplankton was locally or seasonally important (Carlander 1969; McAfee 1966; Jeppson and Platts 1959).

Since headwater streams are relatively unproductive and cutthroat trout specialize as invertebrate feeders, a large portion of the energy input to lower order streams is allochthonous insects (Chapman 1966; Harrell and Dorris 1968; Wilzbach and Hall 1985; Liknes and Graham 1988); these are especially important to fish greater than 110 millimeters in length (Shepard *et. al.* 1984). Fish less than 110 millimeters prefer a diet of larger zooplankton and smaller aquatic insects (Jeppson and Platts 1959). Studies have shown that the optimum substrate in riffle-run areas for the greatest abundance and diversity in macroinvertebrate populations consisted of a greater than 50 percent mixture of rubble or small boulders or aquatic vegetation in spring areas, with limited amounts of gravel, large boulders or bedrock (Pennack and Van Gerpen 1947; Hynes 1970; Hanson 1977; Binns and Eiserman 1979; Murphy *et. al.* 1981; Table A.l). Although macroinvertebrate biomass was greater and more diverse in riffle areas than in pools, a 1 :1 ratio of pools to riffle habitat provided an optimal proportion of rearing and food producing areas (Hynes 1970; Raleigh *et. al.* 1983; Rieman and Apperson 1989). Lere (1982) found westslope cutthroat trout densities were correlated to pool-riffle periodicity. Studies have shown that in riffle-run areas, the presence of more than ten percent fines reduced standing crop of forage organisms significantly (Cordone and Kelly 1961; Bjornn 1969; Platts 1974; Crouse *et. al.* 1981).

APPENDIX B

LITERATURE REVIEW

FOR

BULL TROUT

APPENDIX B

B.I Literature Review for Bull Trout

B.I.I. General Information

Bull trout (*Salvelinus confluentus*) were historically considered to have originated in the Columbia River basin. Historical distribution of bull trout existed between 41-60 degrees north latitude and was distributed on both sides of the continental divide. Bull trout and Dolly Varden have been identified as different species based on morphometric, meristic and osteological characteristics (Cavender 1978). Three life history patterns are known to occur:

1. Resident, which do not migrate, are normally isolated by a physical barrier, and occupy headwater streams. Resident bull trout are smaller, have lower fecundity, and mature at an earlier age than other stocks of bull trout. They may retain juvenile parr marks (Scott and Crossman 1979).

2. Fluvial, which are associated with rivers and larger streams. Juveniles may remain in nursery stream up to six years before migrating to the river. Fluvial bull trout will spend two or three years in the river before migrating back to the nursery stream to spawn.

3. Adfluvial, which are found in lakes and reservoirs associated with larger tributaries. Juveniles remain in the nursery stream for one to six years before migrating to the lake. They spend approximately two to three years in the lake before returning to the nursery stream to spawn.

Dam construction and habitat degradation, due to logging, agricultural practices, grazing and mining, have influenced bull trout populations in the Pacific northwest.

B.1.2 Life History

The life life history of bull trout can be categorized by advanced age of maturity, increased size, alternate year spawning, extensive migrations, and separation of juvenile and adult populations (McCart 1985). Bull trout mature at age 6-7+ but may mature as early as age 4+ (Fraley and Shepard 1989). Bull trout matured at age 5-6+ in the Swan River system (Leathe and Enk 1985); bull trout on the upper Clark Fork River reached maturity between age 4-7+ (Heimer 1965; Pratt 1985). Length at maturity ranged from 171 millimeters for resident populations of bull trout in Sun Creek, Oregon, to 690 millimeters for an adfluvial population in the Upper Flathead River, Montana. In studying Flathead Lake bull trout, Hanzel (1985) found that adfluvial juveniles emigrated at ages 2-3+ at 102-175 millimeters. Growth rate in the lake increased until age 4+, and then remained constant. Average incremental growth was 70 millimeters (60-132 mm) annually; 450 millimeters delineated the change from subadult to adult in Flathead Lake (Hanzel 1985, Cross 1985).

