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POTENTIAL EFFECTS OF TWO ALTERNATIVE HYDROELECTRIC DEVELOPMENTS ON THE FISHERY RESOURCES OF THE LOWER TAZIMINA RIVER, ALASKA

A Preliminary Instream Flow Assessment
Draft Final Report

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

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STATEMENT OF CONCLUSION

The University of Alaska's Arctic Environmental Information and Data Center (AEIDC) conducted a preliminary instream flow assessment of the Tazimina River in cooperation with Dames and Moore. Two proposed hydroelectric development scenarios for the Tazimina River were considered; a 1200 kilowatt run-of-river plant and a 16-megawatt storage reservoir facility. A 90-foot waterfall at River Mile (RM) 9.5, which completely blocks upstream fish migrations, would provide much of the head for these proposed developments. This report is limited to a preliminary discussion of the generic effects which these proposed developments might have on existing fishery resources in the lower 9.5 miles of the Tazimina River.

The run-of-river plant is not expected to alter naturally occurring streamflows or stream temperatures in the lower 9 miles of the Tazimina River. Thus no changes in the availability or quality of fish habitat are expected to occur below the powerhouse (RM 9.3). Habitat changes would be confined to the quarter-mile segment between the falls (RM 9.5) and the powerhouse (RM 9.3). Due to the predominance of bedrock and undesirable velocities, this reach presently contains extremely limited (if any) low quality spawning habitat. Project-induced changes are not expected to adversely affect sockeye salmon production in the lower Tazimina River.

Little is known about seasonal use of the Tazimina River canyon by resident species. Therefore, a definitive statement cannot be made regarding effects of the proposed run-of-river development on rainbow trout, Arctic grayling, and Arctic char production in the river's lower 9.5 miles. The authors' experience and familiarity with the lower Tazimina River lead to the collective judgement that the anticipated changes in habitat conditions associated with the proposed run-of-river plant would not significantly affect resident fish populations. Additional field study would be required to specifically define the degree to which the river canyon is utilized by resident species and project-induced changes in availability or quality of canyon habitats.

Several questions remain regarding specific effects of the proposed storage reservoir development on existing fishery resources. Additional studies would be required to refine monthly streamflow estimates, particularly during low-flow years, and to develop specific streamflow recommendations to meet seasonal fishery requirements. From our review of the project proposal and our present understanding of the fishery resources, we conclude that most adverse effects on downstream fish habitats could be avoided or minimized by adopting a project design which provides adequate downstream temperatures and an operating schedule compatible with the seasonal streamflow requirements of the fishery resources. Based upon our evaluation of the available data on the fishery resources, estimated preproject streamflows, and the proposed storage reservoir development, it appears that sufficient water exists to both meet project needs and to provide adequate downstream flows which avoid or minimize adverse effects on fish habitat.

The specific findings and recommendations of this study which pertain to the proposed storage reservoir development scenario are summarized below:

<u>Above the powerhouse</u>

1. Naturally occurring streamflows and existing fish habitat conditions in the river canyon (RM 9.3 to 9.5) would be dramatically altered. However, the canyon contains only a limited amount of low-quality spawning habitat compared to that available in the lower 6 miles of the river and incubation success in this reach is questionable. Therefore the habitat losses in this .25-mile reach is unlikely to adversely affect sockeye salmon production in the Tazimina River.

2. It is also unlikely that changes in habitat conditions within this portion of the canyon would significanly affect resident fish populations. However, additional data are needed to ascertain the degree of resident species' use of this portion of the canyon.

Below the powerhouse

1. Streamflows of 650 and 2,000 cfs appear to define an acceptable range of streamflow for sockeye salmon spawning in existing habitats within the single-channel segments of the mainstem Tazimina River. The lower 3 miles of mainstem appear to provide the most important sockeye salmon spawning areas. Additional study would be required to quantitfy changes in spawning habitat associated with post-project streamflows.

2. A determination has yet to be made of incubation success for sockeye salmon in the various segments of the mainstem river and associated side channels. The proposed storage reservoir project has the potential of altering the availability of spawning habitat and decreasing the degree to which redds are naturally dewatered. Therefore, preemergent studies are recommended to determine whether productive spawning habitats would be jeopardized by reduced summer flows or if increased winter streamflows would likely result in greater survival of incubating eggs.

3. Main-channel streamflows of 1,000 cfs appear adequate to maintain flow through side channels utilized by sockeye spawners within the braided segments of the Tazimina River. Additional study would be needed to determine seasonal use of these side channels by resident species and to determine the quantitative changes in spawning and rearing habitats of resident species associated with postproject streamflows.

4. Rainbow and grayling spawning areas which may exist in the braided river segments or along the stream margins in single-channel segments could be dewatered or degraded by the proposed reduction of streamflows in late May and June. Additional streamflow could be provided during late May and June to avoid or minimize adverse effects to resident fish spawning below the powerhouse by modifying the proposed

annual reservoir filling schedule. The reservoir could be filled at a slower rate during June, thereby extending the filling period into August. This would result in smaller spills but no loss to monthly power production. Additional study would be required to determine the magnitude and timing of the releases required to protect existing rainbow and grayling spawning habitats.

5. Seasonal temperature gradients within the reservoir should be forecast and the downstream temperature requirements of the various life stages of resident and anadromous fish identified. This data could be used to determine if a special intake structure would be required to prevent powerhouse outflows from adversely affecting winter and spring stream temperatures in the lower 8 miles of river.

6. The Tazimina River channel is relatively stable and anticipated postproject flows would probably have a negligible effect on altering stream channel geometry or substrate composition. Additional fieldwork could be undertaken to provide a more substantive basis for determining the reservoir releases necessary to maintain the substrate composition and channel geometry in the braided river segments.

7. It does not appear that adverse water quality conditions would exist in the proposed reservoir. Additional study should be undertaken to confirm or modify this hypothesis and forecast seasonal limnologic characteristics of the impoundment.

INTRODUCTION

This report represents only one element of the environmental assessment being undertaken by Dames and Moore for Stone and Webster Engineering Company and the Alaska Power Authority. Dames and Moore is to identify the nature and magnitude of potential sociocultural and environmental impacts attributable to several alternative energy development scenarios for the Bristol Bay region of Alaska. The University of Alaska's Arctic Environmental Information and Data Center (AEIDC) participated in the Dames and Moore study by providing technical assistance and by conducting a preliminary instream flow assessment for the Tazimina River.

This report presents a preliminary discussion of the generic effects which operation of a 1200 kilowatt run-of-river or a 16-megawatt storage reservoir facility might have on the fishery resources in the lower 9.5 miles of the Tazimina River in the Bristol Bay region. A 90-foot waterfall presently blocking upstream migration of anadromous and resident fish at RM 9.5 would provide much of the head for these proposed developments.

SCOPE AND PURPOSE

Project effects are discussed in terms of four principal components of riverine fish habitat: streamflow, stream temperature, channel morphology, and water quality (Bovee 1980). A very limited amount of specific data and information are available on the biology, hydrology, and morphology of the Tazimina River as well as for design specifications of the two hydroelectric development concepts being proposed. As a result, the discussions and concluding statement pertaining to project effects are based on the professional judgment of the authors, limited field data, and a preliminary understanding of the river and its fishery resources.

This is not a report to assess impact, but rather to comment on project feasibility from a fishery resources perspective. More specifically, it (1) identifies generic changes in existing fish habitat likely to result from project operation (excluding construction and initial filling), (2) discusses the possible effect these changes may have on the fishery resource, (3) provides preliminary recommendations regarding design or operational changes which could be further investigated as methods to avoid or minimize adverse effects on existing fish habitat, and (4) provide necessary background information for planning additional studies which may be undertaken at a later date to support preparation of an environmental impact statement and mitigation plan as required by the Federal Energy Regulatory Commission (FERC).

STUDY APPROACH

Between July 20 and 23, 1981 AEIDC made several inquiries regarding the availability of information on biologic, hydrologic, and morphologic characteristics of the Tazmina River. AEIDC conducted an aerial and foot reconnaissance July 24-26, 1981 to obtain a firsthand impression of the project area and the instream uses or resources most likely to be affected by the proposed hydroelectric developments.

On the basis of this field reconnaissance, AEIDC recommended that the principal objective of the instream flow studies during the July 1981-January 1982 contract period be to obtain a qualitative appreciation of seasonal streamflow patterns and the resultant availability of various types of fisheries habitat in the lower 9.5 miles of river. We proposed that this begin with a preliminary description of (1) the comparative importance of mainstem and side channel sockeye salmon spawning habitats, (2) utilization of available overwintering habitat by resident species, (3) winter survival of incubating sockeye eggs, (4) the annual and seasonal variability of streamflows and stream temperatures, (5) background water chemistry conditions, and (6) stream channel stability. Additional detail regarding the objectives and recommended approaches for a preliminary assessment are contained in Appendix I.

DATA BASE

The limited analysis presented in this report is based on information and data obtained by AEIDC and Dames and Moore from periodic field investigations during their August through October 1981 field season as well as pertinent background information and data obtained from the literature and agency contacts. The University of Washington's Fishery Research Institute (FRI) participated in an August 28 aerial spawning count and provided much of the background information on sockeye salmon. FRI also provided results of its annual sockeye salmon spawning index surveys for the Kvichak system of which the Tazimina River is a part. The Alaska Department of Fish and Game (ADF&G) provided background information on resident species and results of their sampling efforts in the Tazimina River. All published streamflow data for the Newhalen River were provided by the U.S. Geological Survey (USGS). In addition, unpublished miscellaneous midwinter streamflow measurements, and a partial record of 1981 daily streamflows for the Tazimina River were provided by the USGS in the form of provisional data. The water quality sampling and analysis was conducted by L.A. Peterson and Associates, Fairbanks, Alaska.

SITE DESCRIPTION

The Tazimina River is located in southwestern Alaska in the Kvichak River drainage. The Kvichak basin is a broad, flat lowland surrounded by high mountains on three sides and Bristol Bay to the southwest. The Tazimina River enters the Newhalen River from the east between Illiamna Lake and Lake Clark. Figure 1 presents a map of the study area.

The Tazimina River is a nonglacial stream originating in the Chigmit Mountains and flowing southwest approximately 45 miles, then northwest for an additional 9 miles before entering Sixmile Lake directly opposite the village of Nondalton. Two relatively large lakes

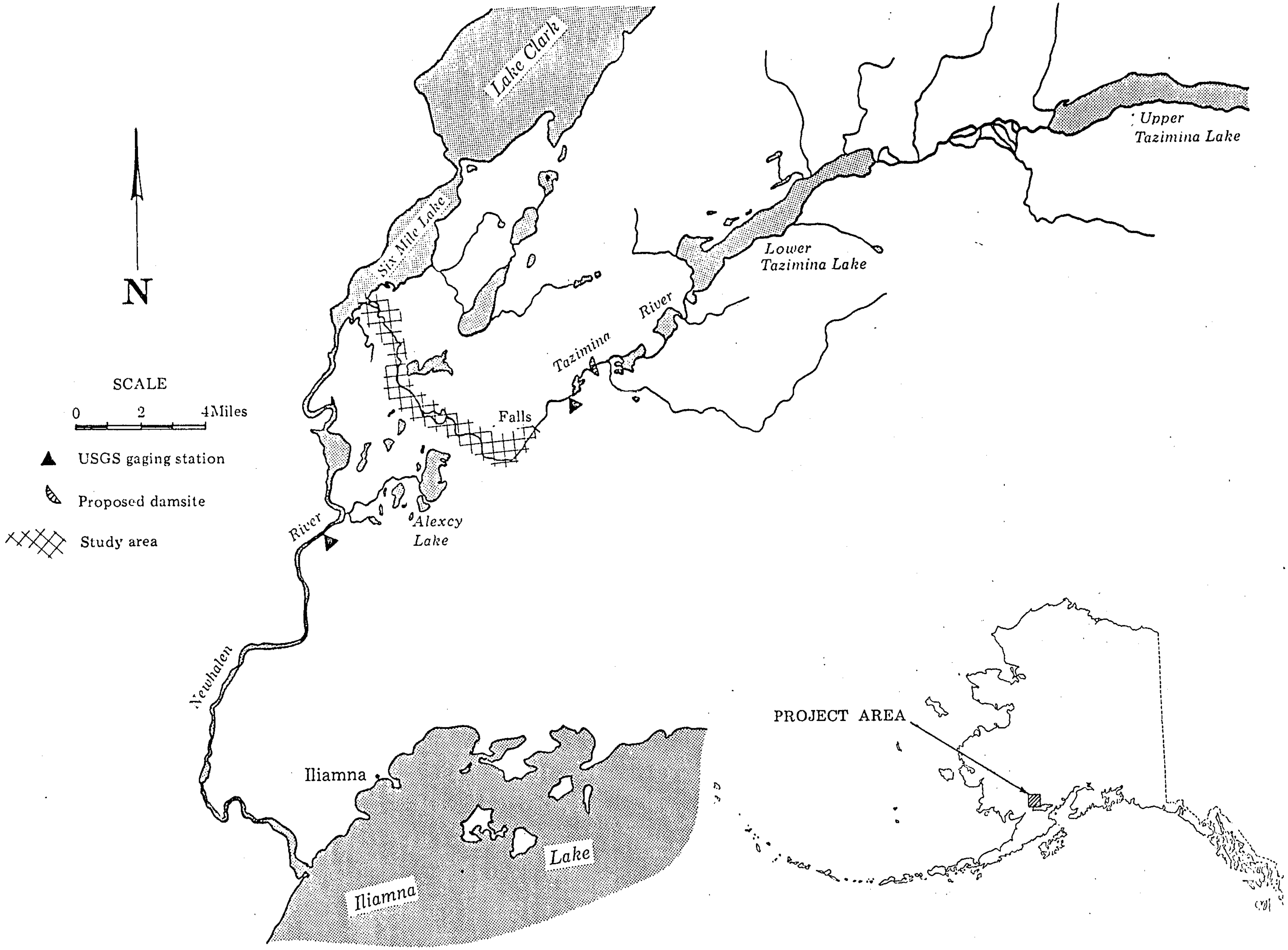

Figure 1. Location map for the study area.

exist in the upper Tazimina basin. Their combined surface areas comprise nearly 3 percent of the total drainage area (350 sq mi). Above River Mile (RM) 41 the Tazimina River passes through a steep, narrow valley before entering Upper Tazimina Lake. The river flows out of the upper lake at RM 32 through 7 miles of a spruce-forested glacial basin and into Lower Tazimina Lake at RM 25. Downstream from the lower lake, the terrain flattens out to a broad forested plateau. The river widens to form several small lakes between the lower lake outlet (RM 18) and RM 11.5. The river passes over a 90-foot falls and into a steep walled canyon near RM 9.5. Downstream from the canyon the river flows through an 8-mile segment of relatively flat, tundra-covered terrain with mixed forest and shrubs along the river channel.

FISHERY RESOURCES OF THE LOWER TAZIMINA RIVER

Major fishery resources of the lower Tazimina River include sockeye salmon (Oncorhynchus nerka), rainbow trout (Salmo gairdneri), Arctic char/Dolly Varden (Savelinus alpinus/malma)[1], and Arctic grayling (Thymallus arcticus). Other species occurring in the lower river include round whitefish (Prosopium cylindraceum), chinook salmon (Oncorhynhcus tshawytscha), longnosed sucker (Catostomus catostomus), threespine stickleback (Gasterosteus aculeatus), ninespine stickleback (Pungitius pungitius), and slimy sculpin (Cottus cognatus). Only sockeye salmon, rainbow trout, Arctic grayling, and Arctic char are addressed in this report.

Because of its importance to the commercial and subsistance fisheries, sockeye salmon is the principal fishery resource of the Tazimina River. Historically, the Tazimina River sockeye stocks contribute up to 5 percent of the total Kvichak River run--the largest sockeye salmon fishery in the world. The Kvichak watershed, excluding Lake Clark and its tributaries, is designated as a Wild Trout Area by the ADF&G and is managed as a trophy sport fishery. Tazimina River Arctic grayling and rainbow trout, in particular, are much sought after by sportsmen and provide substantial business for commercial guides and private lodges. Numbers of Arctic char in the lower Tazimina River appear to be relatively small and, although occasionally captured by anglers, they are not a dominant sport fish.

Little site-specific information exists which would allow definition of the seasonal distribution, relative abundance, and life history requirements of major fish species inhabiting the Tazimina River. However, a general description of the fishery resources of the

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[1] Because of their close morphological resemblance, some confusion exists concerning the taxonomy of Arctic char and Dolly Varden. Since discrimination between the two species was not essential for the purposes of this assessment, specific taxonomic identification was not attempted. We refer to these fish as Arctic char.

Tazimina River can be assembled from information for the same species inhabiting nearby drainages in the Iliamna area and from information for the Naknek and Wood River systems. Figure 2 summarizes such information.

Most species appear to utilize the Tazimina River seasonally or only during a particular life history stage. We used available data to generate the following generalized phenology chart, which indicates the species/life stages probably present in the lower Tazimina River at various times of the year (Figure 2).

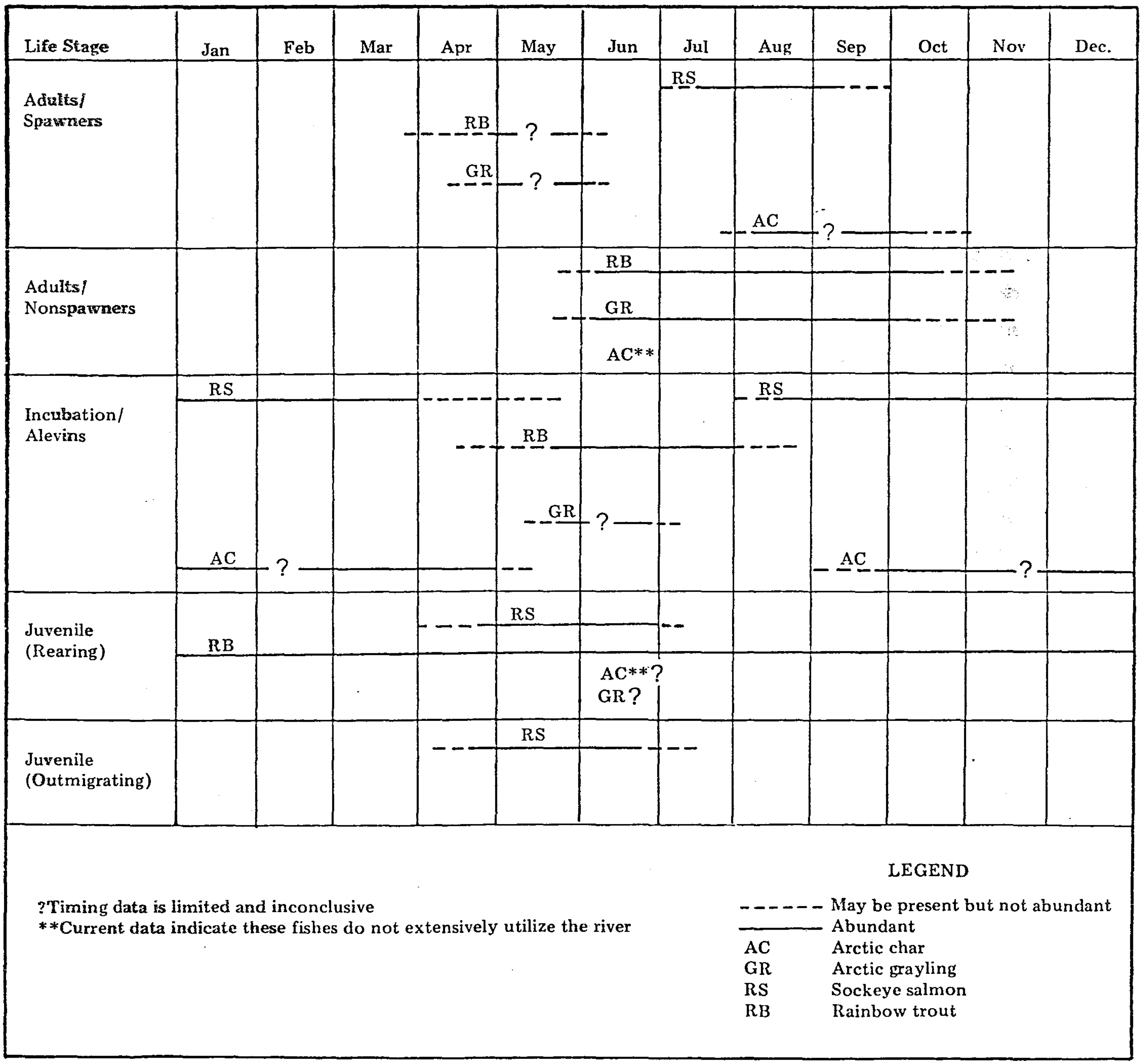
SOCKEYE SALMON

Though sockeye salmon inhabit the lower Tazimina River throughout most of the year, various life stages are present only seasonally. Much of their lives are spent in a lake or marine environment. Sockeye depend on the Tazimina River habitat for reproduction. Spawners generally begin to enter the Tazimina River in early to mid-July. Returns continue to increase throughout August. Peak spawning activity generally occurs in late August or early September and by mid-September few live sockeye remain in the river (Poe, pers. comm.). Fertilized eggs incubate in the stream gravels and probably hatch from February to mid-March depending on intergravel water temperatures. The alevins generally remain in the gravels until emergence, which generally coincides with breakup (late April to mid-June). After emergenece, fry move immediately downstream to lake nursery areas. Young sockeye salmon spend one or two years in fresh water before outmigrating to Bristol Bay. Sockeye salmon return to the Tazimina River to spawn after two or three years in the ocean.