Spawning usually occurs between September and October, but has been observed as early as July. Bull trout enter tributaries approximately one month prior to spawning (Leggett 1969; McPhail and Murray 1979; Ratliff 1987; Fraley and Shepard 1989). Upstream migration has been found to coincide with maximum water temperatures (IO-12°C) and minimum flows in 0.76-0.80 meter deep water (McPhail and Murray 1979). For the Flathead River basin, timing of spawning migration occurred as follows (Shepard 1985; Carl 1985):

1. Migrate from lake	April-May
2. Arrive at tributaries	mid July - late August
3. Enter tributaries	early August - late September (two hours after dusk)
4. Spawn	early September - late October
5. Leave tributaries	mid September - end October
6. Return to lake	October-November

Initiation of spawning appears to be related to declining water temperatures, photoperiod and possibly stream flow.

In Flathead River tributaries, Montana and in upper Arrow Lakes, British Columbia, spawning began when water temperature fell below 9°C (McPhail and Murray 1979; Weaver and White 1985). Wydoski and Whiting (1979) reported that spawning occurred when water temperatures reached 5 to 6°C in Washington. Most spawning activity occurs at night (Heimer 1965; Weaver and White 1985). Bull trout pairs remain over the nest for up to six days (Aquatico 1976). Oliver (1979) noted females moved downstream soon after spawning was completed, but males remained late into the fall.

Fertilization rate was estimated to be approximately 90 percent (Enk 1985). Fecundity (# eggs/female) for bull trout is lower than or equal to other charrs of comparable size; 610 millimeter fish averaged 5050 eggs. Egg retention was 2-5 percent (Hanzel 1985; Fidler 1985). From numerous studies, distribution of sex ratio averaged 1 .1 females per male (Shepard 1985; Carl 1985). In the Flathead River system, there was an average of 3.2 spawners per redd (Fraley 1985).

Incubation continues through winter months, with peak hatch occurring by mid-January. In tributaries to North Fork Flathead, peak emergence of fry took place by 1 May (MacDonald and Fidler 1985). After one to three years of rearing in tributary streams, bull trout smolts migrated in late September to Flathead Lake.

Most fluvial and adfluvial young remain in nursery, streams for one to six years (Allan 1980). Juveniles in most river systems migrated at 2 to 3 years of age (McPhail and Murray 1979; Oliver 1979; Fraley and Shepard 1989). Time of migration varies depending upon age and size of fish, and amount of available habitat. Migration was observed as early as May and as late as October (Pratt 1985; Aquatico 1976). In the spring, downstream migration occurred to areas where water velocities were lower (McPhail and Murray 1979; Oliver 1979; Allan 1980).

Occasionally upstream migrations have been observed for juvenile bull trout. Fraley and Shepard (1988) observed juvenile bull trout migrating to upper reaches of the stream to rear. These fish were concentrated in spring areas where temperatures did not exceed 15°C, and adult bull trout were absent from the stream reach.

B.1.3 Water Quality

B.1.3.1 Temperature

All life history stages of bull trout are strongly influenced by temperature. They are seldom associated with tributaries where summer temperatures exceed 15°C and are normally associated with cold perennial springs (Allan 1980; Shepard *et. al.* 1984) or groundwater influence (Shepard 1985), and a closed-forest canopy (Pratt 1985).

Spawning migration coincides with water temperatures around 1 O-l 2°C. During embryo development, optimal incubation temperature range is 2-4°C (McPhail and Murray 1979; Brown 1985; Carl 1985). Highest average temperature range during warmest period of year for fry and juvenile bull trout is 5-15°C, with optimum range of 5-8°C for fry and 5-12°C for juveniles (Pratt 1985; Carl 1985: Ratliff 1988; Fraley and Shepard 1989). For resident and fluvial adult bull trout, the average maximum temperature range is 9-l 5°C, with 9-10°C as optimum (Moyle 1976; Shepard 1985; Skeesick 1988). Adfluvial adults prefer 7.2-14.0°C temperatures; 8.0-l 2.8°C range is optimum (Bjornn 1961; Shepard 1985).

In studies of bull trout culture in British Columbia, Brown (1985) found water temperature to be a major factor in incubation success. During egg development, groundwater supply, which was normally 7-8°C, was chilled to about 4°C for best survival. Conversely, it has been found by most authors, as water temperatures increased, size and survival of eggs and alevins decreased (McPhail and Murray 1979; Brown 1985; Weaver and White 1985). Water temperatures of 8-20°C were found to produce the smallest alevins with the highest mortality rate of 80-100 percent (McPhail and Murray 1979).

For rearing fry, water temperature was increased to 7-8°C in bull trout studies by Carl (1985). Brown (1985) reared fry in 7-8°C for 4-6 weeks, following alevin stage.

Juvenile bull trout can tolerate slightly warmer temperatures, which may vary from 7-12°C. Brown (1985) raised juveniles in 7-11 °C water, but rarely exceeded 12°C, because disease problems were more acute above this temperature. In the Metolius drainage of the Deschutes River in Oregon, juveniles occupied only groundwater-fed tributaries where summer temperatures seldom exceeded 10°C (Ratliff 1988). Similarly, in the Flathead River system in Montana, juveniles were not observed in waters above 15°C (Fraley and Shepard 1989; Fraley *et. al.* 1989). Most authors agreed that water temperatures influenced the distribution of bull trout juveniles and that they grew slowly, as a result of the cold water temperature and low-productivity of nursery streams (Oliver 1979; Allan 1980; Pratt 1984, 1985; Slaney and Martin 1985).

Adult bull trout show a preference for cold water rivers, lakes and reservoirs (Moyle 1976). Summer water temperatures for resident bull trout ranged from 9-15°C in the upper Klamath River (Bond and Long 1979). In upper reaches of the John Day River, bull trout were not observed in waters that exceeded 10°C (Skeesick 1989).

Adfluvial bull trout in Priest Lake, Idaho were reported to occupy the lower thermocline in summer, where temperatures ranged from 7.2-l 2.8°C. In spring and fall, the bull trout moved to near surface waters when temperatures were below 12.8°C (Bjornn 1961). In Libby Reservoir, Montana, adults preferred the water stratum of 8-14°C (Shepard 1985).

B.1.3.2 Other Water Quality Parameters

No conclusive information exists on chemical parameters, such as dissolved oxygen, pH, alkalinity and hardness, total dissolved solids or turbidity.

B.1.4. Substrate

According to Fraley and Shepard (1989) unembedded gravel substrates with low compaction and low gradients were selected as bull trout spawning sites. Substrate composition for the highest redd frequency in the Flathead River tributaries of Montana was gravel-cobble (62%) and boulder (10%) composition (Fraley and Shepard 1989; Graham *et. al.* 1981; Shepard 1985).

If gravel-cobble-boulder substrates contained fines of 6.35 millimeters or less in size at time of redd construction, Weaver (1985) found that higher egg mortality resulted.

Fraley and Graham (1981) found that stream sections of 23 percent cobble and 60 percent gravel contained the highest bull trout densities. Gravel-cobble-boulder substrates are often associated with changes in substrate and geological material. These changes ultimately result in braided, sinuous and/or multiple stream channels, that are sites for groundwater inflections. These inflections result in tributary recharge, which favor bull trout habitation.

Substrate is a critical parameter for bull trout egg and alevin survival. The amount of fine material (<9.5 mm) in the substrate will effect emergence success (Weaver and White 1985). Shepard *et. al.* (1984) found that mortality increased sharply, if the substrate was composed of 30 percent or more fines (≤ 6.35 mm); no survival was recorded at 50 percent fines. Weaver and White (1985) found that even a substrate composition of 44 percent fine material resulted in no emergence.

Oliver (1979, 1985) observed that young fry showed a preference for sand and gravel, whereas highest density of juveniles was found in stream segments dominated by rubble-boulder bed material. Studies by Pratt (1985) showed that juveniles require clean unembedded, stacked rubble-cobble substrate with large interstitial spaces between particles. In assessing the effects of forest and hydropower development in the Swan River drainage in Montana, Enk (1985) showed that densities of juvenile and adult fluvial bull trout in 26 reaches were significantly correlated to substrate quality, as measured by percent fines less that 6.4 millimeters. In modeling the effects of forest sediment on bull trout density, Enk (1985) found losses of potential bull trout production to be 4-12 percent due to road development.