The majority of sockeye salmon spawning occurs in the lower 6.5 miles of the Tazimina River--both in the main stem and in side channels. Main stem habitats in the lower 3 miles are most heavily utlized. In years of high abundance, sockeye salmon spawners are found throughout the entire 9.5 miles of the river below the falls.

Escapement of sockeye spawners to the Tazimina River has been monitored since 1920. Surveys indicate that historic index counts of the

Figure 2. Phenology chart for major fish species of the lower Tazimina River.



Tazimina River have varied from zero to almost 500,000. In recent years, the escapements to the Tazimina River have increased. The increase is attributable to increased ocean survival and to better management of the commercial harvest in Bristol Bay (Poe 1980, 1981). Figure 3 presents index survey results for sockeye salmon spawners in the Tazimina River for the last eight years. (Additional survey data are presented in Figure II-1, Appendix II.) The Tazimina stocks are on a five year cycle with two years of high escapements, a subdominate year after or before the dominate year, and two or three years of average or fairly low escapements. The next peak returns to Bristol Bay are predicted for 1984 and 1985.

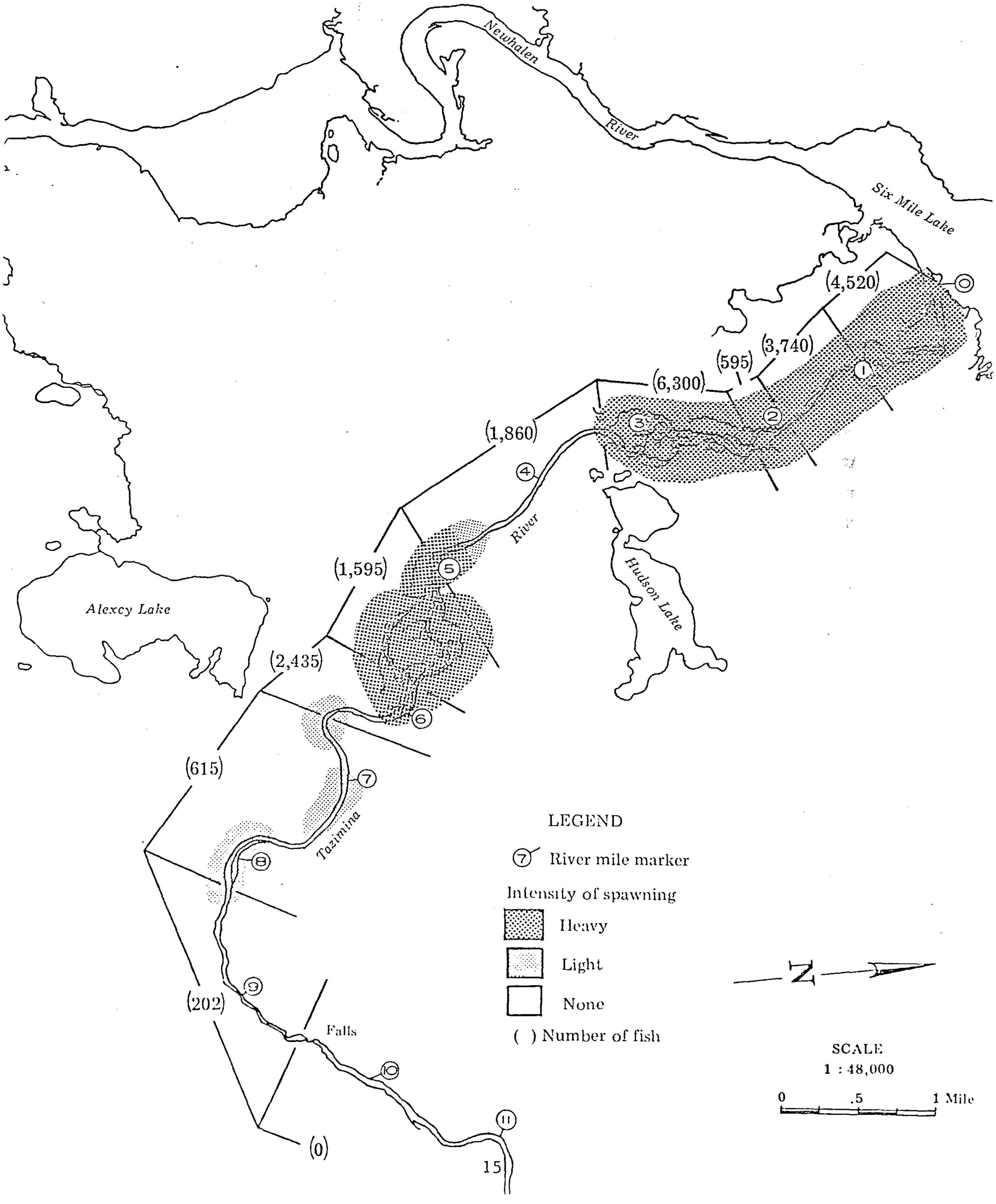
Sockeye salmon spawner distribution was determined by helicopter survey on August 28, 1981 and recorded on a 1:15,840-scale drawing of the lower river. Mr. Poe of FRI provided the numerical index, and Mr. Isakson of Dames and Moore noted the distribution within the river (Figure 4). Of the 21,900 spawners, 70 percent was in the lower 3 miles of the river, and 90 percent was counted downstream of RM 6.5.

Figure 3. Index survey results since 1974 for sockeye salmon in the Tazimina River.

Year	Number of fish	Year	Number of fish
1974	104,470	1978	146,900
1975	149,950	1979	495,750
1976	16,200	1980	128,500
1977	7,205	1981	28,215

Source: Data from Poe and Mathisen (1982).

Figure 4. Distribution and abundance of sockeye salmon spawners in the Tazimina River from aerial survey on August 28, 1981.



RESIDENT FISH

Although referred to as resident fish, rainbow trout, Arctic grayling and Arctic char are probably intrabasin migrants. These species appear to be most abundant in the Tazimina River during the open-water season. Little information exists regarding life histories of these fish or their seasonal distribution in the Tazimina River. (Appendix I summarizes the available data.)

Rainbow trout probably migrate from lake overwintering areas to the Tazimina River in late March and April. In the Bristol Bay region, rainbow trout usually spawn just after breakup (mid-April to mid-June). Commencement of rainbow trout spawning activities may be closely related to stream temperature. Spawning has been reported in stream temperatures of 5° to 7°C (Russell 1974, 1976).

Exact locations of spawning areas could not be identified because the field season did not begin until late July when spawning activity had terminated. Rainbow trout probably spawn in the side channels of braided segments and in some single-channel mainstem areas. Side channel habitats are very important spawning areas in other Iliamna systems. Spawning activity has been reported in Hudson and Alexcy Braids (Russell, pers. comm. and ADF&G 1974). Rainbow spawners have also been found in the Tazimina River canyon at RM 8.7 (Sims, pers. comm.), and Dames and Moore personnel captured young-of-the-year trout near RM 8.8. Due to the apparent limited availability of suitable substrate, spawning habitat present in the canyon probably does not account for a significant portion of rainbow trout production in the Tazimina River.

Postspawn rainbow trout probably remain in the Tazimina River until sockeye salmon spawning activity ends and trout move downstream and into the lake. Rainbow trout were observed in Tazimina River throughout the open-water season in 1981. During the summer, trout eggs incubate in the gravels until mid- to late July when fry emerge. Young-of-the-year trout may remain in the Tazimina River for the winter.

Numerous young rainbow trout were observed in the lower Tazimina River during the 1981 field season. Although no systematic sampling program was undertaken, juveniles were observed in slow, shallow water along stream margins, in side channels, and in backwater areas. Most of the good rearing habitat is located in the braided reaches and side channels. Outside of these areas young fish appear to be restricted to streambank margins.

Few data are available for Arctic grayling spawning activities in the Tazimina River. Arctic grayling probably spawn in Six Mile and Hudson braids (Russell, pers. comm.). In the Iliamna area, grayling spawn in May and June, generally during spring breakup. The slightly adhesive eggs sink to the stream bottom and become attached to substrate. Spawning activity generally covers the eggs with a layer of gravels. Embryo development is rapid, and eggs generally hatch in 13 to 32 days. As with other salmonids, development time is influenced by water temperatures. Fry generally remain in their natal stream during the summer. Young grayling occupy habitat similar to that of other young salmonids, selecting shallow, low-velocity areas with cover. Only one young grayling was collected by Dames and Moore personnel in the lower Tazimina River; however, side channels below Alexcy Braid were not sampled.

Few observations of Arctic char were made during the 1981 field season. Char reportedly move into the Tazimina River to feed on salmon eggs and remain to spawn in late September through October. Spawners were captured by sportsmen near RM 6.2 in September. No young Arctic char were found in the lower Tazimina River during the 1981 field season. The eggs incubate in the stream gravels until hatching in March and April. Emergence probably occurs in May and June. The young fish may move downstream to the lake to rear. No juvenile arctic char were captured in the lower river during the 1981 field season.

PHYSICAL CHARACTERISTICS OF THE LOWER TAZIMINA RIVER

STREAMFLOW

The Tazimina River, a tributary to the Newhalen River, drains approximately 10 percent of the Newhalen River basin. Although the size of the river basins differ by a factor of 10, there are many similarities between them. The same general climate influences both river systems, they drain similar topography, and large lakes are a part of both systems. Several large glaciers exist in the headwaters of the Newhalen River, whereas glaciers have entirely receded from the Tazimina River basin.

The USGS maintained a continuous recording station on the Newhalen River approximately 9 miles downstream from the mouth of the Tazimina River from July 1951 through September 1967. In addition, annual crest-stage data (annual flood peaks) were recorded from 1968 through 1977.

The USGS installed a continuous recording gage near RM 11.6 on the Tazimina River on June 19, 1981 and obtained several winter-spring base flow measurements during the 1980, 1981, and 1982 water years near RM 13.6. Additional streamflow data were periodically obtained by AEIDC and Dames and Moore personnel in the lower 8 miles of the Tazimina River from late July through mid-October 1981.

On July 25, 1981 AEIDC installed a staff gage at RM 1.7 to supplement the USGS recording station at RM 11.6. In addition, the USGS gage on the Newhalen River, which was maintained from 1951 to 1967, was visited, and AEIDC found the stilling well and staff gage to be communicating with the river at gage heights above 5.4 ft. (At water surface elevations below 5.4 ft, the stilling well was isolated from the river.)

Throughout the late summer and fall of 1981, periodic observations were made of the staff gages at these three locations. USGS and AEIDC personnel also measured streamflows to confirm the reliability of the existing rating curve for the Newhalen River gage and to develop preliminary rating curves for the two installations on the

Figure 5. Average monthly streamflows for the Tazimina River

Month	Estimated* Long-term Average	1981 USGS Record
Januray	255	250
February	200	No Record
March	180	No Record
April	180	No Record
May	565	No Record
June	1,680	No Record
July	1,995	2,560
August	2,090	2,340
September	1,260	863
October	770	635
November	600	638
December	340	342
Average Annual	843	

*Refer to Appendix II for methodology.

Tazimina River. These data provided the basis for estimating average monthly streamflows for the Tazimina River (Figure 5).

The daily streamflow record obtained by the USGS for the Tazimina River during 1981 was reviewed to determine the characteristic shape of peak runoff events (Figure 6). Because of the two natural lakes in the upper Tazimina River basin, rainstorm runoff events possess a broad flat flood crest rather than a sharp pronounced peak. Thus, a considerable degree of protection from streambed scouring and streambank erosion is naturally provided to the lower river by the upper lake system.

Figure 6. Comparison of 1-, 3-, 5-, and 7-day high flows in the Tazimina River to the respective monthly and long-term average monthly flows (cfs).

Date	Average Streamflow for Duration Indicated				Average Monthly	Estimated Long-term Average (cfs)
	1-day	3-day	5-day	7-day		
June 29 to July 5	3,050	2,923	2,814	2,691	2,560	1,890
July 12 to July 18	3,010	2,960	2,932	2,933	2,560	1,890
Aug 2 to Aug 8	3,210	3,150	2,994	2,863	2,280	1,980
Aug 13 to Aug 19	3,050	3,007	2,906	2,800	2,280	1,980
Oct 24 to Oct 30	1,010	1,003	986	966	635	770

Insufficient data have been collected on the Tazimina River to describe variations in monthly streamflows during wet and dry years. It is known, however, that July and August 1981 streamflows were above normal throughout the region. Newhalen River streamflows during late July and early August were of such magnitude as to be considered between one-in-five- and one-in-ten-year high flows.

Field observations made on the Tazimina River during October 1981 indicated that groundwater inflow provides a measurable contribution to the Tazimina River streamflow between RM 4.8 and 5.8 (Figure 7). Groundwater may be an important factor in maintaining winter streamflow.

WATER TEMPERATURE

As with the streamflow record, stream temperature and water chemistry data have only recently been obtained for the Tazimina River.

Figure 7. Reach gain measurements for the Tazimina River, October 13, 1981.

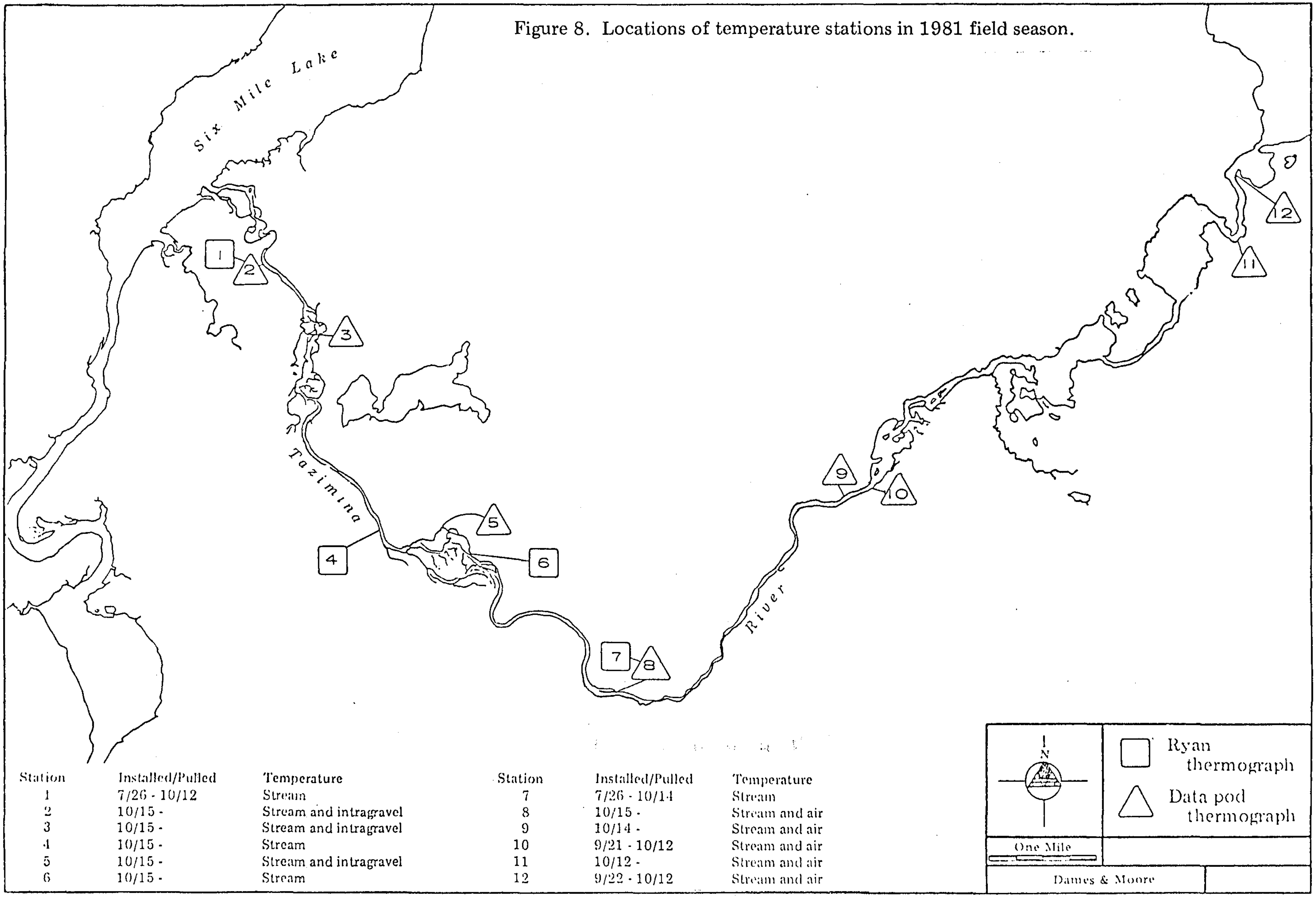
Location	River Mile	Streamflow (cfs)	Reach Gain (cfs)
USGS Gage	11.6	601.4	--
Mouth of Canyon	8.3	595.2	-2
Above Alexcy Braid	5.8	592.8	-1
Below Alexcy Braid	4.8	645.2	52
Above Hudson Braid	3.4	650.4	4
Below Hudson Braid	1.7	663.8	7

Two Ryan model J-90 thermographs were installed July 26, 1981 near RM 1.7 and RM 8.3 to record stream temperature data. Two Datapod model DP2321 dual channel temperature recorders were installed September 22 at RM 18 and 11.6 to monitor air and stream temperatures. Four additional Datapod recorders were installed in mid-October to monitor air, stream, and intergravel temperatures (Figure 8).

Maximum, minimum, and average daily stream and air temperatures are being obtained at two locations above the falls: approximately 0.3 miles below the outlet of Lower Tazimina Lake (RM 18.0) and at the USGS stream gage (RM 11.6). The same information is being recorded at the mouth of the river canyon near the proposed powerhouse site (RM 8.3). In addition, the average four-hour stream and intergravel water temperatures are being recorded at three locations in the lower river where numerous sockeye salmon spawners were observed: Alexcy Braid (RM 5.5), Hudson Braid (RM 2.3), and in a single-channel reach of the mainstem below the Hudson Braid (RM 1.0 to 2.0). The Ryan thermographs which were installed July 26 at RM 1.7 and RM 8.3 were reinstalled in the mainstem of the Tazimina River upstream (RM 5.7) and downstream (RM 4.8) of the Alexcy Braid to monitor anticipated groundwater influence on winter stream temperatures.

An initial review of the available data indicates that mainstem river temperatures were approximately 10 to 12°C from late July to mid-September, then rapidly dropped to the 2 to 4°C range by early October (Figures 9 and 10). Mean daily water temperatures during the July through August period were approximately 0.5°C warmer at RM 1.7 than at RM 8.3. From mid-September through mid-October mean daily

Figure 8. Locations of temperature stations in 1981 field season.



Station	Installed/Pulled	Temperature	Station	Installed/Pulled	Temperature
1	7/26 - 10/12	Stream	7	7/26 - 10/14	Stream
2	10/15 -	Stream and intragravel	8	10/15 -	Stream and air
3	10/15 -	Stream and intragravel	9	10/14 -	Stream and air
4	10/15 -	Stream	10	9/21 - 10/12	Stream and air
5	10/15 -	Stream and intragravel	11	10/12 -	Stream and air
6	10/15 -	Stream	12	9/22 - 10/12	Stream and air

Figure 9. Mean daily stream temperatures (°C) at two locations on the Tazimina River during July and August 1981.

	July 1981		August 1981	
Date	Canyon Mouth RM 8.3	River Mouth RM 1.7	Canyon Mouth RM 8.3	River Mouth RM 1.7
1			10.9	11.5
2			10.6	11.4
3			10.7	11.4
4			11.1	12.1
5			11.7	12.4
6			11.5	12.2
7			11.7	12.3
8			11.7	12.4
9			11.7	12.4
10			11.5	12.2
11			11.2	11.9
12			11.2	11.9
13			10.9	11.1
14			10.5	11.0
15			10.0	10.5
16			10.2	10.7
17			10.0	10.4
18			10.0	10.4
19			10.1	10.5
20			9.6	10.0
21			9.7	10.7
22			10.0	10.5
23			10.1	10.5
24			10.0	10.3
25			10.6	11.5
26	12.2*	12.9*	11.3	11.9
27	11.9	12.6	11.2	11.8
28	11.7	12.3	11.2	12.0
29	11.4	11.9	11.1	11.8
30	11.0	11.6	10.7	11.1
31	11.0	11.6	10.8	11.4

*Thermograph installed July 26, 1981.

Figure 10. Mean daily stream temperatures (°C) at four locations on the Tazimina River during September and October 1981.

	September 1981				October 1981			
Date	Lake Outlet RM 18	USGS Gage RM 11.6	Canyon Mouth RM 8.3	River Mouth RM 1.7	Lake Outlet RM 18	USGS Gage RM 11.6	Canyon Mouth RM 8.3	River Mouth RM 1.7
1			10.9	11.7	7.0	4.5	**	4.3
2			10.8	11.5	7.0	4.0		4.2
3			10.6	11.1	7.0	5.0		5.0
4			10.7	11.2	7.0	3.5		3.6
5			10.8	11.5	6.0	3.0		2.7
6			10.7	11.2	6.0	2.5		2.3
7			10.7	11.0	5.5	2.5		2.4
8			10.6	11.0	5.0	1.5		1.4
9			10.5	10.6	5.0	2.0		1.7
10			10.2	10.7	5.0	1.5		1.6
11			10.3	10.7	5.5	3.5		3.2
12			10.3	10.4	5.5	4.0	***	3.7***
13			9.8	10.2				
14			10.0	10.0				
15			9.6	9.8				
16			9.5	9.9				
17			8.1	9.3				
18			8.5	8.5				
19			8.3	8.3				
20			7.8	8.0				
21		7.5*	7.2**	7.1				
22	9.0*	7.5		6.9				
23	9.0	7.5		7.4				
24	9.0	7.5		6.8				
25	8.5	7.0		6.2				
26	8.5	6.0		6.0				
27	8.5	6.5		6.3				
28	8.0	6.0		5.6				
29	7.5	5.0		5.1				
30	7.5	4.0		4.5				

* Thermograph installed.
** Chart stopped September 21, 1981; thermograph removed October 12, 1981.
*** Thermograph removed October 12, 1981.

stream temperatures are approximately 3°C cooler at RM 1.7 than the outlet of Lower Tazimina Lake (RM 18).