Adult bull trout are bottom dwellers, preferring deep pools of cold water with boulder-rubble substrate (Allan 1980; MacDonald and Fidler 1985), which ensures good winter survival (Carl 1985).

B.1.5 Velocity and Gradient

Low channel gradient has been significantly correlated with high redd frequency of bull trout; frequency is highest where gradient is less than three percent (Fraley and Graham 1981; Graham *et. al.* 1981; Shepard 1985; Fraley and Shepard 1989). Most authors agreed that spawners most often selected areas in stream channel characterized by low gradient, generally in high order streams with groundwater influence (Fraley and Graham 1981; Graham *et. al.* 1981; Shepard 1985; Weaver 1985; Carl 1985: Oliver 1985; Fraley and Shepard 1989). Graham *et. al.* (1981) found that bull trout spawned immediately downstream of a high-low gradient interface.

Juveniles distribute themselves along the stream bottom, seeking low velocities (10 cm/sec) in association with submerged cover (Brown 1985; Pratt 1985; Fraley 1985). Pratt (1985) found that water depth was not as important as wetted surface area, because increasing water volume and velocity did not necessarily increase rearing capacity for juveniles. Optimal water velocities were found only in small pockets, therefore describing mean velocities by conventional methods did not provide velocity information on available rearing habitat (Pratt 1985). In discussing early rearing of juveniles, Pratt (1985) and Fraley (1985) agreed that extremely high flows may reduce survival rates by pushing fry out of tributaries and into mainstem, where predation rates maybe higher. On the other extreme, Pratt (1985) and Fraley (1985) agreed that low flows reduce wetted area and, therefore, reduce the amount of space available for rearing fry and juveniles.

Adult bull trout inhabit streams with IO-20 percent gradients and moderate to fast currents (Bond and Long 1979).

Variable velocities were reported in the literature for bull trout. Carl (1985) found that bull trout in Alberta, British Columbia preferred unstable, cold and unproductive streams, even though such streams were vulnerable to habitat degradation, erosion, occasional flooding and low winter flow. Adults spawned in groundwater fed streams; advantaged to these streams were warmer winter temperatures, stable winter velocities, low sediment loads and lack of winter anchor ice. The large size of female spawners allowed deeper placement of eggs. This increased chances of egg survival in fast-flowing streams, where spring flooding may scour smaller gravel on river bottom or where low flows in winter may leave redds, that were dug along stream edge, stranded (Carl 1985; Weaver 1985; Enk 1985). Weaver (1985) reported that low flow and stranding accounted for 25-30 percent loss of production in some Flathead River tributaries in Montana. Oliver (1985) found that females selected redd sites in shallow depths, characteristic of low surface velocities, within an average of 2.5 meters of the streambank.

B.1.6. Cover

Upon emergence, bull trout fry migrate to low-velocity areas that are separated from adults, such as side channels, back waters, lateral stream margins, and pools (McPhail and Murray 1979; Allan 1980; Fraley and Graham 1981; Shepard 1985; Pratt 1985; Elliot 1986; Skeesick 1989; Fraley and Shepard 1989).

Most authors have found that juveniles, also, relied on gravel-cobble-rubble substrate for cover and resting areas (McPhail and Murray 1970; Allan 1980; Fraley and Graham 1981; Shepard 1985; Pratt 1985; Elliot 1986; Heifetz *et. al.* 1986; Skeesick 1989; Fraley and Shepard 1989). Pratt (1985) reported that bull trout fry (cl00 mm) remained near bottom, close to streambed materials and submerged debris, or burrowed into interstices of unembedded substrate cobble. Juveniles (>100 mm) remained near large instream debris and cover. Pratt (1984, 1985) discovered that woody debris used by bull trout for cover can be a single piece of submerged debris along stream margins or a large jam of unconsolidated woody debris; flow should go through the debris jam or root wad, not necessarily over it into a plunge pool. Streams can be manipulated to enhance rearing capacity for juvenile bull trout (40-200 mm). Submerged cover (<0.2 m) along the stream bottoms in the Flathead River basin, Montana created slow (0.1 mps) water and increased rearing and small pockets of hiding capacity of tributaries (Pratt 1985). Skeesick (1989) found that juveniles were very territorial and became quite aggressive under high fry densities. In a study conducted by Elliott (1986), cover resulted in visual isolation of juveniles; aggressiveness was decreased, and smaller habitat spaces were occupied. As bull trout increased in size, Pratt (1984, 1985) found that juveniles became less dependent upon instream cover.