Diurnal temperature variations during August ranged from 0 to 2.1°C at RM 8.3 and 0.2 to 3.3°C at RM 1.7 (Figure 11). A representative summer diurnal temperature change for the lower river would be approximately 1 to 2°C. From late September through mid-October diurnal temperature variations ranged from 0 to 1.0°C at the outlet of Lower Tazimina Lake, from 1 to 4.5°C at RM 11.6, and 0.2 to 2.0 at RM 1.7 (Figure 12). Representative fall diurnal temperature changes would be 0.5°C at the lake outlet and 1.5°C at RM 1.7.

Figure 11. Maximum and mininum summer stream temperatures (°C) at two locations on the Tazimina River.

	Canyon Mouth River Mile 8.3			River Mouth River Mile 1.7		
Date	Max	Min	ΔT	Max	Min	ΔT
Aug. 1	11.0	10.6	0.4	11.7	11.3	0.4
2	10.8	10.5	0.3	12.0	11.0	1.0
3	11.3	10.1	1.2	12.3	10.4	1.9
4	12.0	10.5	1.5	13.0	11.2	1.8
5	12.2	11.2	1.0	13.2	11.8	1.4
6	11.8	11.3	0.5	12.6	12.0	0.6
7	12.0	11.2	0.8	13.0	11.8	1.2
8	11.9	11.4	0.5	12.9	11.9	1.0
9	11.9	11.4	0.5	12.8	12.0	0.8
10	11.8	11.2	0.6	12.6	12.0	0.6
11	11.4	11.0	0.4	12.0	11.8	0.2
12	11.7	11.0	0.7	12.3	11.5	0.8
13	11.0	10.8	0.2	11.5	10.8	0.7
14	10.8	10.2	0.6	11.3	10.8	0.5
15	10.4	9.7	0.7	11.0	9.9	1.1
16	10.7	9.7	1.0	11.5	9.8	1.7
17	10.2	10.2	0.0	10.5	10.3	0.2
18	10.2	9.9	0.3	10.8	10.2	0.6
19	10.2	9.9	0.3	10.7	10.0	0.7
20	10.0	9.3	0.7	10.3	9.5	0.8
21	10.3	9.1	1.2	11.3	9.3	2.0
22	10.8	9.2	1.6	11.8	9.5	2.3
23	10.8	9.6	1.2	11.3	10.0	1.3
24	10.3	9.8	0.5	10.8	9.9	0.9
25	11.8	10.0	1.8	12.8	10.4	2.4
26	12.5	10.4	2.1	13.6	10.5	3.1
27	12.2	10.5	1.7	13.1	10.8	2.3
28	12.2	10.3	1.9	13.8	10.5	3.3
29	12.0	10.5	1.5	13.0	11.0	2.0
30	11.2	10.1	1.1	12.0	10.2	1.8
31	11.2	10.5	0.7	12.0	11.0	1.0

Figure 12. Maximum and minimum fall stream temperatures (°C) at two locations on the Tazimina River.

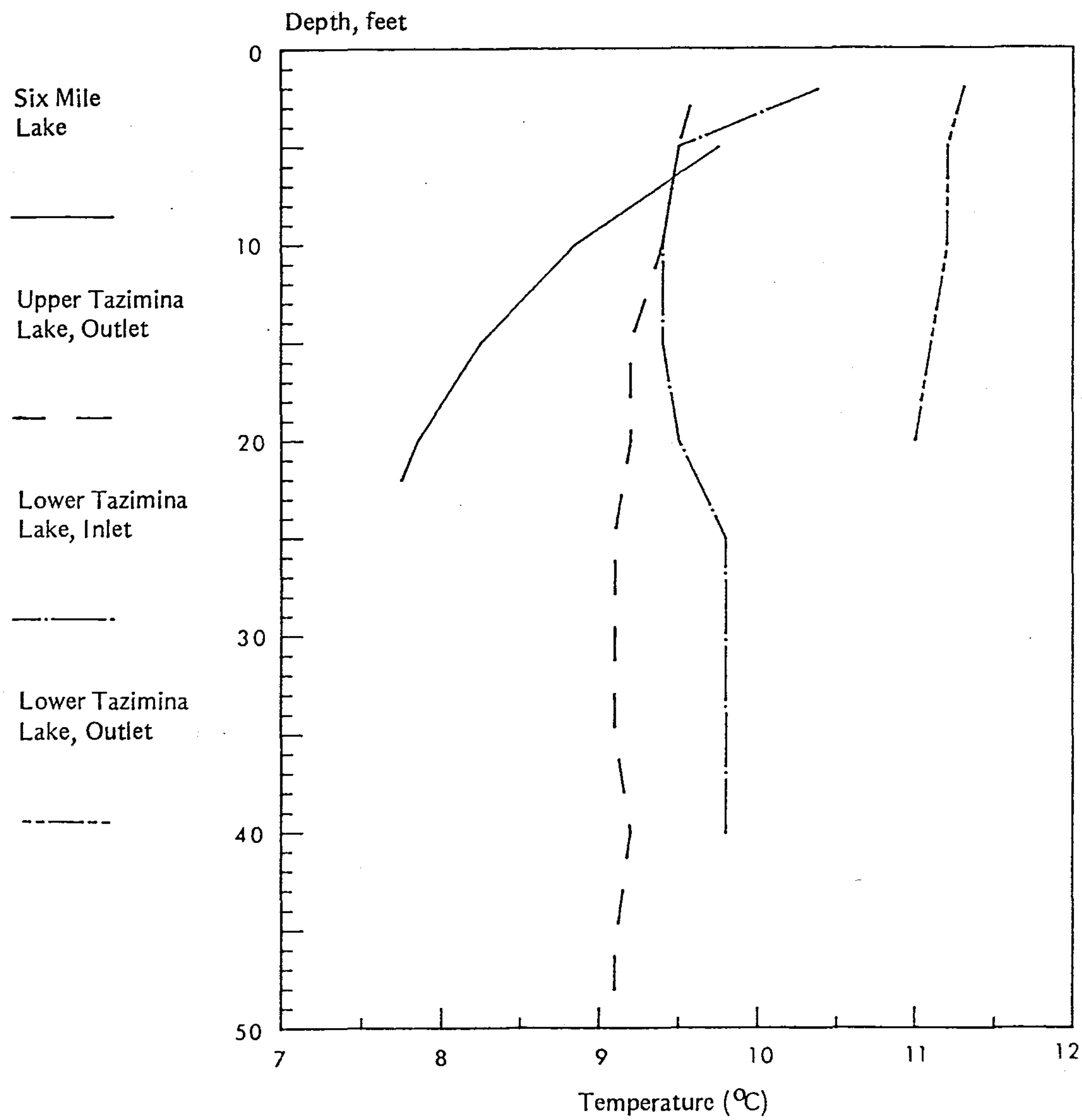
Date	Lake Outlet River Mile 18.0			River Mouth River Mile 1.7		
	Max	Min	ΔT	Max	Min	ΔT
Sept. 21				8.0	6.3	1.7
22	9.0	8.5	0.5	7.8	6.0	1.8
23	9.0	9.0	0.0	7.8	7.0	0.8
24	9.0	8.5	0.5	7.2	6.5	0.7
25	9.0	8.5	0.5	7.0	5.5	1.5
26	8.5	8.0	0.5	6.8	5.1	1.7
27	8.5	8.5	0.0	7.0	5.7	1.3
28	8.5	8.0	0.5	6.5	5.2	1.3
29	8.0	7.5	0.5	5.8	4.5	1.3
30	7.5	7.0	0.5	5.2	3.8	1.4
Oct. 1	7.0	7.0	0.0	4.2	3.5	0.7
2	7.0	6.5	0.5	5.0	3.2	1.8
3	7.5	7.0	0.5	5.4	4.6	0.8
4	7.5	6.5	1.0	5.0	3.0	2.0
5	6.5	6.0	0.5	3.4	2.2	1.2
6	6.0	5.5	0.5	2.8	2.0	1.8
7	6.0	5.5	0.5	2.8	1.8	1.0
8	5.5	5.0	0.5	1.9	0.6	1.3
9	5.5	5.0	0.5	2.3	1.2	1.1
10	5.5	5.0	0.5	2.5	0.5	2.0
11	6.0	5.0	1.0	3.8	2.5	1.3
12	6.0	5.5	0.5	3.8	3.6	0.2

Lake temperature profiles were obtained in early August by L.A. Peterson and Associates (Peterson 1981) at four locations: Six Mile Lake, the outlet of Lower Tazimina Lake, the inlet to Lower Tazimina Lake, and the outlet of Upper Tazimina Lake. August lake temperature profiles indicated that neither Upper nor Lower Tazimina Lake is stratified, but the lower lake is slightly warmer than the upper lake (Figure 13). Corresponding average daily stream temperatures were 11.5°C at RM 8.3 and 12.1°C at RM 1.7.

WATER QUALITY

Little historical water quality and limnological data exist for Upper and Lower Tazimina lakes, Tazimina River, and Six Mile Lake near the mouth of the Tazimina River. During August 4-5, 1981 L. A. Peterson & Associates sampled six locations for water quality data: the outlet of Upper Tazimina Lake, inlet and outlet portions of Lower Tazi-

Figure 13. Summer temperature profiles of Sixmile Lake and Tazimina lakes.



Source: Peterson (1981).

mina Lake, upper Tazimina River above the USGS gaging station, lower Tazimina River (approximately 1.7 miles above the mouth), and Six Mile Lake (off the mouth of the Tazimina River). Parameters measured in the field included dissolved oxygen, temperature, pH, conductivity, settleable solids, and alkalinity. Reported field values are averages of three separate measurements made at each sample site. Laboratory samples were composited from at least three locations at each sample site. River sample stations were divided so that samples were collected near the right and left banks and from the center as three depth-integrated samples and then composited. Lake sample stations were treated in a similar manner because samples were collected at the inlets or outlets.

Dissolved oxygen measurements obtained during August 1981 indicated that the Tazimina River/Lake system was near saturation. Dissolved oxygen levels in both Lower Tazimina and Six Mile lakes were 11 mg/l, 95 to 98 percent saturation throughout the depth ranges sampled (Figure 14). Dissolved oxygen measured at two locations on the Tazimina River was also near saturation levels. Measurements obtained near RM 11.6 and RM 1.7 were 10.7 and 10.1 mg/l. These measurements represent dissolved oxygen levels of 97 and 94 percent saturation. Measurements were not made in the river canyon below the falls; we believe that dissolved gas levels are at present slightly supersaturated.

The water chemistry data obtained throughout the Tazimina River system and in Six Mile Lake during August 1981 were similar (Figures 15 and 16). Because of this similarity, the following discussion provided by Mr. Peterson generally does not differentiate between sample locations.

Alkalinity and hardness values were low, pH was slightly acidic, and free carbon dioxide levels were low to moderate. Turbidity and total suspended solids levels were low, indicative of a clear water system. Settleable solids were less than the detection limit, 0.1 ml/l, at all sample stations. These low levels of solids and turbidity are particularly noteworthy since discharge, measured at the USGS gaging station, was at its highest peak for the period of record on the dates the water quality sampling was conducted. Because solids levels and turbidity are directly related to discharge, the values measured on August 4 and 5 are likely to be among the highest levels occurring naturally in the Tazimina system.

Figure 14. Summer dissolved oxygen profiles of Sixmile Lake and Tazimina lakes.

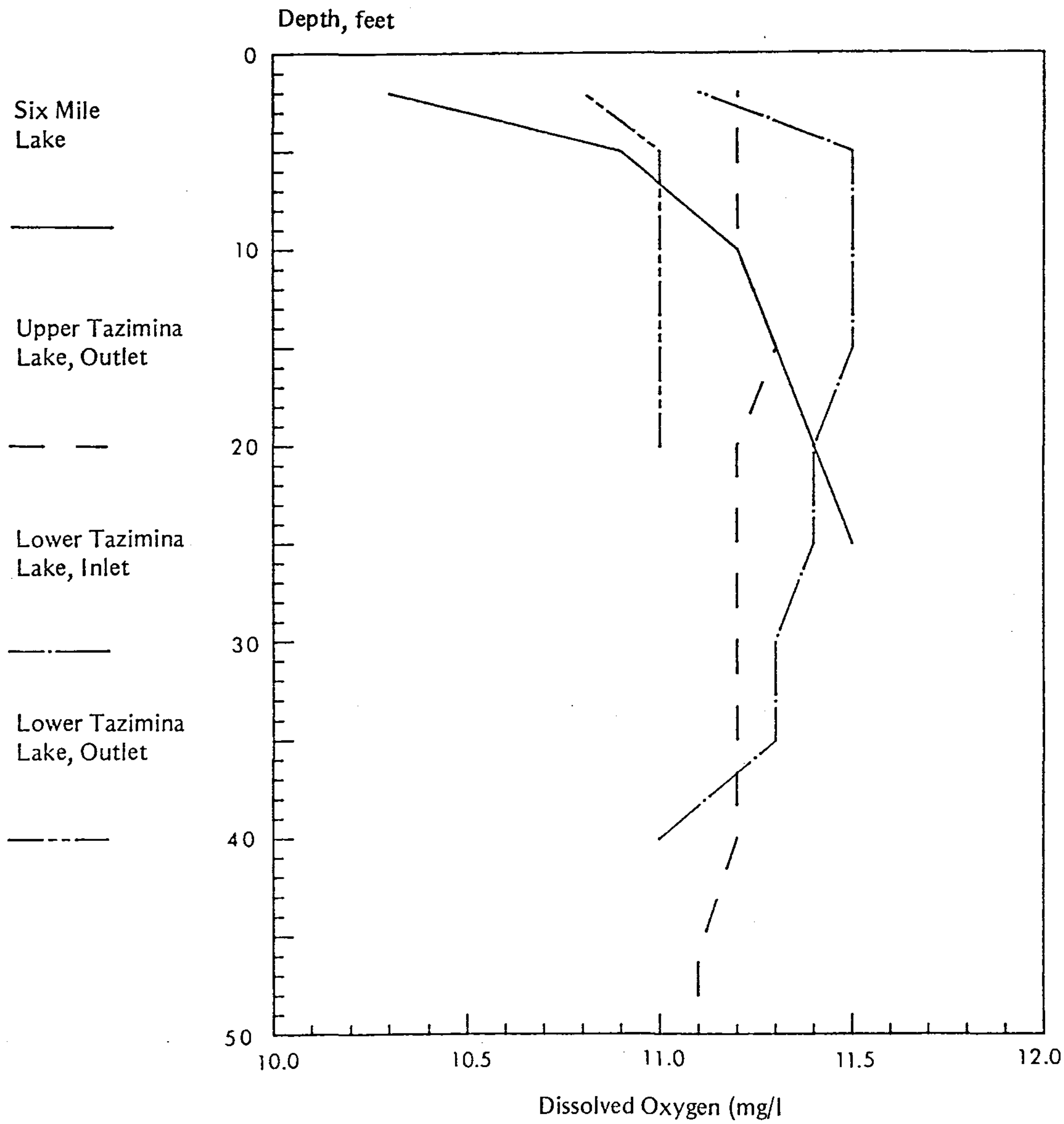


Figure 15. Summary of basic water quality data from August 1981 Sampling of the Tazimina River/Lake system.

Parameters*	Outlet Upper Tazimina	Inlet Lower Tazimina	Outlet Lower Tazimina	RM 11.6 Tazimina River	RM 1.7 Tazimina River	RM 0.0 Six Mile Lake
			Field Measurements			
Dissolved Oxygen	11.2	11.3	11.3	10.7	10.1	11.1
Conductivity, mhos/cm @25°C	22.0	21.0	23.0	24.0	23.0	45.0
pH, pH Units	6.6	6.5	6.8	6.7	6.2	6.2
Temperature, °C	9.2	9.7	11.0	11.9	12.1	9.0
Settleable Solids, ml/l	0.1	0.1	0.1	0.1	0.1	0.1
Alkalinity, as $CaCO_3$	11.0	12.0	12.0	13.0	13.0	27.0
			Office Calculations			
Hardness, Ca+Mg, as $CaCO_3$	6.8	6.6	6.8	6.4	6.7	20.0
Carbon Dioxide	7.0	9.0	5.0	6.0	18.0	40.0
D.O., % Saturation	97.0	98.0	98.0	97.0	94.0	95.0

*Values in mg/l unless otherwise noted
Adapted from Peterson (1981).

Figure 16. Summer concentrations of dissolved physical/chemical, nutrient, and metal parameters for the Tazimina River/Lake System.

Parameters*	Outlet Upper Tazimina Lake	Inlet Lower Tazimina Lake	Outlet Lower Tazimina Lake	RM 11.6 Tazimina River	RM 1.7 Tazimina River	RM 0.0 Six Mile Lake
			Physical/Chemical			
Turbidity	0.35	0.50	0.30	0.50	2.5	1.4
Total Dissolved Solids	24	28	30	23	23	34
Total Suspended Solids	0.4	1.0	0.2	0.5	2.0	1.2
Chloride	0.6	0.6	1.0	0.8	0.9	1.4
Sulfate	6.4	7.1	7.8	6.2	6.5	8.3
			Dissolved Nutrients			
Total Phosphate, as P	0.03	0.03	0.04	0.03	0.03	0.03
Ortho-Phosphate, as P	0.03	0.03	0.04	0.03	0.03	0.03
Total Nitrogen, as N	<0.38	<0.23	<0.37	<0.20	<0.36	<0.16
Ammonia, as N	0.01	0.01	0.01	0.01	0.01	0.02
Nitrate, as N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate, as N	0.32	<0.10	0.31	0.14	0.30	<0.10
Total Kjeldahl Nitrogen, as N	<0.05	0.12	<0.05	<0.05	<0.05	<0.05
Silicon	1.68	1.64	1.86	1.79	1.76	1.63
			Dissolved Metals			
Arsenic	0.0009	0.0010	0.0006	0.0007	0.0008	0.0008
Barium	0.18	0.04	0.11	<0.01	0.08	0.04
Calcium	2.220	2.117	2.136	1.957	2.090	6.49
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium	0.006	<0.003	<0.003	0.010	<0.003	<0.003
Copper	0.003	<0.002	<0.002	<0.002	0.007	0.003
Iron	<0.005	0.014	<0.005	0.016	0.011	0.027
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Potassium	6.2	1.8	3.0	1.8	4.3	3.2
Magnesium	0.316	0.309	0.347	0.360	0.358	0.92
Manganese	<0.002	0.003	<0.002	<0.002	<0.006	0.003
Silver	<0.002	0.002	<0.002	<0.002	0.002	0.003
Sodium	2.3	5.5	5.7	2.3	2.4	6.6
Nickel	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	0.0003	<0.0001	<0.0001	0.0002	<0.0001	0.0001
Selenium	0.0042	0.0033	0.0034	0.0047	0.0033	0.0035
Strontium	0.012	0.007	0.009	0.009	0.005	0.025
Zinc	0.006	0.004	<0.001	<0.001	<0.001	0.009

*Values in mg/l unless otherwise noted
Source: Data from Peterson (1981)

Concentrations of nutrients were low to moderate at all sites. Nitrite was not detected at any site and ammonia was low at all sites. Total Kjeldahl nitrogen, the sum of ammonia and organic nitrogen, was only detected at the inlet of Lower Tazimina Lake. Consequently, this site was the only one having a detectable concentration of organic nitrogen. Nitrate and ortho-phosphate concentrations were sufficient to provide for biological uptake at all sites except the inlet of Lower Tazimina Lake and Six Mile Lake. These sample locations exhibited nitrate concentrations less than the detection limit.

Mineralization, as measured by conductivity and total dissolved solids, in the Tazimina system and Six Mile Lake was also low. This is typical for freshwater systems in this part of Alaska. However, these measurements were made during a period of high discharge. Therefore mineralization in the system could have been somewhat depressed because of the typical inverse relationship between mineralization and discharge.

The major anion at all sites is biocarbonate. Sodium and calcium are the major cations in Lower Tazimina Lake, Six Mile Lake, and upper Tazimina River. Sodium, calcium, and potassium are roughly equal in terms of milliequivalents per liter in Upper Tazimina Lake and lower Tazimina River.

Cadmium, mercury, and nickel concentrations were less than their respective detection limits. The remaining potentially toxic trace elements, except copper, were below levels considered to be safe for the growth and propagation of freshwater aquatic organisms (ADEC 1979, EPA 1976, McNeely et al. 1979, Sittig 1981, and EPA 1980). Copper was 7 ug/l at the lower Tazimina River site, which exceeds the acceptable level of 5 ug/l presented by McNeely et al. (1979). However, EPA (1976) presents information stating that in most natural fresh waters in the United States copper concentration below 25 ug/l as copper evidently is not rapidly fatal for most common fish species. The copper concentration that would be fatal to fish in the lower Tazimina River must be in excess of 7 ug/l because this section of the river supports an abundant fish population; or, this value was a laboratory error. (Peterson 1981)

SEDIMENT TRANSPORT

A series of water samples was collected throughout the Tazimina River/Lake system coincident with the highest recorded streamflows for 1981 (3,130 and 3,020 cfs). Analysis of these samples (refer to Figure 16) as well as periodic field observations during the high runoff period indicated that a very small amount of suspended sediment was being transported by the Tazimina River. The low sediment transport rate was further evidenced by the substrate composition of the lower river, which grades from silty sands at the river mouth to exposed bedrock and large boulders in the river canyon. With the exception of a 0.3 mile reach immediately upstream of the the river's mouth and a 0.25 mile reach near RM 2, a very small percentage of fines (silts and sands) is contained in the streambed.

The most apparent sources for sediment recruitment to the lower river are localized streambank erosion (landslides) and temporary disturbances of isolated sand deposits and gravel bars within the braided river segments. Currently, the river channel is relatively stable and natural streamflows probably could transport more fine sediments through the system.

RELATIONSHIPS BETWEEN MORPHOLOGIC AND HYDROLOGIC CHARACTERISTICS AND SOCKEYE SALMON SPAWNING AND INCUBATION SUCCESS

Classification of a river system into subreaches based upon physical and biological considerations provides a basis for evaluating different responses of a variety of habitat types to changes in streamflow and related physical parameters. For example, more spawning habitat would likely become dewatered in a braided river segment than in a single-channel reach for the same reduction in streamflow. In addition, habitat responses to changes in physical parameters at an established study site within a specific river segment can be viewed as being applicable to all similar habitats within that river segment. Thus, the general response of relatively homogeneous river segments can be determined through the detailed evaluation of habitat responses to changes in streamflow and related physical parameters at one or two study sites in that segment.

The lower 9.5-miles of the Tazimina River was subdivided into relatively homogeneous segments based on biologic, morphologic, and hydraulic considerations. Reach-specific substrate characteristics, streambank stability, cross-sectional geometry, and the distribution of sockeye salmon spawners were identified by helicopter survey and recorded on a 1:15,840 scale map. Representative areas were photographed, and the river segmentation was confirmed by follow-up helicopter and foot surveys. Four study sites were established on the Tazimina River: three at side channels (one at the canyon mouth and two within Alexcy Braid) and one single-channel site (RM 1.7).

SUBSTRATE COMPOSITION AND SPAWNER DISTRIBUTION

The predominant streambed materials observed in the Tazimina River graded from silty sands at the river mouth (RM 0.0) to bedrock and large boulders in the canyon (RM 8.3 to 9.5). Streambed and streambank materials upstream from RM 6.5 are of volcanic origin. Available spawning substrates between RM 6.5 and 9.5 are primarily sharp, angular, platelike particles of metamorphosed volcanic tuff. Downstream of RM 6.5 the river flows through an extensive glacial

Spawning ground surveys were conducted on the Tazimina River by FRI in 1961 and 1962 (FRI unpublished data). Due to differences in classification methodologies and the inability to reliably determine river mile indices for the FRI transects, a direct comparison cannot be made between the earlier stream survey data and our 1981 observations. However, it can be concluded from a review of these data that the general gradation of streambed material sizes from silty-sands to boulders has not changed appreciably in 20 years (Figure 17). Both surveys indicated that the most suitable sockeye salmon spawning areas are found in the lower 3 miles of the river. The 1981 survey also identified the braided reach between RM 5 and RM 6 as an important sockeye salmon spawning area.

During the 1981 season, sockeye salmon were observed in significant numbers within discrete river segments (Figure 18). Spawners were well distributed in the three braided reaches. However, sockeye were observed in significant numbers only in the single-channel river segment between RM 1.0 and 2.0 and in the short transitory single-channel segments immediately upstream of Hudson Braid (near RM 3.4) and Alexcy Braid (near RM 6.1).

Spawners made scant use of the remaining 4.4 miles of single-channel habitat below the falls. Lack of suitable spawning substrates and high velocities appear to be the principal reason for its limited use by spawners. The adult sockeye observed in the single-channel segments between RM 3.6 and 4.9 and from RM 6.4 to 8.3 occupied the few isolated pockets of suitable spawning substrate available in these reaches. Poe (FRI unpublished data) indicated that spawners use the river segment from RM 3.6 to 4.9 more extensively than was observed in 1981 during years of larger escapments.

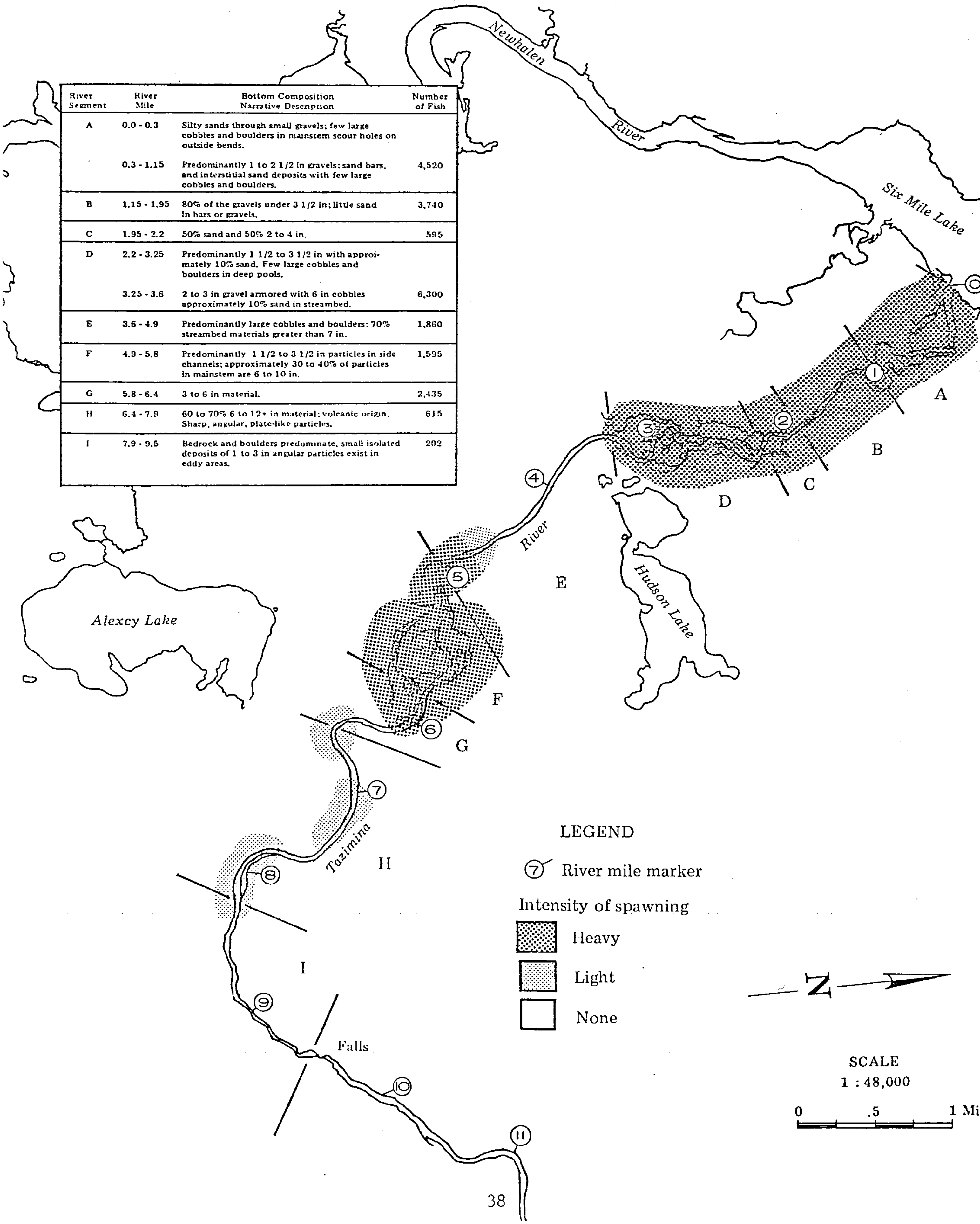
Limited use is made of the canyon area (RM 8.3 to 9.5) by sockeye spawners. Few fish were observed in the canyon during the 1981 field season. No fish were observed here during the helicopter survey, as high velocities and turbulence limits visibility in this reach. As with the other single-channel segments of the river, spawning appears to be limited by lack of suitable substrates. Canyon substrates are dominated by large boulders and bedrock; however, small isolated

Figure 17. Comparison between 1981 AEIDC and 1962 Fisheries Research Institute stream bottom composition surveys for the lower Tazimina River.

1981 AEIDC Survey				1962 Fisheries Research Institute Survey				
					Bottom Composition			
River Segment	River Mile	Bottom Composition Narrative Description	Transect Number	Estimated River Mile	<1/8 in	1/8 - 3 in	3 - 12 in	>12 in
1	0.0 - 0.3	Silty sands through small gravels; few large cobbles and boulders in mainstem scour holes on outside bends.	1	0.0	40%	30%	20%	10%
2	0.3 - 1.15	Predominately 1- to 2 1/2-in gravels; sand bars, and interstitial sand deposits with few large cobbles and boulders.	2	0.6	30%	30%	30%	10%
3	1.15 - 1.95	80% of the gravels under 3 1/2 in; little sand in bars or gravels.	3	1.2	30%	30%	30%	10%
			4	1.8	40%	20%	30%	10%
4	1.95 - 2.2	50% sand and 50% 2 to 4 in.						
5	2.2 - 3.25	Predominately 1 1/2- to 3 1/2-in with approximately 10% sand. Few large cobbles and boulders in deep pools.	5	2.4	20%	30%	30%	20%
			6	3.0	20%	30%	30%	20%
6	3.25 - 3.6	2- to 3-in gravel armored with 6-in cobbles approximately 10% sand in streambed.	7	3.6	20%	20%	30%	30%
7	3.6 - 4.9	Predominately large cobbles and boulders; 70% streambed materials greater than 7 in.	8	4.5	20%	20%	30%	30%
8	4.9 - 5.8	Predominately 1 1/2- to 3 1/2-in particles in side channels; approximately 30 to 40% of particles in mainstem are 6 to 10 in.						
9	5.8 - 6.4	3- to 6-in material.						
10	6.4 - 7.9	60 to 70% 6- to 12-in material; volcanic origin. Sharp, angular, platelike particles	9	6.5	20%	20%	20%	40%
			10	7.5	20%	20%	20%	40%
11	7.9 - 9.5	Bedrock and boulders predominate, small isolated deposits of 1- to 3-in angular particles exist in eddy areas.	11*	8.0	10%	10%	30%	40%
			12*	9.0	10%	10%	30%	40%

*10% substrate material unknown size (assume bedrock).

Figure 18. Sockeye salmon spawner distribution with respect to substrate type.



River Segment	River Mile	Bottom Composition Narrative Description	Number of Fish
A	0.0 - 0.3	Silty sands through small gravels; few large cobbles and boulders in mainstem scour holes on outside bends.	
	0.3 - 1.15	Predominantly 1 to 2 1/2 in gravels; sand bars, and interstitial sand deposits with few large cobbles and boulders.	4,520
B	1.15 - 1.95	80% of the gravels under 3 1/2 in; little sand in bars or gravels.	3,740
C	1.95 - 2.2	50% sand and 50% 2 to 4 in.	595
D	2.2 - 3.25	Predominantly 1 1/2 to 3 1/2 in with approi-mately 10% sand. Few large cobbles and boulders in deep pools.	
	3.25 - 3.6	2 to 3 in gravel armored with 6 in cobbles approximately 10% sand in streambed.	6,300
E	3.6 - 4.9	Predominantly large cobbles and boulders; 70% streambed materials greater than 7 in.	1,860
F	4.9 - 5.8	Predominantly 1 1/2 to 3 1/2 in particles in side channels; approximately 30 to 40% of particles in mainstem are 6 to 10 in.	1,595
G	5.8 - 6.4	3 to 6 in material.	2,435
H	6.4 - 7.9	60 to 70% 6 to 12+ in material; volcanic origin. Sharp, angular, plate-like particles.	615
I	7.9 - 9.5	Bedrock and boulders predominate, small isolated deposits of 1 to 3 in angular particles exist in eddy areas.	202

with the other single-channel segments of the river, spawning appears to be limited by lack of suitable substrates. Canyon substrates are dominated by large boulders and bedrock; however, small isolated pockets of suitable spawning substrates are present and probably accommodate some spawners.

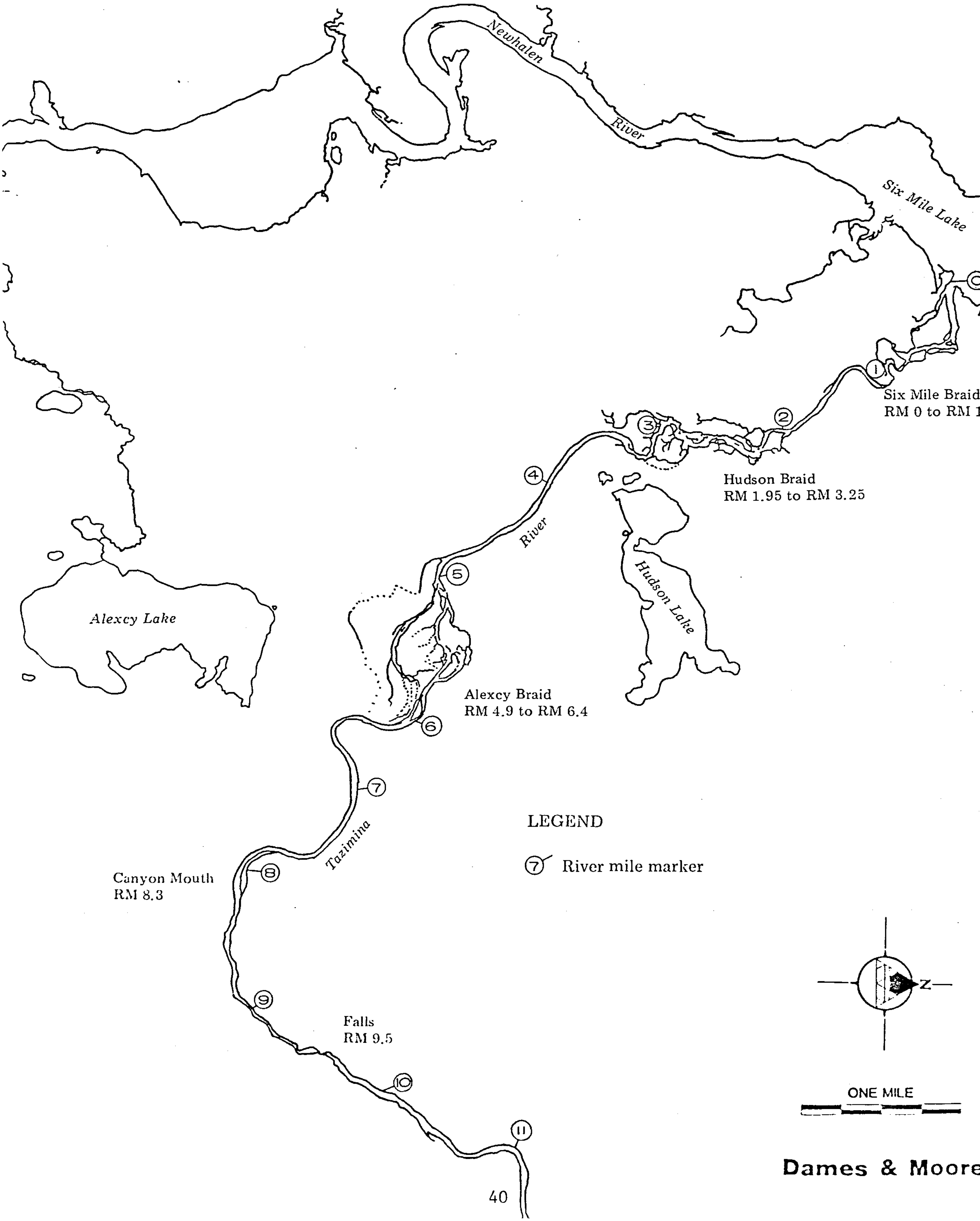
HYDRAULIC CONDITIONS AND SPAWNER DISTRIBUTION

The lower 9.5 miles of the Tazimina River consist of two basic types of stream channel: very stable, rectangular single-channel reaches (three reaches) of nearly uniform gradient and fairly stable, braided segments (three reaches) possessing irregular streambed profiles and nonuniform cross sections (Figure 19). Within the single-channel segments streamflow velocities are relatively high and quite uniform. Little variation exists in the velocity pattern due to the uniform streambed gradient and cross-sectional shape. At moderate and high flows, low-velocity areas are principally restricted to narrow, sometimes discontinuous bands adjacent to the streambanks. Hydraulic conditions within the braided reaches are not uniform. Depths and velocities vary markedly throughout the reach due to irregular streambed gradients and stream channel cross sections. At moderate and high flows, low-velocity areas are quite abundant within the braided reaches due to backwater effects near the numerous junctions of merging side channels.

Velocities associated with high streamflows during the spawning season may at times adversely affect sockeye salmon production in the Tazimina River. In addition to providing a potential for scouring streambed gravels, high velocities may deny spawners access to suitable mainstem spawning areas. The high river stage also provides access to overbank areas which then dewater as the river returns to more "normal" seasonal levels.

During an August 17 overflight, adult sockeye observed in the single-channel river segments were concentrated in narrow discontinuous bands along the streambanks and immediately downstream of partially submerged debris jams. The distribution pattern was far more coincident with the limited low-velocity areas in the river segment

Figure 19. Stream channel patterns of the lower Tazimina River.



Dames & Moore

than with readily available spawning substrates. These fish may have been seeking shelter from the high velocities in the mainstem river.

This supposition was supported when, during the same overflight, adult sockeye were dispersed and defending territories throughout the braided segments of the lower river where velocities were lower. In both Alexcy and Hudson braids adult sockeye were observed holding over suitable spawning substrates in pairs and small groups. Observations and fish captures during a follow-up foot survey confirmed that these fish were still "green." Actual spawning was two to three weeks away.

On August 28 and 29, at a discharge of 1,600 cfs, adult sockeye were well distributed over the suitable spawning substrates throughout the lower river. In the single-channel segments, where a week earlier adults had occupied stream margins and other low-velocity zones, they were observed spread out across the width of the channel.

Streamflow measurements were made in this same single-channel segment (RM 1.7), where numerous sockeye were observed. Mean column velocities between 3.0 and 4.0 fps were frequently recorded at a streamflow of 1,582 cfs and between 4.5 and 5.0 fps for a streamflow of 2,415 cfs. Mean column velocities were not measured at this site for the August 17 discharge of 3,130 cfs, but we estimated them to be in the range of 5.5 to 6 fps.

Shallow depths associated with low flows during the spawning season may deny adults access to desirable spawning areas in the braided reaches. Even though low flows may not prevent adults from entering some side channels, the accompanying shallow depths and low velocities could deter spawners from using these areas. Fish may be forced to use less suitable spawning substrates, such as those available in the mainstem between RM 3.6 to 4.9 and RM 6.4 to 9.5.

Within the single-channel segments and the main channel of the braided segments, abnormally low streamflows probably concentrate spawners in mid-channel areas. Although this may reduce the potential for eggs to be dewatered during midwinter, some spawners may be forced to use less suitable substrates, as low flows reduce the available habitat in traditional spawning areas.

HABITAT UTILIZATION

Adult sockeye were located by helicopter survey, and characteristic spawning areas were selected which encompassed the range of hydraulic and substrate conditions utilized by sockeye salmon in the lower Tazimina River (Figure 20). Field measurements were made to describe the characteristic range of specific habitat conditions selected by spawning sockeye salmon using field techniques as described in Appendix III of Wilson, et al. (1981).