Adult spawners depend upon closed forest-canopy shade and overhanging banks and vegetation as cover. Shepard (1985) found generally that higher redd frequency was associated with this type of cover. · Skeesick (1988) reported that adults used woody debris and overhanging banks for shelter, during upstream migration and while waiting to spawn. These areas are characterized by low velocity and shallow depths (<50 mm). Resident and fluvial adults require large deep pools for cover in summer **and winter (Carl 1985).** Adfluvial bull trout in lakes utilize depth as cover. Hanzel (1 985) netted bull trout at depths of 284 meters (260 ft) and believed that they existed at 394 meters (360 ft); sampling was performed in spring, during isothermal conditions of lake.

B.1.7 Diet

Bull trout are voracious predators and have been noted to be opportunistic and adaptive in feeding habits (Boag 1987).

Bull trout larvae remain in gravel until yolk sac absorption is nearly complete (MacDonald and Fidler 1985). Bull trout begin feeding at emergence and select aquatic insects from the entire water column (McPhail and Murray 1979; Balon 1984).

Bull trout fry (<100 mm) feed exclusively on aquatic insects (Shepard *et. al.* 1984; Carl 1985; Pratt 1984, 1985), however, salmon eggs are important components of juvenile diets in the fall (Skeesick 1988). When juveniles reach 11 O-140 millimeters, they become increasingly piscivorous, however some overlap in size exists (Shepard *et. al.* 1984; Carl 1985; Hanzel 1985). Growth and condition improve after bull trout begin feeding on fish (Carl 1985), Jeppson and Platts (1959) observed that 100-300 millimeter trout consumed only insects. Hanzel (1985) reported that subadults (<300 mm) ate primarily sculpins, whitefish, kokanee, and incidentally consumed yellow perch, squawfish, peamouth chubs and suckers, and Mysis shrimp, if opportunely available (Fraley and Shepard 1988).

When bull trout reach 400 millimeters, consumption is primarily fish and insects. Adult resident bull trout fed almost exclusively on insects (Scott and Crossman 1979; Armstrong and Morrow 1980). Food preferences were Diptera (midges and flies), Trichoptera (caddisflies), Ephemeroptera (mayflies), and Plecoptera (stoneflies), in decreasing order of importance.

Adult fluvial populations tend toward increasing piscivory. Bull trout in McKenzie Rivers, Oregon consumed forage fish, insects and crayfish, while bull trout in Imnaha River, Oregon fed almost exclusively on salmon fingerlings (Skeesick 1988). To ensure winter survival, resident and fluvial bull trout require large deep pools to provide cover and an abundant prey source; whitefish, a preferred prey, cohabitate in pools with the bull trout (Carl 1985).

Adfluvial populations of bull trout are highly piscivorous and reach the largest size of all stocks. Preference for kokanee and whitefish have been documented by Bjornn (1961) and Shepard *et. al.* (1984). Hanzel (1985) documented diet preferences by availability and season; kokanee were most available and consumed in spring, whitefish in summer and fall, and yellow perch in winter. Overall, three whitefish species were the most important food items year-around; lake, mountain and pygmy. In addition to the above, sculpin, peamouth chub, suckers and squawfish were the next important prey items consumed (Hanzel 1985).

Spawning adults were observed to feed very little, if at all (Apperson *et. al.* 1988; Fraley and Shepard 1988).

During hatchery production of Dolly Varden and bull trout in British Columbia, Brown (1985) extensively explained the difficulties of providing a suitable diet for these bottom-dwellers. Palatability was a major concern with respect to these fish, as they demonstrated clear preferences for certain flavors and textures (Brown 1985). Since bull trout feed exclusively on the bottom, feeding and disease control (gill infections) were more difficult to control than in aquaculture of any other species of trout or charr (Hanzel 1985).