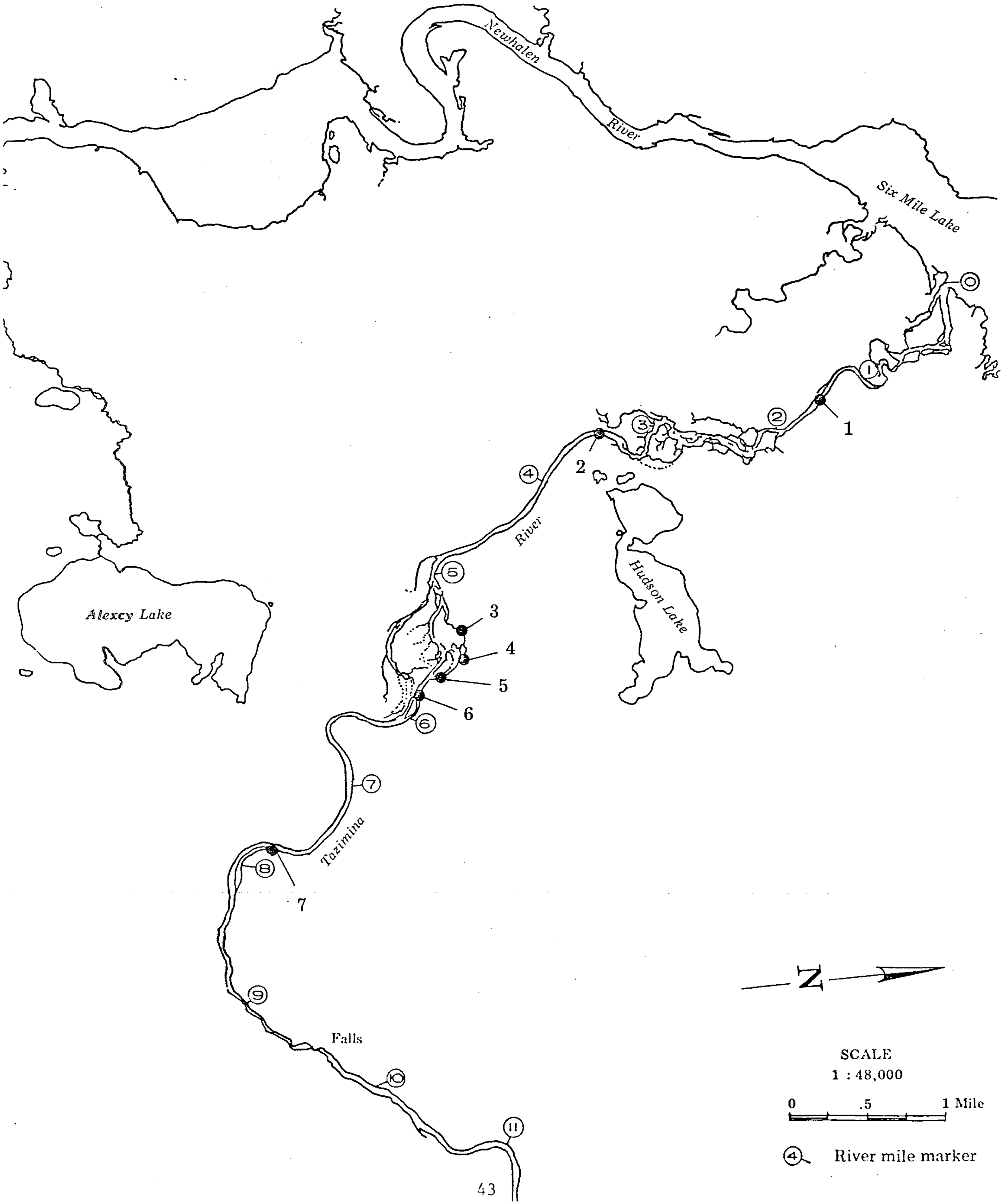
Sockeye salmon spawners selected areas which possessed rather specific hydraulic and substrate conditions. Spawners were observed in areas with mean column velocities which ranged from 0.2 to 4.4 fps and in depths which ranged from 0.6 to more than 4.5 ft. The majority of fish was observed in water flowing at 0.5 to 1.5 fps and in depths ranging from 1.0 to 2 ft. Dominant substrate particle size ranged from 0.25 to 4 in. Fish were observed over substrates with up to 40 percent sand, but generally appeared to use areas with 1- to 3-in gravels and less than 10 percent sand.

A literature review was conducted to determine the applicability of published habitat criteria to evaluate sockeye salmon spawning habitat in the Tazimina River. Results of this survey indicated that published criteria are not transferable to the Tazimina River. Measurements collected in the Tazimina River indicate that Tazimina River sockeye salmon use a broader range of habitat values than those expressed in published sources (Burgner 1951; Chambers, Allen, and Pressey 1955; Bovee 1978; Hoopes 1962). Should application of the incremental method of instream flow assessment be undertaken, field investigation to develop habitat suitability criteria should be conducted as an integral part of the assessment.

CHANNEL GEOMETRY AND INCUBATION SUCCESS

A major factor influencing the survival of fertilized sockeye salmon eggs is the potential of low winter streamflows to dewater redds. Normal streamflows during the spawning season provide easy

Figure 20. Sampling locations for characterization of sockeye salmon spawning habitat.



access to spawning habitat along the stream margins and throughout the braided river segments. Midwinter water surface elevations drop appreciably below those present during the spawning season. As a result, spawning areas along the stream margins and in the braided segments may become dewatered. If not maintained by some subsurface source, intergravel flow through these spawning areas would cease, and the incubation success within these streambed gravels would be substantially reduced.

The differences in the cross-sectional shapes and streambed profiles of the braided and single-channel segments are important to recognize when evaluating the effects of changes in river stage on incubating eggs and alevins. The single-channel segments of the mainstem possess a near uniform gradient and rectangular cross-sectional shape. Only at a few river bends and isolated scour holes near debris jams does the cross-sectional shape and streambed profile change. Therefore, a substantial change in water surface elevation may result in no appreciable loss of wetted perimeter.

Streambed gradients within the braided segments are nonuniform and the cross-sectional shape of the channel quite irregular. Small changes in water surface elevation can result in significant reductions in wetted perimeter. Streambed elevations at the upstream ends of the side channels within the braided segments are generally higher than those of the main channel in the braid. Thus, as streamflows recede, spawning areas in the head end of side channels are potentially the first to become dewatered and theoretically the most vulnerable to dessication and freezing.

During October 1981, mainstem Tazimina River streamflows were in the range of 650 cfs. Few side channels observed were completely dewatered, but many were no longer connected at their upper end to the mainstem by surface flow. The upper reaches of these side channels were dry or contained isolated pools of standing water with streamflows reappearing in the lower reaches. This indicates that significant intergravel flow enters these side channels from either a local aquifer or the mainstem river. Some spawning areas were dewatered in the upper portions of these side channels. Spawners had been observed here, but no redds could be located by digging in the dewatered areas. Portions of the side channels that held the largest number of adult spawners in August were still covered by flowing water under a discharge of 650 cfs. Groundwater inflow is suspected of maintaining intergravel flow at some of these locations even though the stream channel may be dry during winter months. However, it is not known if these flows are sufficient to support embryo development.

STREAM TEMPERATURE AND INCUBATION

Intergravel water temperatures directly influence embryo development, and in many areas of the Tazimina River intergravel temperatures appear to be directly related to stream temperatures. A data collection program was initiated to determine the existing thermal regime and the interrelationship between intergravel and stream temperatures in the Tazimina River (refer to Figure 8).

Few data are presently available to describe this relationship between stream temperatures and incubation success. Field data collected during the 1981 field season indicated that when the eggs were deposited in the gravels (late August), stream temperatures ranged from 10 to 11°C. Little diurnal fluctuation was observed in stream temperatures. Temperatures remained relatively constant through mid-September and then decreased rapidly. Eggs were not exposed to temperatures below 4.5°C until 30 days after fertilization (September 30). Hence, under the existing thermal regime, it does not appear that eggs would suffer from deformity or mortality associated with low temperatures.

RELATIONSHIPS BETWEEN MOPRHOLOGIC AND HYDROLOGIC CHARACTERISTICS AND RESIDENT FISH

Rainbow trout and Arctic grayling are present in the Tazimina River in considerable numbers. Data on the seasonal distribution and habitat use patterns of resident fish in the Tazimina River are sparse. Relationships between the biologic requirements of resident species which inhabit the lower Tazimina River and the river's geomorphologic and hydraulic characteristics can only be generally discussed. Since our field studies were not initiated until late July, spawning areas were not located. At present only generalizations about streamflow and stream channel characteristics as they relate to spawning habitat and incubation success can be provided for these species. Little is known about the specific location of areas used by immature fish within the lower 9.5 miles of the Tazimina River. Thus, this report is limited to subjective statements about the availability or quality of rearing habitat in relation to morphologic or hydraulic characteristics of the various river segments.

Rainbow trout probably spawn in suitable habitats which exist throughout the lower Tazimina River. Few spawners were located in a 1974 ADF&G survey of the lower 5 miles of the river (ADF&G 1974). However, Dames and Moore collected young-of-year trout in the canyon (RM 8.8), near RM 5.5, and near RM 7.5 indicating spawning activity had occurred in these vicinities.

Due to the large size of the rainbow trout which inhabit the Tazimina River, Isakson (pers. comm.) suggested that the habitat suitability criteria developed by the U.S. Fish and Wildlife Service's Cooperative Instream Flow Group (IFG) for Pacific Northwest steelhead spawners might be used to evaluate rainbow spawning habitat in the Tazimina River. Discussions with the ADF&G area biologist indicate that the depth and velocity criteria curves developed by IFG generally represent the range of habitat values utilized by rainbow trout spawners in the Iliamna area (Russell, pers. comm., Bovee 1978). The IFG substrate criteria were determined to be unsuitable for application to the Tazimina River due to their lack of resolution.

If rainbow trout spawning habitat were to be assessed by the incremental method of instream flow assessment, field investigations to verify the applicability of the depth and velocity ranges expressed in the IFG curves and to determine the preferred range of depth and velocity values for Tazimina River rainbow trout spawners would be required. In addition, river specific habitat preferences with respect to substrate curves should be developed.

Rearing areas for young trout can principally be divided into two types: mainstem and side-channel habitats. Rearing habitats in the mainstem are generally confined to low-velocity areas along the river margins and scour holes with debris jams. These habitats appear to be available over a fairly wide range of streamflows. As the stage drops, low-velocity areas associated with the stream margins are still present. In some cases they may be further away from the streambank. The habitat associated with the scour holes is also relatively stable over a wide range of flows. These areas would become unsuitable for small fish in high flows as the velocities would increase greatly.

Side-channel rearing habitat fluctuates in relationship to mainstem discharges. At moderate and high flows, low-velocity areas are quite abundant within the braided reaches due to the backwater effects near the numerous junctions of merging side channels. As the stage in the river recedes the size of these low-velocity areas is reduced. At low flows during the open-water season, the upper portions of the side channels dewater. Generally, flow reappears in the lower two-thirds to one-half of the side channel. Velocities are generally low when the head of the side channel is not connected to the mainstem river. Thus it appears that rearing habitat is present over a wide range of flows.

Arctic grayling reportedly use the side channel areas of Six Mile Braid and Hudson Braid for spawning. They tend to occupy areas with small, sandy substrates (Russell, pers. comm.) Information regarding the general relationships between various life history stages of Arctic grayling and selected habitat variables were summarized by ADF&G (Krueger, 1982). This summary provides valuable descriptive information on the range of morphologic and hydraulic conditions which are often utilized by various life stages of Arctic grayling. Unfortunately, this information is not appropriate for development of habitat suitability criteria since the data were collected for other purposes by several individuals using a variety of different field techniques. Should habitat suitability criteria be desired for application to the Tazimina River in the near future, a specific field study would be required to establish the relationship between spawning grayling and relevant physical habitat variables.

ANTICIPATED DOWNSTREAM EFFECTS OF THE RUN-OF-RIVER HYDROELECTRIC DEVELOPMENT

This section of the report presents a conceptual discussion of the generic effects which operation of a proposed 1200 kilowatt, run-of-river hydroelectric development may have on the fishery resources in the lower 9.5 miles of the Tazimina River. It is based on the professional judgement of the authors, very limited field data, and only a preliminary understanding of the river and its fishery resources. The discussion is not intended to serve as an impact assessment. Its purpose is to identify changes in fish habitat that are likely or unlikely to occur as a result of project operation, present a plausible description of these changes, and discuss their possible effects on the fishery resources.

The proposed run-of-river project would withdraw water from behind a small diversion dam near RM 9.6 and discharge it through a powerhouse at the base of the falls, RM 9.3 (Figure 21). Average monthly generating flows would range between 58 and 111 cfs with diversions to meet peak monthly power demands ranging as high as 166 cfs. This development concept meets projected energy needs of Iliamna, Newhalen, and Nondalton for the year 2000 (Critikos, pers. comm.).

ABOVE THE POWERHOUSE

PHYSICAL CHARACTERISTICS

Streamflow

Average monthly streamflows in the Tazimina River are estimated to range between 500 and 2000 cfs during the open-water season and approximately 200 cfs during the winter months (Figure 22). Streamflow diversions to meet generating requirements for the proposed run-of-river project would reduce average monthly streamflows through a 0.25-mile river segment between the falls and the powerhouse at RM 9.3. Under postproject conditions long-term average monthly streamflows would be reduced from 3 to 7 percent during the period

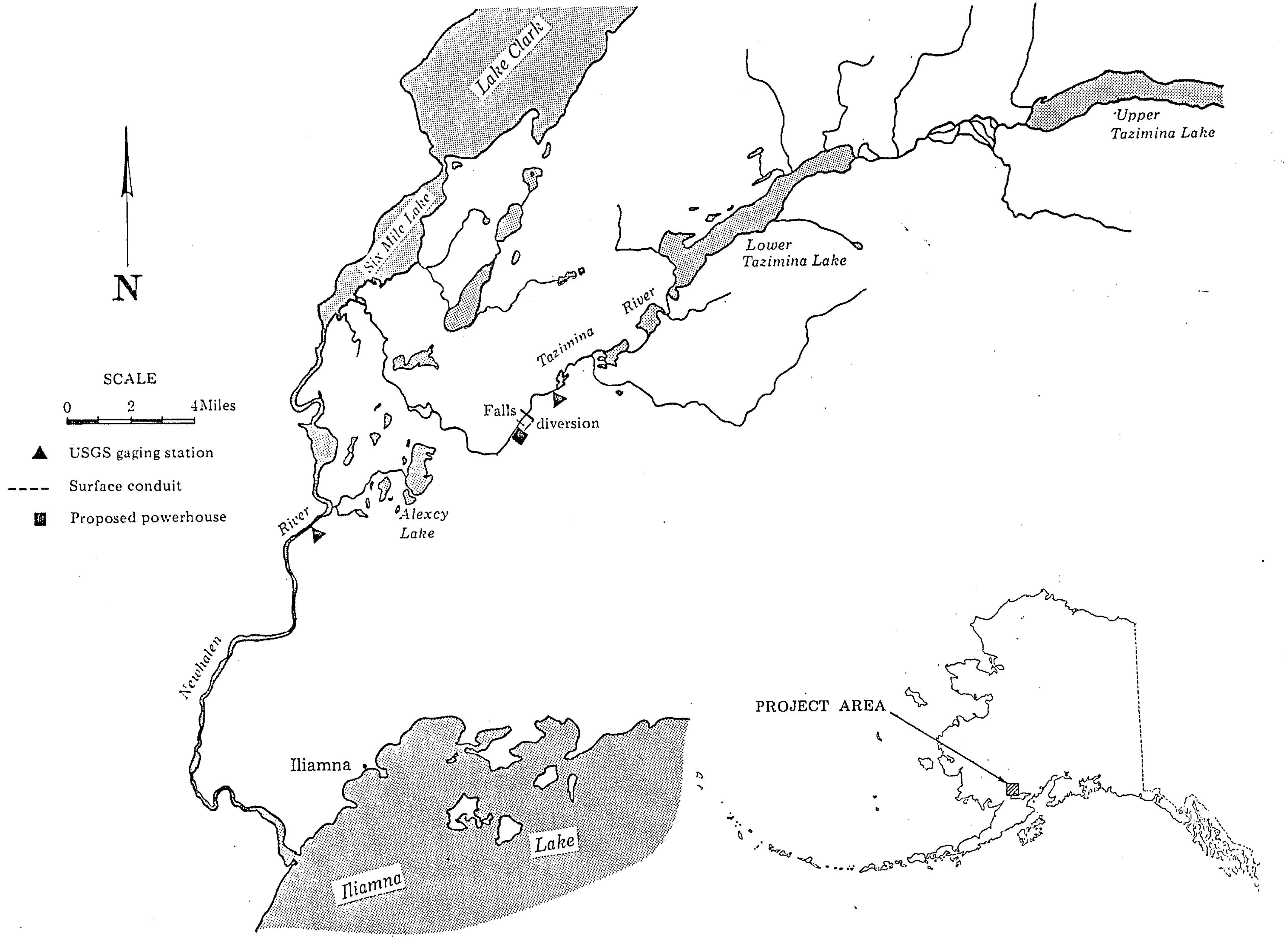


Figure 21. Location of project facilities for run-of-river scenario.

Figure 22. Pre- and postproject streamflows (cfs) for run-of-river development.

Month	Pre-project	Generating Flow*		Postproject Flow above powerhouse		% Reduction pre- to postproject		Postproject flow below powerhouse
		Avg.	Peak	Avg.	Minimum	Avg.	Peak	
January	255	105	139	150	105	41	59	255
February	200	111	139	89	61	55	70	200
March	180	89	132	91	48	49	73	180
April	180	83	111	97	69	46	62	180
May	565	74	111	491	454	13	20	565
June	1680	65	69	1615	1611	4	4	1680
July	1995	58	76	1937	1919	3	4	1995
August	2090	72	138	1948	1952	7	7	2090
September	1260	87	125	1173	1135	7	10	1260
October	770	94	139	676	631	12	18	770
November	600	105	145	495	455	17	24	600
December	340	105	166	235	174	31	49	340
Average Annual	843	87	124	750	718	N/A	N/A	843

*Critikos, pers. comm.

June through September, 13 percent in May, and 12 percent in November. Due to the steep rapids and adjoining pools which exist in this portion of the river canyon, reductions in streamflow of such magnitudes are not anticipated to significantly change the range of depths and velocities normally found in this reach during this period of the year.

The most significant reduction in average monthly streamflows (31 to 55 percent reductions) would occur between early December and late April. The effect of these decreases in winter streamflows on habitat conditions in the upper river canyon is difficult to forecast due to the synergistic effects of ice cover on depths and velocities. The presence of ice in a river channel causes a backwater effect (staging) which results in slower velocities and greater depths than would otherwise be associated with a given streamflow. Although not observed, the formation of slush ice and anchor ice probably is an annual occurrence in the Tazimina River canyon. This would result in a greater depth of flow (perhaps notably greater) than would exist for a similar discharge during the open-water season. Presently the magnitude of the increase in depth caused by ice under preproject conditions is unknown.

Reduced postproject streamflows might increase the formation of anchor and slush ice in the Tazimina River canyon. Since the magnitude of backwater effects associated with pre- and postproject icing conditions is not known, it is impossible at this time to determine if the postproject winter depths would increase or decrease.

Water Temperature

Since a storage reservoir would not be constructed as part of the proposed run-of-river project, stream temperatures would not be influenced by an upstream impoundment.

Stream temperature is mainly influenced by solar radiation, surface area of the stream, and ambient air temperature. Reach velocity would only become an important influence on stream temperature if very large changes in streamflow are involved. The proposed powerhouse diversions would have only a minor effect on the surface area and reach velocity of the 0.25 mile river segment during the period May through September, so no changes in stream temperature in the river canyon.

Although no data have been reviewed, present winter stream temperatures in the canyon area are expected to be near zero. Thus the proposed reductions in winter streamflow through the 0.25 mile reach of canyon is not expected to result in substantially colder midwinter stream temperatures. However, reduced streamflows during the period October through December likely accelerate the cooling process, causing stream temperatures in this portion of the canyon to reach 0°C and ice to begin forming in the channel somewhat earlier in the year.

Water Quality

Proposed 58 to 139 cfs powerhouse diversions during the open-water season (when average monthly streamflows range between 500 and 2,000 cfs) are unlikely to so reduce stream velocities that existing water quality conditions (toxicants or nutrients) would be affected. To date, no dissolved gas measurements have been made in the river in the canyon below the falls; hence, it is not known whether or not a gas supersaturation problem presently exists. Nonetheless, powerhouse diversions would result in such a small reduction in natural flow over the falls that naturally occurring postproject dissolved gas levels probably would not change.

Sediment Transport and Channel Geometry

The run-of-river project would probably have little effect on reducing peak flows or increasing sediment input to the river. In other words, it would not be expected to affect the naturally occurring processes which determine the cross-sectional shape and substrate composition of the river channel.

FISHERY RESOURCES

Minor changes in habitat utilization may result from physical changes which are likely to occur in this reach from project operation, but they are not expected to significantly alter fish production in the canyon (RM 8.3 to 9.5). Since the diversion would alter streamfows by such a small percentage, little change is expected in the availability or utilization of the habitat in the upper canyon during the open-water season. Greater changes are anticipated in the winter. Because of the seasonal habitat use patterns, the changes would probably cause only minor changes in utilization of this reach.

Sockeye Salmon

Sockeye salmon spawning habitat in this reach appears severly limited by the lack of suitable substrates and few spawners were observed during the 1981 field season in the canyon. During the spawning season, depths and velocities are not expected to change appreciably and water temperatures and dissolved gas levels should remain unchanged from preproject conditions. Utilization by spawners is not expected to change from preproject levels.

The effect of the project on incubation success is the canyon cannot be predicted. In the fall, low flows naturally dewater the stream margins probably exposing any eggs present to dessication and freezing. Due to the large amount of exposed bedrock in the canyon walls and river channel, it seems unlikely that intergravel flows would be maintained by groundwater infiltration. Spawning which may occur in deeper portions of the channel would probably be more successful as these areas are not naturally dewatered and are unlikely to dewater under postproject conditions. Because of the inability to estimate the depth of flow in the river canyon when the river is ice-covered (for both pre- and postproject), the effects of a 31 to 73 percent reduction in midwinter streamflow on incubation success cannot be identified.

Postproject stream temperatures are not expected to differ much for preproject temperatures during much of the year. Stream temperatures are likely to cool to near 0°C earlier in the fall (October to November), which may affect embryo development. Colder water temperatures may slow the development process and delay hatching and emergence. The consequences of these delays are unknown.

Emergence and outmigration generally occur in May and June. Powerhouse withdrawals are expected to reduce naturally occuring streamflows by only 4 to 14 percent. Thus, sufficeint streamflow is anticipated for fry transport in this reach.

Resident Fish

Field studies indicate that some rainbow trout spawning occurs in the canyon. However, spawning habitat in this reach appears to be very limited. Suitable spawning gravels are primarily restricted to a few deep holes and small isolated deposits behind boulders. Project development is not expected to significantly affect spring spawners (Figure 23). Streamflow reductions anticipated from mid-May through June are approximately 4 to 8 percent. These forecasted postproject streamflows would not result in substantially different depths and velocities over available spawning substrates. Neither stream temperature nor dissolved gas concentrations are expected to be influenced by the project during the period rainbow trout spawn. Thus habitat conditions which are normally present during May and June are not expected to be substantially the same under postproject conditions. Therefore, the run-of-river project would probably not influence rainbow spawning in the canyon.

Incubation occurs from the time of egg deposition (late May to June) until August. The 3 to 7 percent reduction in streamflow forecast for the period June through August is well within the range of natural streamflow variations. Changes of this magnitude are not expected to effect preproject hydraulic, morphologic, or water quality conditions. Thus, rainbow trout incubation is not expected to be adversely affected by the proposed run-of river development.

Rearing habitat in the canyon area is confined to narrow discontinuous zones along the stream margins and to isolated low velocity areas behind large boulders. The availability of rearing habitat in the canyon is about the same all year. The proposed powerhouse diversions would be unlikely to have a detectable influence on the availability or quality of rearing habitats during the period mid-May through October as the forecasted changes in average monthly streamflows would be too small to cause notable changes in the amount of shallow, low-velocity water along stream margins.

Under reduced winter flows, the availability of rearing habitat could change. At this time, however, the magnitude or direction of this change could not be predicted. Uncertainties regarding pre- and

Figure 23. Anticipated effects of the proposed Run-of-River Hydroelectric Development on fishery resources above the powerhouse (RM 9.3 to 9.5).

Species/Lifestage Affected	Downstream Effects Related to Changes in: stream flow	stream tempera-ture	sub-strate	channel morph-ology	water quality
SOCKEYE SALMON					
Spawners	0	0	0	0	0
Incubation/alevins	?	?	0	0	0
Emergence/outmigration	0	0	0	0	0
RAINBOW					
Spawners	0	0	0	0	0
Incubation	0	0	0	0	0
Emergence	0	0	0	0	0
Juveniles	?	?	0	0	0
Adults	?	?	0	0	0
ARCTIC GRAYLING					
Spawners	0	0	0	0	0
Incubation/alevins	?	?	0	0	0
Juveniles	?	?	0	0	0
Adults	?	?	0	0	0
ARCTIC CHAR					
Spawners	0	?	0	0	0
Incubation/alevins	?	?	0	0	0
Emergence	0	0	0	0	0
Juveniles	?	?	0	0	0
Adults	?	?	0	0	0

X effect likely

0 effect unlikely

? insufficient data for determination

postproject ice conditions in the river canyon and the overriding effect of ice on depth would make it impossible to draw any valid conclusions about whether the postproject river stage would be higher or lower than present midwinter water surface levels. During winter months immature rainbow trout probably spend a lot of time streambed gravels (Everest and Chapman 1972; Edmundson, Everest, and Chapman 1968; Bustard and Narver 1975). A reduction in midwinter streamflows could increase the amount of anchor and slush ice which forms in the canyon area, and, in turn, also increase overall fish mortality as more are frozen into the substrate and lost from the reproductive cycle.

Grayling have been found in the river canyon, but little information exists about their seasonal use of this area. If grayling spawn in the canyon, spawners would be present between late April and early May. The effect of decreased streamflows during this period on the availability of grayling spawning habitat cannot be forecast because of uncertainties about the location of such habitat and the effects of postproject ice conditions on river stage in the river canyon.

Field studies indicated that grayling may utilize the canyon only during the open-water season. Adult grayling were captured by angling in the canyon throughout the 1981 summer field season (none were captured in October). Physical characteristics of the canyon during the period May through November would not be expected to be markedly different under postproject conditions. Therefore, postproject use of the canyon by nonspawning adults probably would not differ significantly from that which presently occurs.

BELOW THE POWERHOUSE

The proposed run-of-river development would not alter the natural flow regime of the Tazimina River below RM 9.3 (refer to Figure 22). Consequently, it would not affect thermal characteristics, sediment transport, or water quality below RM 9.3. If streamflow, water quality, stream temperatures, and sediment transport characteristics were to remain essentially unaltered below the powerhouse, the run-of-river project would not be expected to perceptibly alter the availability or quality of fish habitat downstream of the powerhouse.

SUMMARY

The run-of-river plant probably would not alter naturally occurring streamflows or stream temperatures in the lower 9 miles of the Tazimina River. Any changes in the availability or quality of fish habitat in the lower 9.5 miles of the river could be expected to be confined to a .25 mile reach immediately below the falls (RM 9.3 to RM 9.5). This reach contains only a small amount (if any) of low quality sockeye salmon spawning habitat. Thus, project-induced changes in habitat conditions would not adversely affect sockeye salmon production in the lower Tazimina River.

An extremely small data base exists regarding seasonal use of the Tazimina River by resident species. Therefore, a definitive statement cannot be provided regarding effects of the proposed run-of-river development on rainbow trout, Arctic grayling, and Arctic char production in the lower 9.5 miles of the Tazimina River. However, on the basis of the authors' experience and familiarity with the lower river, it does not appear that anticipated changes in habitat conditions within the .25 miles of canyon would significantly affect resident fish populations of the lower river. Additional work would be required to ascertain the degree to which this reach within the river canyon is utilized by resident species.

ANTICIPATED DOWNSTREAM EFFECTS OF THE STORAGE RESERVOIR HYDROELECTRIC DEVELOPMENT

This section of the report presents a conceptual discussion of the generic effects operation of a hydroelectric development with a storage reservoir may have on the fishery resources in the lower 9.5 miles of the Tazimina River. It is based on the professional judgement of the authors, very limited field data, and on only a preliminary understanding of the river and its fishery resources. The discussion is not intended to serve as an impact assessment. Its purpose is to identify potential changes that are likely or unlikely to occur as a result of a proposed development, and discuss their possible effects on the fishery resource.

A 60-ft high dam would be constructed at RM 13.1 to impound water and provide regulation of streamflow from the upper two thirds of the Tazimina River basin. Water would be withdrawn into a closed conduit at the storage dam and pass through a powerhouse to be returned to the Tazimina River at approximate RM 8.3 (Figure 24). This 16-megawatt development would meet the projected energy demands of the Bristol Bay region through the year 2000 (Critikos, pers. comm.).

The proposed reservoir would provide approximately 300,000 acre feet of storage. During normal operation the reservoir is expected to fill by early August and remain at the full pool elevation of 690 ft through October. Draw-down would begin in November and continue through May. Streamflows in the 13 miles of river below the proposed dam would be altered throughout the year (Figure 25). The most significant change would occur in a 4.8 mile section between the dam and the powerhouse.

The impoundment would increase the surface area of Lower Tazimina Lake from 4,100 acres to 8,200 acres by inundating three existing pondages on the Tazimina River between the dam site and outlet to Lower Tazimina Lake and inundating the river upstream from the lake. The water surface elevation of Lower Tazimina Lake is expected to increase by 45 ft (from 645 to 690 ft).

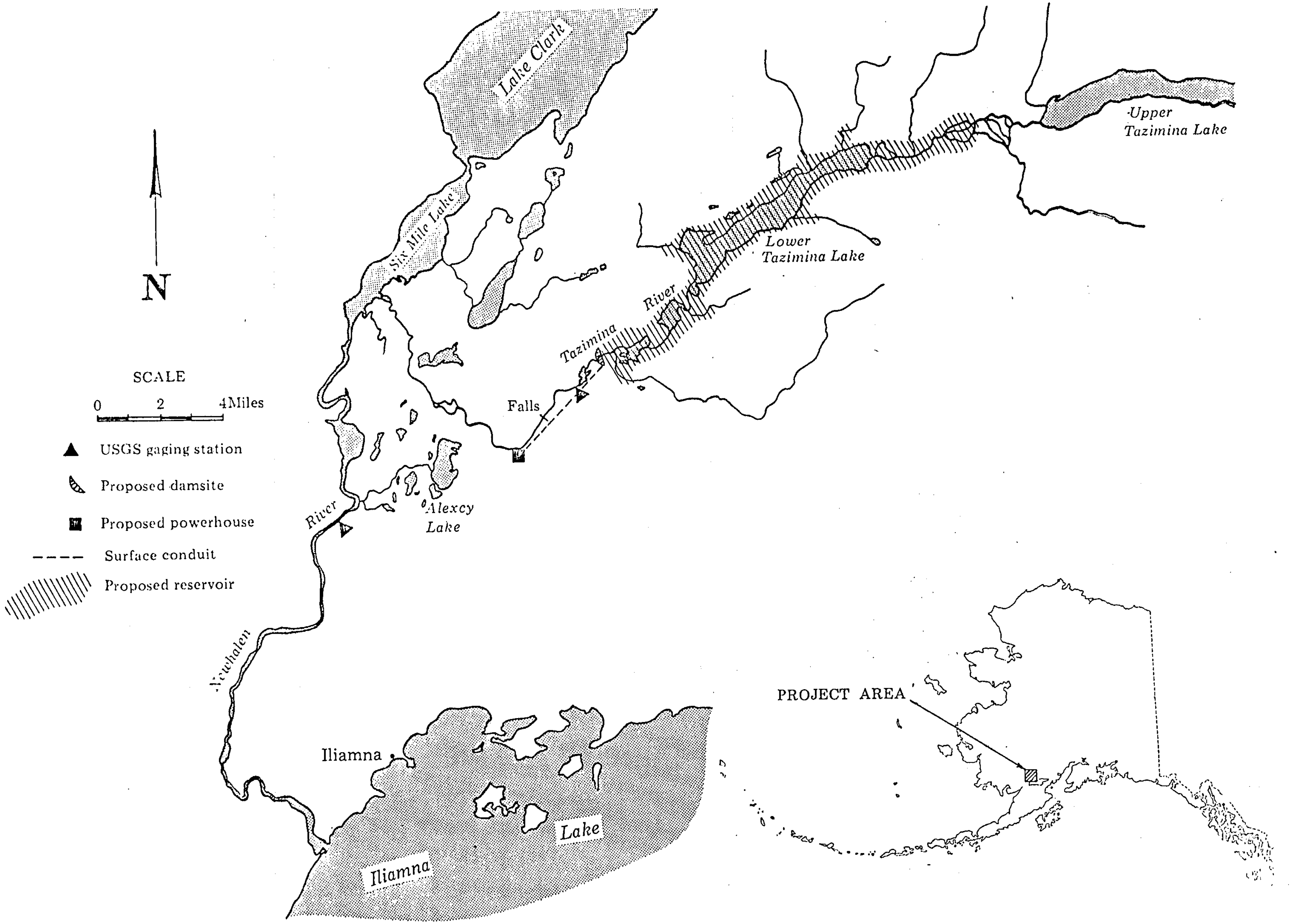


Figure Location of project facilities for storage scenario.

Figure 25. Pre- and postproject streamflows (cfs) for the proposed storage reservoir development.

Month	Preproject Streamflow	Generating Flow	Storage Flow*	Streamflow between Dam and Powerhouse	Streamflow below Powerhouse
January	255	663	- 408	0	663
February	200	669	- 469	0	669
March	180	570	- 390	0	570
April	180	597	- 417	0	597
May	565	639	- 74	0	639
June	1,680	806	+ 874	0	806
July	1,995	884	+1,111	0	884
August	2,090	710	+ 208	1,172	1,882
September	1,260	592	0	668	1,260
October	770	594	0	176	770
November	600	649	- 49	0	649
December	340	726	- 386	0	726
Average Annual	843	675	0	168	843

*Approximate live storage 133,000 acre/ft.

TAZIMINA RIVER CANYON

PHYSICAL CHARACTERISTICS

Streamflows

This development proposal would interrupt the natural streamflow through the Tazimina River canyon during nine months of the year (Figure 26). Water needed for power generation would be diverted around this river segment in a closed conduit to a powerhouse located near the mouth of the canyon. The river canyon is not expected to become completely dewatered, however. Several deep scour holes exist in the river canyon which would retain relatively large volumes of water even if streamflows were extremely small.

Surface runoff and groundwater inflow may also enter the river channel below the dam. However, streamflow measurements made during August and October 1981 indicate a negligible amount of flow accrues to the river between the USGS gage at RM 11.6 and the mouth of the river canyon at RM 8.3 (refer to Figure 7). Therefore, surface runoff is not expected to be sufficient to provide any significant amount of flow through the river canyon.

In addition, spills are expected from the reservoir during late summer and fall (August to October) which could provide appreciable but temporary flow in the river canyon. However, it is unlikely these spills would occur during low-runoff years.

Water Temperature

Since streamflows between the dam and the powerhouse would be significantly reduced (Figure 27), stream temperatures within the river canyon are likely to be affected.

The least amount of change in stream temperatures is expected to occur during winter months. Although no data have been reviewed, pre-project winter stream temperatures in the canyon area are expected to be near zero. The proposed reduction in winter streamflow through the canyon is not expected to result in substantially colder midwinter stream temperatures. However, reduced streamflows during the period October through December are likely to accelerate the cooling process, causing stream temperatures in the canyon to reach 0°C and ice to begin forming in the channel somewhat earlier in the year.

The reduction of streamflows during May and June are likely to result in the ice cover remaining in the river canyon longer because it would have a greater tendency to melt off rather than being washed out during breakup runoff. June water temperatures are likely to be warmer because of the solar heating of a rather tranquil reach.

Figure 26. Anticipated effect of the proposed storage reservoir development on preproject streamflow in the Tazimina River canyon.

Month	Preproject Flow cfs	Postproject Flow cfs	Percent Reduction
January	255	0	100
February	200	0	100
March	180	0	100
April	180	0	100
May	565	0	100
June	1,680	0	100
July	1,995	0	100
August	2,090	1,172	44
September	1,260	668	47
October	770	176	77
November	600	0	100
December	340	0	100
Average Annual	843	168	80

Spills expected during August would wash the warmer water from the canyon and probably provide stream temperatures which are not too different from present August temperatures. Insufficient data have been obtained to provide a more quantitative statement.

FISHERY RESOURCES

Sockeye Salmon

Lack of suitable spawning substrates is probably the major factor limiting sockeye spawning in the canyon area. Spawning may occur in the suitable substrates present along stream margins and in deep scour holes, but few spawners were observed in the canyon during 1981 field studies. During the period August through October, flowing water would be present in the canyon and projected postproject flows would probably be sufficient to provide habitat similar to present conditions. Streamflow reductions during the period August through September would not appreciably change depths and velocities over the available spawning substrates in this river segment. Reduced streamflows may dewater some lateral margins and lower velocities in some areas of high velocity. Sockeye salmon spawners would have access to suitable spawning habitat in scour holes and most lateral areas along stream margins similar to present conditions. During this period water temperatures and dissolved gas levels could also be expected to remain unchanged from preproject conditions. Thus habitat conditions for spawners are not anticipated to change significantly.

Successful incubation of sockeye salmon eggs in the canyon under postproject conditions appears unlikely. However, present incubation sucess in this area is probably limited. Low flows during fall naturally dewater the stream margins, probably exposing any eggs present to dessication and freezing. Due to the large amount of exposed bedrock in the canyon walls and river channel, it seems unlikely that intergravel flow could be maintained by groundwater infiltration. Spawning that might occur in deeper portions of the channel would probably be more successful, as these areas are not dewatered under natural conditions. During the period from November through July, the scour holes are expected to become deep tranquil pools connected by only a trickle of surface water or perhaps completely isolated from the lower river. It is not known if the flow would be sufficient for incubation in the scour holes. Most of the lateral spawning areas would be dewatered.

If some incubation were successful, outmigration of emergent fry would likely be delayed until August spills provided access to the lower Tazimina River. Outmigration generally occurs in May and June. Small numbers of sockeye fry were seen in the river as late as July 28, 1981. The effects of delaying outmigration are not known. But the loss of the canyon habitat is not expected to significantly reduce sockeye salmon production in the Tazimina River due to the small amount of spawning which naturally occurs in the canyon area and the limited incubation success.

Resident Fish

Field studies indicated that some rainbow trout spawning occurs in the canyon, although spawning habitat in this reach appears to be very limited. Suitable spawning substrates are primarily restricted to a few deep holes and small isolated deposits behind boulders. No evidence of grayling spawning was discovered. Under postproject conditions rainbow trout and grayling would not have access to the Tazimina River canyon during their spawning season (May-June).

Suitable rearing and feeding areas may be present from November through July in the deep tranquil pools likely to be in the canyon. However, due to the seasonal movement patterns of rainbow and grayling, little use is expected of these areas. In June and July, when resident fish are migrating upstream to summer feeding areas, the canyon probably would not be accessible. Under the proposed operating scenario, access to the canyon would likely exist only from August through October. Resident fish accompanying the sockeye spawners could enter the canyon and utilized rearing and feeding areas. Both rainbow trout and grayling were observed in the canyon in summer 1981. Field observations during that fall indicated that resident fish appear to travel downstream to overwintering areas. Few fish would be expected to remain in the canyon. Thus, under postproject conditions, seasonal movement patterns would preclude use of the rearing habitat which may be present in the canyon from November through July.

In the limited field studies, no information has been collected to indicate that Arctic char utilize canyon habitats. Due to similarites in seasonal-use patterns Arctic char, if present, would be affected in a somewhat similar manner as sockeye salmon for spawning and incubation (see preceding section). The delay in outmigration would likely have a minimal effect on young Arctic char which feed mainly on aquatic insects.

Figure 27 summarizes anticipated effects of the proposed storage reservoir development on the fishery resource of the Tazimina River canyon.

Figure 27. Anticipated effects of the proposed storage reservoir on fishery resources within the Tazimina River canyon RM 8.3 to 9.5.

Species/Lifestage Affected	Downstream Effects Related to Changes in: stream flow	stream temperature	substrate	channel morphology	water quality
SOCKEYE SALMON					
Spawners	0	0	0	0	0
Incubation/alevins	X	?	0	0	?
Emergence/outmigration	X	?	0	0	?
RAINBOW					
Spawners	X	–	–	–	–
Incubation	–	–	–	–	–
Emergence	–	–	–	–	–
Juveniles	?	?	0	0	?
Adults	?	?	0	0	?
ARCTIC GRAYLING					
Spawners	X	–	–	–	–
Incubation/alevins	–	–	–	–	–
Juveniles	?	?	0	0	?
Adults	?	?	0	0	?
ARCTIC CHAR					
Spawners	0	0	0	0	0
Incubation/alevins	X	?	0	0	?
Emergence	X	?	0	0	?
Juveniles	?	?	0	0	?
Adults	?	?	0	0	?

X effect likely

0 effect unlikely

? insufficient data for determination

– not applicable

DOWNSTREAM OF THE POWERHOUSE

PHYSICAL CHARACTERISTICS

Streamflow

Although the long-term average annual streamflow in the lower 8.3 miles of the Tazimina River would remain unchanged, the proposed storage reservoir facility would have an appreciable effect on seasonal streamflows (Figure 28). Streamflows below the powerhouse would be reduced by more than 50 percent (from 1,800 to 850 cfs) during June and July. Midwinter streamflows would increase by 200 percent (from 200 to 600 cfs). Streamflows below the powerhouse from December through April would be very close to actual generation flows, since very little natural flow could be expected through the river canyon during winter. Any daily peaking or weekly base loading that might occur would be directly evidenced as an immediate change in downstream flow patterns.

Field investigations during October 1981 documented the inflow of approximately 50 cfs of groundwater in the Alexcy Braid, which is probably important in maintaining winter base flows in the lower river. Postproject generation flows during winter months would negate the importance of groundwater inflows for maintaining streamflow in the single-channel segments. It is also quite likely that they would result in increased subsurface inflow to the side channels in the braided river segments.

Summer streamflows below the powerhouse would be the sum of the powerhouse outflows plus the streamflow at the mouth of the Tazimina River canyon. Generally, powerhouse outflows would not be expected to influence daily or weekly streamflow patterns during summer months to the same degree as they might during winter months. The forecasted reservoir spills during August and September would be large enough to buffer effects of reasonable (±15 percent) changes in daily generating flows. Surface runoff and groundwater inflow might also enter the river channel below the dam site, though discharge measurements made during August and October 1981 indicated that a negligible amount of flow accrued to the river between the USGS gaging station at RM 11.6 and the mouth of the canyon at RM 8.3 (refer to Figure 7).

Figure 28. Effect of the proposed storage reservoir development on preproject streamflow below the river canyon (RM 0 to 8.3).

Month	Preproject Flow cfs	Postproject Flow cfs	Percent Reduction
January	255	663	+ 160
February	200	669	+ 235
March	180	570	+ 217
April	180	597	+ 232
May	565	639	+ 13
June	1,680	806	- 52
July	1,995	884	- 56
August	2,090	1,882	- 10
September	1,260	1,260	0
October	770	770	0
November	600	649	+ 8
December	340	726	+ 114
Average Annual	843	168	80

Because the single-channel sections of the Tazimina River are relatively uniform in gradient and rectangular in cross section, large changes in streamflow would have relatively little effect on the top width or wetted area of the channel (Figure 29). The most apparent changes would be associated with depth and velocity.

Hydraulic characteristics associated with flow in the side-channel braids of the Tazimina River are influenced by changes in mainstem streamflow. During the 1981 field season aerial surveys, staff gage readings, and streamflow measurements were made for use in

Figure 29. Comparison of hydraulic parameters from discharge measurements in a single channel segment of the Tazimina River.

Date 1981	Streamflow cfs	Top width ft	Average Velocity fps	Average Depth ft	Flow Area sq ft	Wetted Perimeter ft
Aug 11	2,415	223	4.3	2.5	557	228
Aug 29	1,582	217	3.7	2.0	429	221
Oct 13	664	214	2.3	1.3	284	216

determining the discharge required to maintain surface flow from the mainstem into the side-channel braids.