B.1.8 Species Interactions

Interactions between bull trout and northern squawfish, cutthroat, rainbow, and lake trout have been documented (Jeppson and Platts 1959; Thompson and Tufts 1967; Pratt 1984; Boag 1987; Marnell 1985). Jeppson and Platts (1959) found at 200-300 millimeters, northern squawfish were in competition with bull trout for food, since both species shifted to a piscivorous diet at that length. Thompson and Tufts (1967) agreed that bull trout and northern squawfish had similar preferences for food.

Although rainbow and bull trout do no compete for food resources or living space (Allan 1980; Boag 1987), it has been suggested that bull trout and juvenile rainbow trout partioned habitat and rainbow trout choose areas of higher water velocity (McPhail and Murray 1979).

In an intensive study, Pratt (1984) reported active habitat partitioning between juvenile bull and cutthroat trout. A second relationship was discovered between age 1+ cutthroat and larger bull trout. Bull trout were located in areas of high cutthroat densities, which suggested cutthroat fry served as prey for adult and subadult bull trout (Pratt 1984). Marnell (1985) studied- lakes of Glacier National Park and found well defined habitat partitioning; there was, however, an absence of the predator-prey relationship typically seen between these species. Shepard et. *al.* (1948) reported interspecific aggression between larger juvenile and subadult bull trout, and adult cutthroat trout.

Fluvial populations of bull trout and brook trout, that cohabitate in the same stream, have been observed to share the same habitat during at least one stage of their life histories (Peters 1985; Rode 1988). Hybridization of the two species has been common and extensive (Cavender 1978; Leary *et. al.* 1983). In Montana, Skeesick (1988) reported that fluvial bull trout populations in symapatry with brook trout are now declining. It was hypothesized by Rode (1988) that introduction of brook trout and competition with brown trout have led to the decline of bull trout populations.

A decline of adfluvial bull trout stocks, has been reported from Glacier National Park, Montana. Marnell (1985) attributed the decline to flood damage of spawning and rearing habitat and competition from introduced lake trout.

Cover & Woody Debris	Water Quality	Barriers
-	good	waterfalls
	good	-
	[illegible]	gradient, flow, woody debris
		flow

...g aerial survey for lower, middle and upper reaches of the ninete[...] excluded).

	Substrate-Riffle:Pool	Soils & Bank Stability	Riparian	Channel	Cover & Woody Debris	Water Quality	Barrie[...]
	silted	highly erodible; wasted & unstable	none none none	unstable meander	good good good	marginal-poor heavy silt load	cement embu[...] culverts; cumulative imp[...]
le le	silted silted boulders	highly erodible	damaged to none	unstable meander	. . .	poor poor poor	cement embuttm[...] water quality; cumulative impac[...]
le le apids	silted substrate 50/50 r:p-high riffle high riffle	highly erodible; wasted and undercut	site-specific protected limited	unstable meander; unstable braided	. . .	silted; moderate-poor	none none none
	. . .	. . .	. . .	dry dry dry	. . .	none none none	concreet channel; no water
	gravel 50/50 riffle:pool	stable stable stable	undamaged undamaged none	unstable meander	good; logs and debris	good good good	none (potential for log jams and intermitte[...] flow in upper)
le-	50/50 riffle: pool	highly erodible; stable	damaged with residual snags	stable meander	good good good	muddy-poor	upper: Town of Plummer; culverts; sewage ponds + storm drain effluent; water quality
le-	gravel 50/50 riffle:pool	erodible; stable	undamaged; stable	stable stable stable	good good good	good good good	gravel pit; numerous culverts; possible log jams
	. . .	. . .	. . .	dry dry dry	. . .	none none none	frozen in winter; gradient
te te 'apids	50/50 riffle: pool	erodible; stable	site-specific:disturbed stable, protected. limited	stable stable stable	good good good	good good good	improperly graded culverts; headwaters: steep gradinet rapids
	. . .	. . .	. . .	dry dry dry	. . .	. . .	no water; gradient
te ntly high	high riffle: low pool cascades	stable stable stable	stable; undamaged	stable stable stable	good good good	good	