Because of its apparent susceptibility to being dewatered, a principal side channel within the Alexcy Braid was selected as a study channel. Staff gage readings and discharge measurements were periodically obtained to describe flow conditions in this side channel at corresponding levels of flow in the mainstem (Figure 30). As mainstem flow receded in September this side channel was one of the first to be cut off from the mainstem at its upstream end. Overflights during the

Figure 30. Comparison of Alexcy Braid side channel flow to Tazimina River streamflows.

Date 1981	Side channel Gage Height (ft)	Side channel Flow (cfs)	Tazimina USGS Gage (cfs)
July 26	1.25	118	2,400
August 11	1.24	105	2,380
August 12	1.28		2,460
August 17	1.40		2,840
August 19	1.34		2,470
August 28	0.44	8.9	1,500
August 29	0.35		1,450
September 21	Dewatered		718
September 25	Dewatered		654
October 13	Dewatered		493
October 19	Dewatered		556

October 13-19 field study indicated that numerous side channels in the Alexcy and Hudson braids were either flowing or wetted by intragravel seepage and ponded water but the study channel in the Alexcy braid was substantially dewatered. On the basis of the field measurements and observations made during 1981, it appears that mainstem streamflows of 1,000 cfs would provide streamflow throughout most of the existing side channels in the braided segments of the Tazimina River. Mainstem streamflows in excess of 600 cfs would provide backwater effects and stimulate intragravel seepage sufficient to prevent most of the side channels from being significantly dewatered.

No winter field investigations have been conducted, so the degree to which side channels currently dewater during winter months is unknown. However, field observations and streamflow measurements made during October strongly suggest that groundwater inflows maintain base flow in many of the side channels (refer to Figure 17).

Stream Temperature

Although very few temperature data are available for the Tazimina River, winter stream temperatures are probably near zero, and intragravel water temperatures are between 0 and 4°C. Stream temperatures recorded during summer 1981 ranged from 8 to 12°C (refer to Figure 11). The proposed reservoir would be expected to narrow the overall range between existing winter and summer stream temperatures.

The proposed dam would increase the surface area of Lower Tazimina Lake from 4,100 to 8,200 acres and provide a live storage volume of approximately 133,000 acre/ft. The reservoir is expected to be at high pool elevation from August through October and at low pool elevation in May. Depending upon the previous year's snowfall and the amount of carry-over in storage, this would represent a reservoir drawdown of approximately 35 ft.

Solar radiation, wind action, and summer inflow to the reservoir could be expected to provide sufficient mixing action in the upper 35 to 40 ft of the reservoir to maintain midsummer water temperatures quite similar to present water temperatures in the upper 35 feet of Lower Tazimina Lake. Lake temperature profiles obtained during August 1981 indicated that little change occurs in water temperature within the upper 40 to 45 ft of Lower Tazimina Lake (refer to Figure 13). Thus, stream temperatures below the proposed dam during midsummer and early fall are expected to remain similar to preproject stream temperatures (in the 8 to 12°C range).

The proposed operating schedule indicates that the reservoir would remain nearly full through October. Based on information from other studies, water temperatures during September and early October at depths of 30 to 40 ft would probably not differ significantly from August water temperatures at these same depths. Controlled spills forecast for September and October are expected to principally draw water off the reservoir surface. These spills would flow through 4.8 miles of the natural river channel before mixing with water being discharged from the powerhouse at R.M. 8.3. During September these spills comprise a significant percentage of the total streamflow below the powerhouse. Postproject stream temperatures in the lower 8 miles of the river during September should remain similar to preproject temperatures. The controlled spills are expected to decrease in October. Therefore, a greater percentage of the streamflow below the powerhouse would originate at a depth of 35 ft beneath the reservoir surface. As a result, stream temperatures in the lower 8 miles of the Tazimina River are expected to be slightly warmer during October.

No spills are expected after October and streamflow in the lower 8 miles of river would result from powerhouse outflow. During November reservoir temperatures could be expected to be in a state of flux as surface water temperatures cool and the reservoir stratifies. Near the reservoir outlet water temperatures would probably range between 4 and 6°C. Stream temperatures immediately below the powerhouse would also be in this range, perhaps cooling to between 2 and 4°C near the river mouth.

During winter lake temperatures cool and, theoretically, stratify with surface water temperatures near zero and the underlying water at 4°C. However, some evidence exists in the literature which indicates subarctic lakes are isothermal (near 2°C) to depths in excess of 100 ft during winter even though ice-covered (LaPerrier and Casper 1976, AEIDC 1980, U.S. Army Corps of Engineers 1978).

Hence, winter (January to April) stream temperatures immediately below the powerhouse would also be in the range of 2°C, possibly cooling to 0°C near the mouth of the river. By late April the reservoir would normally be drawn down to a level at which the relatively thin layer of colder surface immediately beneath the lake ice cover could enter the outlet. If cold water temperatures occur they would most likely be present during April and May when the reservoir would be at its lowest elevation. Some degree of mixing would likely occur in the reservoir near the outlet, thus, it is doubtful that the temperature of the powerhouse outflows would suddenly drop from 2°C to zero. During this period the temperature of powerhouse outflows might be 1°C with stream temperatures near the mouth of the river possibly ranging between zero and 2°C.

A very limited data base is currently available to describe the existing thermal regime of the Tazimina River or to discuss anticipated postproject stream temperatures. Additional lake, stream, and intragravel temperature data would be required. A thermodynamic analysis of the reservoir and downstream temperatures could be undertaken to confirm or modify the various hypotheses discussed above.

Water Quality

Other than its effects on water temperature, the proposed storage reservoir probably would not significantly alter downstream water quality conditions (dissolved solids, gases, and nutrients).

Due to the flooding of forest soils within the impoundment zone, seasonal dissolved solids concentrations in Lower Tazimina Lake could be expected to increase from preproject concentrations after the initial filling period, then (over time) return to approximate preproject concentrations. Dissolved solids concentrations presently are 20 to 30 mg/l (refer to Figure 16). A fiftyfold increase would be required before state water quality standards (1,500 mg/l) for salmon streams were exceeded (Alaska Dept. of Environmental Conservation 1979).

Dissolved gas concentrations during midsummer have been measured near saturation levels (10 to 11 mg/l) throughout the Tazimina River-Lake system (refer to Figure 15). Although oxygen consumption during summer months within the new reservoir would likely be greater than current summer consumption levels within Lower Tazimina Lake, dissolved oxygen levels would probably not fall below the state standard of 7 mg/l (L.A. Peterson, pers. comm.). Presently, gas supersaturation is suspected to periodically occur in the Tazimina River below the falls, although no field measurements have been made to confirm this hypothesis or document that its occurrence has an adverse effect on fish within the river canyon. Construction of the proposed storage reservoir would greatly reduce flow over the falls, thereby reducing the potential for gas supersaturation problems to occur in the canyon.

Because of the large volume of organic material that would be inundated by the proposed reservoir, dissolved nutrient concentrations within the reservoir after filling are expected to be substantially higher than current midsummer levels in Lower Tazimina Lake (L.A. Peterson, pers. comm.). Analysis of water samples from Lower Tazmina Lake indicated that August 1981 dissolved nutrient concentrations were very low (refer to Figure 16). Severalfold increases in these concentrations would not be expected to be detrimental to aquatic habitat (Peterson, pers. comm.).

Sediment Transport and Channel Geometry

In general, the impoundment of a river results in a reduction of peak streamflows and disruption of the basin's sediment transport process. If any significant amount of sediment is normally transported by the river, disruption of the sediment transport regime by the impoundment usually results (over time) in a notable change in the existing substrate composition or stream channel geometry. Depending upon the nature and magnitude of the change, it can be viewed as being either detrimental or beneficial to existing habitat conditions.

The stream channel geometry and substrate composition of the lower Tazimina River are current products of an impounded river with a very limited sediment source. Construction and operation of the proposed storage reservoir in itself is not expected to alter this situation.

Based on August 1981 measurements, Lower Tazimina Lake presently traps approximately 80 percent of the suspended sediments entering from the upper basin and a negligible concentration of fines exists in the lower 2 miles of river during high flow events (refer to Figure 16). Hence, there is little likelihood that the proposed reservoir would significantly disrupt the sediment transport process or result in a notable change in substrate composition within the lower 9.5 miles of river.

The effects of annual fluctuations of the reservoir surface and associated wave action on beach erosion are unknown. Incidental field observations in the upper basin suggest that local soils are quite shallow and overlie coarse glacial deposits. In such a case, it is unlikely that shoreline erosion would be very extensive or that suspended sediment concentrations in the outflow from the Lower Tazimina Lake would be substantially increased from preproject concentrations. Further investigation of soil conditions within the impoundment area is warranted.

Peak daily streamflows of the lower Tazimina River are presently muted by existing lakes and pondages in the Tazimina River basin (refer to Figure 6). Hence, construction of the proposed reservoir would not have as great a potential for reducing peak streamflows and protecting against streambed scour and streambank erosion as would exist were the natural lakes not present.

A potential would also exist for regulated streamflows to lead to the eventual loss of riverine habitat due to gradual but persistent changes in stream channel geometry. Generally, a reduction in streamflow results in a more narrow, shallow river channel. If the reduced streamflow condition persists and at least seasonally does not apparently increase, the overall character of the river channel is likely to change as vegetation encroaches along the streambank and stabilizies overflow channels and point bars.

The braided segments of the Tazimina River would be most susceptible to this process if sufficient mainstem flows were not provided to maintain periodic flushing flows through the side channels. Based on field observations to date, it appears that short-term streamflows in the range of 1,600 to 1,800 cfs would be necessary to preserve the existing cross-sectional characteristics of the braided river segments. Additional field observations and data collection/analysis would be required to support a quantified statement.

FISHERY RESOURCES

Sockeye salmon

The majority of the sockeye salmon spawns in the lower 6.5 miles of the Tazimina River. In 1981 Alexcy, Hudson, and Sixmile braids as well as a single-channel reach of the mainstem from RM 1 to 2 were heavily utilized by spawners. Similar distribution patterns have been observed during earlier escapement surveys (Demory, Orrell, and Heinle 1964).

Mainstem spawning habitats are less susceptible to degradation from flow reduction than side-channel habitats. As observed during the 1981 field season, a discharge of 650 cfs at RM 1.7 appears to provide nearly as suitable spawning conditions as does a discharge of 1,500 cfs (refer to Figure 30). Side-channel spawning habitats, however, could be adversely affected if flows dropped below 1,000 cfs during spawning season. Depending on the channel geometry and location of the most suitable spawning gravels, some mainstem areas may also be adversely affected by reduced streamflows. For example, spawning habitats along the gravel bars at RM 2.1, 5.5, and 5.8 would likely be affected if streamflows were below 1,000 cfs in late August.

During 1981 field work sockeye salmon spawners were not observed in depths less than 0.6 ft, nor in velocities less than 0.2 fps, indicating that depths shallower than 0.6 ft or velocities less than 0.2 fps are undesirable for sockeye salmon spawning. If postproject streamflows reduced depths or velocities at existing spawning areas below these levels, it is quite likely that the value of these spawning habitats would be considerably reduced.

High velocities also appear to limit use of otherwise suitable spawning areas. For example, sockeye salmon spawners were not observed in water flowing faster than 4.4 fps. Most adult sockeye observed in single-channel mainstem reaches on August 17 (discharge of 3,130 cfs) were concentrated in low-velocity areas adjacent to the streambanks or downstream of debris jams. Mean column velocities throughout much of the river in these areas were estimated to be from 5 to 6 fps. The proposed project would provide an opportunity to limit the occurrence of such high flows during the spawning season and, perhaps to provide access to suitable spawning substrates in some areas which are presently limited by high velocity. Since many of the areas currently affected by high velocities also have substrate too large for good spawning habitat and since the existing substrate composition is not expected to change, spawning habitat gains resulting from reduction of peak streamflows is expected to be quite small.

Lower flows during the spawning season might possibly benefit spawners by preventing access to lateral areas subject to dewatering under lower winter flows. As a result, fish would be encouraged to utilize spawning habitat less vulnerable to dessication and freezing. In years of high escapement, concentration of spawners by low flows might cause some egg losses due to superimposition.

The long-term average monthly postproject flows during August and September would not be expected to drop below 1,880 and 1,260 cfs, respectively (refer to Figure 28). It is therefore unlikely that sockeye salmon spawning habitat would be significantly reduced. In low-flow years, postproject flows might fall below 1,000 cfs during late August or early September which could adversely affect some sockeye spawning habitat. However, insufficient information exists to quantify changes in availability or quality of sockeye salmon spawning habitat resulting from project operation.

Postproject winter streamflows probably would be significantly greater than naturally occurring winter flows. This might result in streamflow remaining over some spawning areas which are presently subject to dewatering. Eggs and developing embryos in these areas would be protected from dessication and freezing which might result in better production.

Postproject winter stream temperatures in these areas might be as warm as 2°C. If these winter water temperatures are greater than those presently occurring, they could hasten hatching and emergence. Effects of early emergence in the Tazimina River system have not been determined, but in other systems early emergence has been associated with reduced survival due to prolonged exposure to cold stream temperatures and reduced availability of food organisms (Bailey, Pella, and Taylor 1976). It is not yet known whether intergravel water temperatures in the Tazimina River are directly influenced by stream temperatures or respond more to ambient groundwater temperatures. If the intergravel temperatures are influenced most by groundwater, then embryo development would be effected little by changes in surface water temperatures.

Since spring rainbow spawning may be correlated to rising stream temperatures, cooler postproject temperatures during May could delay resident spawning. Rainbow trout spawn in 5 to 7°C water in Lower Talarik Creek and Copper River (Russell 1974, 1976; Seidelman and Engles 1972; Seidelman, Cunningham, and Russell 1973). Grayling spawning has also been correlated with increasing spring water temperatures. Tack (1980) reported grayling spawning behavior commenced when water temperatures reached 4°C. The storage reservoir would approach its maximum level of drawdown during late April and early May, just prior to breakup. This would provide the greatest potential for colder water (which has been above the more dense 2°C water in the reservoir all winter) to be discharged through the powerhouse. If cold releases from the reservoir depress stream temperatures during April and May below preproject levels, rainbow and grayling spawning might be delayed.

Juvenile rearing habitat and summer feeding areas for adults have not been inventoried. Nevertheless, due to the diverse hydraulic condition which would be available in mainstem and side-channel areas during the open-water season, these habitats probably would not be adversely affected. Insufficient information exists to quantify changes in the availability or quality of these habitats resulting from project operation.

Figure 31 summarizes anticipated effects of the proposed storage reservoir scenario on downstream fishery resources.

Figure 31. Anticipated effects of the proposed storage reservoir Hydroelectric Development on fishery resources downstream from the powerhouse RM 0.0 to 8.3.

Species/Lifestage Affected	Downstream Effects Related to Changes in				
	stream flow	stream temperature	substrate	channel morphology	water quality
SOCKEYE SALMON					
Spawners	0	0	0	0	0
Incubation/alevins	X	X	0	0	0
Emergence/outmigration	X	?	0	0	0
RAINBOW					
Spawners	X	?	0	0	0
Incubation	0	?	0	0	0
Emergence	0	0	0	0	0
Juveniles	0	?	0	0	0
Adults	0	?	0	0	0
ARCTIC GRAYLING					
Spawners	X	?	0	0	0
Incubation/alevins	0	?	0	0	0
Juveniles	0	?	0	0	0
Adults	0	?	0	0	0
ARCTIC CHAR					
Spawners	0	0	0	0	0
Incubation/alevins	X	X	0	0	0
Emergence	X	?	0	0	0
Juveniles	0	?	0	0	0
Adults	0	?	0	0	0

X effect likely

0 effect unlikely

? insufficient data for determination

SUMMARY

Several questions remain regarding specific effects of the proposed storage reservoir development on existing fishery resources. Additional studies would be required to refine monthly streamflow estimates, particularly during low-flow years, and to develop specific streamflow recommendations to meet seasonal fishery requirements. From our review of the project proposal and our present understanding of the fishery resources, we conclude that most adverse effects on downstream fish habitats could be avoided or minimized by adopting a project design which provides adequate downstream temperatures and an operating schedule compatible with the seasonal streamflow requirements of the fishery resources. Based upon our evaluation of the available data on the fishery resources, estimated preproject streamflows, and the proposed storage reservoir development, it appears that sufficient water exists to both meet project needs and to provide adequate downstream flows which avoid or minimize adverse effects on fish habitat.

The specific findings and recommendations of this study which pertain to the proposed storage reservoir development scenario are summarized below:

Above the powerhouse

1. Naturally occurring streamflows and existing fish habitat conditions in the river canyon (RM 9.3 to 9.5) would be dramatically altered. However, the canyon contains only a limited amount of low-quality spawning habitat compared to that available in the lower 6 miles of the river and incubation success in this reach is questionable. Therefore the habitat losses in this .25 mile reach is unlikely to adversely affect sockeye salmon production in the Tazimina River.

2. It is also unlikely that changes in habitat conditions within this portion of the canyon would significanly affect resident fish populations. However, additional data are needed to ascertain the degree of resident species' use of this portion of the canyon.

Below the powerhouse

1. Streamflows of 650 and 2,000 cfs appear to define an acceptable range of streamflow for sockeye salmon spawning in existing habitats within the single-channel segments of the mainstem Tazimina River. The lower 3 miles of mainstem appear to provide the most important sockeye salmon spawning areas. Additional study would be required to quantitfy changes in spawning habitat associated with postproject streamflows.

2. A determination has yet to be made of incubation success for sockeye salmon in the various segments of the mainstem river and associated side channels. The proposed storage reservoir project has the potential of altering the availability of spawning habitat and decreasing the degree to which redds are naturally dewatered. Therefore, preemergent studies are recommended to determine whether productive spawning habitats would be jeopardized by reduced summer flows or if increased winter streamflows would likely result in greater survival of incubating eggs.

3. Main-channel streamflows of 1,000 cfs appear adequate to maintain flow through side channels utilized by sockeye spawners within the braided segments of the Tazimina River. Additional study would be needed to determine seasonal use of these side channels by resident species and to determine the quantitative changes in spawning and rearing habitats of resident species associated with postproject streamflows.

4. Rainbow and grayling spawning areas which may exist in the braided river segments or along the stream margins in single-channel segments could be dewatered or degraded by the proposed reduction of streamflows in late May and June. Additional streamflow could be provided during late May and June to avoid or minimize adverse effects to resident fish spawning below the powerhouse by modifying the proposed

annual reservoir filling schedule. The reservoir could be filled at a slower rate during June, thereby extending the filling period into August. This would result in smaller spills but no loss to monthly power production. Additional study would be required to determine the magnitude and timing of the releases required to protect existing rainbow and grayling spawning habitats.

5. Seasonal temperature gradients within the reservoir should be forecast and the downstream temperature requirements of the various life stages of resident and anadromous fish identified. This data could be used to determine if a special intake structure would be required to prevent powerhouse outflows from adversely affecting winter and spring stream temperatures in the lower 8 miles of river.

6. The Tazimina River channel is relatively stable and anticipated postproject flows would probably have a negligible effect on altering stream channel geometry or substrate composition. Additional fieldwork could be undertaken to provide a more substantive basis for determining the reservoir releases necessary to maintain the substrate composition and channel geometry in the braided river segments.

7. It does not appear that adverse water quality conditions would exist in the proposed reservoir. Additional study should be undertaken to confirm or modify this hypothesis and forecast seasonal limnologic characteristics of the impoundment.

Suggested Objectives and Approaches
for a Preliminary Instream Flow Assessment
of the Tazimina River
August 1981 through January 1982

Appendix I

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Fishery resources and habitat utilization in the lower Tazimina River I-1

Streamflows, water temperature, and morphologic characteristics of the Lower Tazimina River I-4

FISHERY RESOURCES AND HABITAT UTILIZATION IN THE LOWER TAZIMINA RIVER

1. Identify relative importance of mainstem and side channel habitat for spawning sockeye salmon.

   Approach: Conduct aerial and foot surveys during spawning season, and indicate the degree of spawning activity on 1 inch to quarter mile maps. Define the comparative degrees of spawning activity in various subreaches of the lower mainstem river and associated side channel and slough areas. Describe general habitat characteristics of spawning areas in terms of depth, velocity, substrate composition, and stream temperature.

2. Identify incubation success at selected sockeye salmon spawning areas.

   Approach: Undertake midwinter examination of selected sockeye salmon spawning areas identified in Task 1 to determine the degree to which redds are dewatered or frozen. If a decision is made to continue the environmental studies beyond February 1982, conduct a preemergent study during March-April 1982.

3. Identify the degree to which resident fish depend upon the lower Tazimina River for overwintering habitat.

   Approach: Conduct periodic aerial and foot surveys throughout the fall and early winter to detect movement into overwintering areas. Record locations of fish on 1 inch to quarter mile maps and note their relative abundance in different habitat types. Sample likely riverine overwintering areas during midwinter. Describe general overwintering habitat in terms of water depth, velocity, substrate, stream temperature, and ice conditions.

4. Identify the relative amount and degree of utilization of rearing habitat in mainstem subreaches, side channels, and backwater areas.

   Approach: Sample potential rearing habitat with minnow traps, seine, electrofishing unit, and by observation. Record rearing areas on 1 inch to quarter mile scale maps. Note relative importance of different habitat types to both juvenile residents and sockeye salmon. Describe general habitat characteristics in terms of depth, velocity, substrate, cover, and water temperature.

5. Identify habitats used by resident adult fish during the open water season.

   Approach: Conduct aerial and foot surveys during the spawning and summer feeding seasons. Note the relative abundance of adults by species if possible for different habitat types, making note of these locations on 1 inch to quarter mile maps. Describe general habitat characteristics in terms of depth, velocity, substrate, cover, and water temperature. Emphasis on this particular study should be deferred until Phase II due to the timing of spawning activities and the manpower requirements of undertaking a credible field study.

6. Identify areas of benthic production and determine their relative productivity.

   Approach: Sample bottom fauna periodically throughout the open water season by surber sampler and/or Ekman dredge in various reaches. Sample drift organiams periodically throughout the open water season with drift nets. Describe general habitat characteristics in terms of depth, velocity, and substrate.

FISHERY RESOURCES OF THE LOWER TAZIMINA RIVER
SUMMARY OF PERTINENT INFORMATION

Appendix II

Jean Baldrige
Fisheries Biologist

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INTRODUCTION

Major fishery resources of the lower Tazimina River include sockeye salmon (Oncorhynchus nerka), rainbow trout (Salmo gairdneri), Arctic char/Dolly Varden (Savelinus alpinus/malma)[1], and Arctic grayling (Thymallus arcticus). Other species occurring in the lower river include round whitefish (Prosopium cylindraceum), chinook salmon (Oncorhynhcus tshawytscha), longnosed sucker (Catostomus catostomus), threespine stickleback (Gasterosteus aculeatus), ninespine stickleback (Pungitius pungitius), and slimy sculpin (Cottus cognatus).

Because of its importance to the commercial and subsistance fisheries, sockeye salmon is the principal fishery resource of the Tazimina River. Historically, the Tazimina River sockeye stocks contribute up to 5 percent of the total Kvichak River run--the largest sockeye salmon fishery in the world. The Kvichak watershed, excluding Lake Clark and its tributaries, is designated as a Wild Trout Area by the ADF&G and is managed as a trophy sport fishery. Tazimina River Arctic grayling and rainbow trout, in particular, are much sought after by sportsmen and provide substantial business for commercial guides and private lodges. Numbers of Arctic char in the lower Tazimina River appear to be relatively small and, although occasionally captured by anglers, they are not a dominant sport fish.

Two adult chinook salmon were observed and several fry were collected in the lower Tazimina River during the 1981 field season. Escapements generally number less than 10 individuals (Sims, pers. comm.). Slimy sculpins and ninespine sticklebacks were captured by Dames and Moore personnel during the 1981 field season. Round whitefish, longnose suckers, and threespine sticklebacks have also been

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[1]Because of their close morphological resemblance, some confusion exists concerning the taxonomy of Arctic char and Dolly Varden. Since discrimination between the two species was not essential for the purposes of this assessment, specific taxonomic identification was not attempted. We refer to these fish as Arctic char.

reported in the lower Tazimina River (Russell 1980). Only information on sockeye salmon, rainbow trout, Arctic grayling, and Arctic char is presented.

Little site-specific information exists which would allow definition of the seasonal distribution, relative abundance, and life history requirements of fish species inhabiting the Tazimina River. However, a general description of the fishery resources of the Tazimina can be assembled from information for the same species inhabiting nearby drainages in the Iliamna area and from information for the Naknek and Wood River systems. Because of their importance to the commercial fisheries, most of the available information pertains to sockeye salmon. Escapements to the Tazimina River have been monitored since 1920, and general life history information has been collected by the FRI for sockeye salmon throughout the Iliamna area. The National Marine Fisheries Service has had an extensive research program on sockeye salmon in the Naknek drainage, the results of which are summarized in Buck et al. (1978).

Existing information pertaining to resident fish in the Tazimina River is very limited. ADF&G conducted a survey in the Tazimina River in conjunction with a fishery inventory of the Lake Clark area (Russell 1980) and a spawning survey for resident fish in 1974 (ADF&G 1974). ADF&G also conducted life history investigations of rainbow trout in several tributaries to Iliamna Lake, including Lower Talarik Creek and the Copper River. Life history information for Arctic grayling and Arctic char in Bristol Bay is absent from the literature. AEIDC and Dames and Moore personnel collected some incidental information on the seasonal distribution and relative abundance of resident fish in the lower Tazimina River during the 1981 field season.

SOCKEYE SALMON

Though sockeye salmon inhabit the lower Tazimina River throughout most of the year, various life stages are present only seasonally. Much of their lives are spent in a lake or marine environment. Sockeye depend on the Tazimina River habitat for reproduction. Summer spawners deposit eggs in the streambed gravels. They incubate through the fall and winter, hatching in late winter. Emergence occurs in spring, and is immediately followed by outmigration from the river to lake nursery areas. As much as a month may elapse between the end of the outmigration period and the first return of the spawners, but in some cases the two events overlap.

Maturing adults move from ocean feeding areas to freshwater spawning areas in early summer. Returning Tazimina River spawners are subject to commercial fishing in Bristol Bay. As they ascend the Kvichak and Newhalen Rivers, they are harvested by the subsistence fisheries located near the villages; a few fish are taken by sportfishermen. Spawners generally begin to enter the Tazimina River in early to mid-July. Returns continue to increase throughout August, and the peak of spawning activity generally occurs in late August or early September. By mid-September few live sockeye remain in the river (Poe, pers. comm.).

Escapements of sockeye spawners to the Tazimina River have been monitored since 1920 (Figure II-1). Periodic index surveys were conducted prior to 1949. Since 1955 the University of Washington FRI has conducted index surveys annually as a part of the Kvichak River sockeye salmon studies. These surveys report that historically index counts in the Tazimina River have varied from zero to almost 500,000. In recent years, the escapements to the Tazimina River have increased. The increase has been attributed to better management of the commercial harvest in Bristol Bay in recent years (Poe 1980, 1981). The Tazimina stocks are on a five-year cycle with two years of high escapements, a subdominate year after or before the dominate year, and two or three years of average or fairly low escapements. Peak returns are predicted for 1984 and 1985 in Bristol Bay.

Figure II-1. Spawning ground index surveys on the Tazimina River.

Date	RM Surveyed	Sockeye Salmon Spawners			
		Live	Dead	Schooled	Total
9-20	9.0				50
1921	9.0				50,000
8-17-24	5.0				40,000
8-21-40	9.0				14,250
1944	9.0				550
9-8-45	9.0				7,500
9-9-49	4.0	6,000	6,000		12,000
1950	9.0				7,500
1951	9.0				4,000
1952	9.0				17,000
1953	9.0				17,000
1954	9.0				3,400
9-13-55	9.0	50	0	50	50
9-9-56	7.0	27,300	5,000		32,300
9-6-57	9.0				28,750
8-28-58	9.0				600
9-16-59	6.0	150	0	0	150
8-28-60	9.0	55,000	0		55,000
8-30-61	9.0	30,000	0		30,000
9-10-62	9.0	3,600	400	0	4,000
9-1-63	9.0	0	0	0	0
8-29-64	5.0	150	0	0	150
9-5-65	5.0	27,500	21,600	0	49,100
8-27-66	5.0	4,800	80	0	48,800
8-14-67	6.0	1,560	0	1,400	1,560
9-12-68	5.0	135	115		250
8-11-69	9.0	22,610	0	22,110	22,610
8-25-70	9.0	85,450	0	42,150	85,450
9-2-71	9.0	12,870	55	0	12,925
9-27-72	9.0	0	20	0	20
9-28-73	4.0	0	12	0	12
9-5-74	9.0	73,920	30,550	1,325	104,470
8-10-75	9.0	149,950	0	149,950	149,950
8-23-76	9.0	16,200	0	1,070	16,200
8-1-77	9.0	6,950	255	625	7,205
8-23-78	9.0	143,475	3,425	34,275	146,900
9-7-79	9.0	269,450	226,300	65,450	495,750
9-6-80	9.0				128,500
9-6-81	9.0				28,215

FRI, unpublished data.

Tazimina sockeye salmon generally return after spending two (or, less frequently, three) years in the ocean (Figure II-2). In years of peak escapements (1964, 1970), 2.2 fish[2] dominated the return. Postpeak years (1966, 1981) had higher percentages of 2.3 fish (2.3 fish predominated in 1966). However, in 1978 most spawners were 1.2 fish. In recent years, the prevelant mild weather conditions have improved rearing conditions in the nursery lakes and a larger portion of young sockeye are leaving as age I smolts.

During 1981 the first spawners arrived at the Tazimina River in late July, and by the first week of September spawning activity had peaked. Schools of spawners moved into the river and remained in pools and scour holes located near spawning areas throughout mid-August. By the last week of August most spawners were spread out and defending territories withing the spawning areas.

Sockeye salmon spawner distribution was determined by helicopter survey on August 28, 1981 and noted on a 1:15,840-scale drawing of the lower river. Mr. Poe of FRI provided the numerical index, and Mr. Isakson of Dames and Moore noted the distribution within the river (Figure II-3). The majority of the 21,900 spawners was found in the lower 6.5 miles of the river; 70 percent of these were in the lower 3 miles of river and 90 percent downstream of RM 6.5.

Although the spawning surveys conducted on the Tazimina River did not record spawner distribution, some field notes indicated that the majority of the fish was observed in the lower 3 to 5 miles of the river. Demory, Orrell, and Heinle (1964) also note that the majority of sockeye spawning occurs in the lower 5 miles of the river; however, in years of high abundance sockeye spawners are found throughout the entire 9.5 miles below the falls (Russell, pers. comm.). Most spawning activity appears to be restricted to a two or three week period in late August to early September. Data indicated that peak spawning activity generally occurred in a 16-day period from August 28 to September 13 (Figure II-4).

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[2] Ages are designated according to the European system--a 1.2 fish has spent one year in freshwater and two in the ocean. It is in its fourth year of life, having gone to sea in its second year.

Figure II-2. Percentage age distribution of Tazimina River spawners in 1965, 1966, 1970, 1978, 1981.

		Age Composition										
		4year				5year				6year		
		2.1		1.2		2.2		1.3		2.3		Total
Year	Sex	%	#	%	#	%	#	%	#	%	#	Number
1965	Male					100.0	46					46
	Female					100.0	47					47
1966	Male	1.0	1			22.0	22	1.0	1	76.0	76	100
	Female					15.2	15			84.8	84	99
1970	Male					100.0	50					50
	Female					100.0	50					50
1978	Male	8.0	8	89.0	89	2.0	2	1.0	1			100
	Female			95.0	95	1.0	1	3.0	3	1.0	1	100
1981	Male			6.1	4	59.1	39	19.7	13	15.1	10	100
	Female			5.6	4	60.0	43	23.6	17	11.1	8	72

Source: Poe, pers. comm.

Figure II-3. Distribution and abundance of sockeye salmon spawners in the Tazimina River from aerial survey on August 28, 1981.

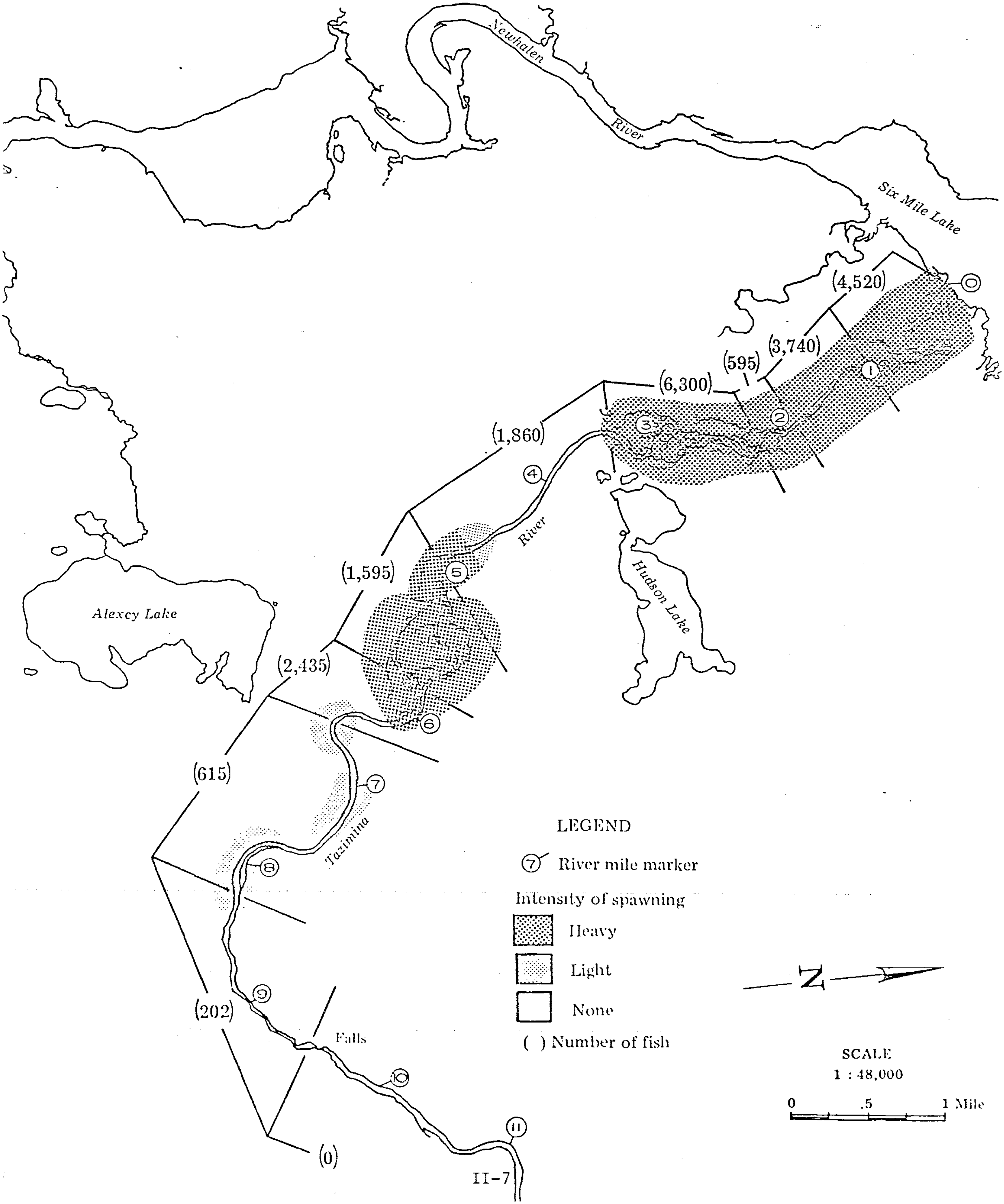


Figure II-4. Timing of peak spawning activity in the Tazimina River.*

Date	Date
8-29-64	9-02-73
8-31-65	9-01-74
8-28-66	9-03-75
8-30-67	9-01-76
9-01-68	9-02-77
9-04-69	9-07-78
9-05-70	9-06-79
9-13-71	9-02-80
9-06-72	9-01-81

*Source: FRI (1979) and Poe (pers. comm.)

This short spawning period may help reduce the problem of superimposition in years of large returns. Female spawners in the Brook River, Naknek Drainage, reportedly defended redds for an average of nine days after spawning (Hartman, Merrell, and Painter 1964) and for a maximum of 16 days (Hoopes 1962). Thus, it appears that females would probably be able to defend their redds from disruption by other spawners. Information collected by FRI in Six Mile Lake indicates that superimposition was not a serious problem in 1979 when Tazimina River index surveys enumerated almost 500,000 fish. Poe (1981) reported that towing results in Six Mile Lake indicated production from the large return was very good. Some egg loss did occur, as Sims (pers. comm.) reported many loose eggs in the river in 1979.

Average fecundity for female sockeye in the Naknek drainage was found to be about 4,000 eggs (Merrell 1964). The eggs are buried in the gravels at a depth of 9 to 12 inches (McAfee 1960). Redds located in the Tazimina River by Dames and Moore were found in this depth range.

Fertilized eggs incubate in the stream gravels and hatch some time in midwinter. Incubation rate and fry development are related to water temperatures and level of dissolved oxygen present in the spawning gravels. Low temperatures and reduced levels of dissolved oxygen can slow embryo development. No site-specific information is available on the timing of incubation or fry emergence in the Tazimina River. A study conducted in the Iliamna area provided some information on egg development. Mathisen, Demory, and Orrell (1962) determined that hatching generally occurred from late February to mid-March, from eggs spawned in late August to September 20, with emergence occurring the end of April through mid-May. Nelson (1964) reported that hatching occurred in the Wood River drainage in February and that development time in the Wood River closely parallels that of the Iliamna-Lake Clark District.

The alevins remain in the gravels until emergence, generally coinciding with breakup. Emergence in the Naknek Drainage spanned a period from late April to mid-June. The timing of emergence is influenced by intergravel temperatures during development.

Fry usually move immediately to nursery areas in downstream lakes after emergence. AEIDC observed few sockeye fry in the Tazimina River in late July. Most migration to nursery areas is conducted during darkness (Hartman, Strickland, and Hoopes 1962); however, migrating fry are subject to considerable predation by rainbow trout, Arctic char, lake trout, northern pike, and various birds. After reaching the lake, sockeye fry generally concentrate in the shallow shoreline areas but disperse to deeper midlake waters in midsummer (Merrell 1964).

Young sockeye from the Tazimina River remain in fresh water for one to two years before outmigrating to Bristol Bay (Anderson 1968; FRI, unpublished data). After leaving the Tazimina River, fry probably remain in Six Mile Lake for a time, but exact length of residence in Six Mile Lake and movements between lakes is unknown. Some evidence from the Naknek drainage suggests that fry generally occupy rearing areas downstream from their spawning areas and movement through the system is a function of drainage pattern. Young fish tend to move in a downstream direction even in a lake environment (Ellis 1974). Sockeye smolts begin leaving the Kvichak system in May and continue to outmigrate through June.

RESIDENT FISH

Several freshwater species including rainbow trout, Arctic grayling, and Arctic char have been identified by the ADF&G as resident populations of the lower Tazimina River. These species appear to be most abundant during the open-water season. Little information exists regarding the seasonal distribution and life histories of these fish. Reconnaissance of the Tazimina River by ADF&G in 1974 (Russell, pers. comm.), in 1979 (Russell 1980), and incidental observations of AEIDC and Dames and Moore personnel in 1981 provided some insight into the general life history and seasonal habitat use by these fish.

Tazimina River rainbow trout may become sexually mature at age five or six. Russell (1980) examined 14 sexually mature fish from the Tazimina River ranging in age from five to ten years. Life history studies conducted on Lower Talarik Creek, tributary to Lake Iliamna, indicated that trout matured at age four through seven (Russell 1974). In the Bristol Bay region, rainbow trout usually spawn from late April to early June. The 1981 field investigations commenced after the completion of the rainbow trout spawning season. Rainbow trout spawning activities may be closely related to stream temperatures. Russell (1974) reported that peak spawning activites occurred on May 10, 1973 and June 6, 1972 in Lower Talarik Creek. Although seasonally these dates are 27 days apart, increasing spring water temperatures reached 7°C on both of these respective dates.

Exact locations of rainbow trout spawning areas have not been identified in the Tazimina River. Rainbow trout probably spawn in the side channels of the braided areas. In Lower Talarik Creek and the Copper River, tributaries to Iliamna Lake, rainbow spawning activity occurs in similar habitats (Russell, pers. comm.). Newly emerged fry were found at several locations in Alexcy Braid and near RM 7.5. In addition, young-of-the-year rainbow trout were captured in the side channel near the mouth of the canyon (RM 8.3) and within the canyon itself. Rainbow spawners have been reported in the canyon at RM 8.7 (Sims, pers. comm.), and Dames and Moore personnel captured young-of-the-year trout near RM 8.8. Due to the apparent limited availability of suitable substrate in this area, spawning habitat present in the canyon probably does not account for a significant portion of rainbow trout production in the Tazimina River.

Russell (1974) reported that after spawning, rainbows left Lower Talarik Creek and entered Iliamna Lake or Talarik Lakes. Postspawn rainbows appear to remain in the Tazimina River. Local sport fishing guides report that the Tazimina River has a good population of large trout throughout the open-water season (Sims; Baluta, pers. comm.). Before the arrival of sockeye spawners in July 1981, AEIDC personnel observed numerous fish, presumably rainbow trout and grayling, throughout the Tazimina River below RM 8.3. Of the 33 rainbow trout captured by angling from August 14 to October 16, 18 fish measured between 400 and 650 mm (fork length). These larger fish may have spawned the previous spring. Most fish appeared to leave the Tazimina River in early fall. Postspawn rainbow trout are reported to remain in the Copper River, tributary to Iliamna Lake for the summer period (Siedelman, Cunningham, and Russell 1973).

During the 1981 field season the abundance of resident fish appeared to increase as sockeye salmon spawning progressed. This increase may have resulted from an influx of nonspawners and subadults moving into the river to feed on salmon eggs. The increase may also be the result of a change in habitat use patterns. Siedelman, Cunningham, and Russell (1973) reported that rainbow trout moved from deeper water into shallower runs where sockeye were spawning, making the trout more visible. In the Tazimina River resident fish were frequently observed in association with sockeye spawners and rainbow, and grayling were captured by angling in sockeye spawning areas.

As fall progressed, resident fish in the Tazimina River moved downstream, many apparently leaving the system. Maps prepared from aerial surveys conducted in September and October 1981 show a general downstream movement with 56 percent fewer fish observed in October (Figures II-5 and II-6).

Dames and Moore angling results supported the conclusions of the aerial surveys. Fewer fish were captured in the upstream reaches as the field season progressed. In October a large school of resident fish was observed in Six Mile Lake, just off the mouth of the Tazimina River. These observations are consistent with the results of trout

Figure II-5. Distribution and abundance of resident fish in the lower Tazimina River from aerial survey on September 22, 1981.

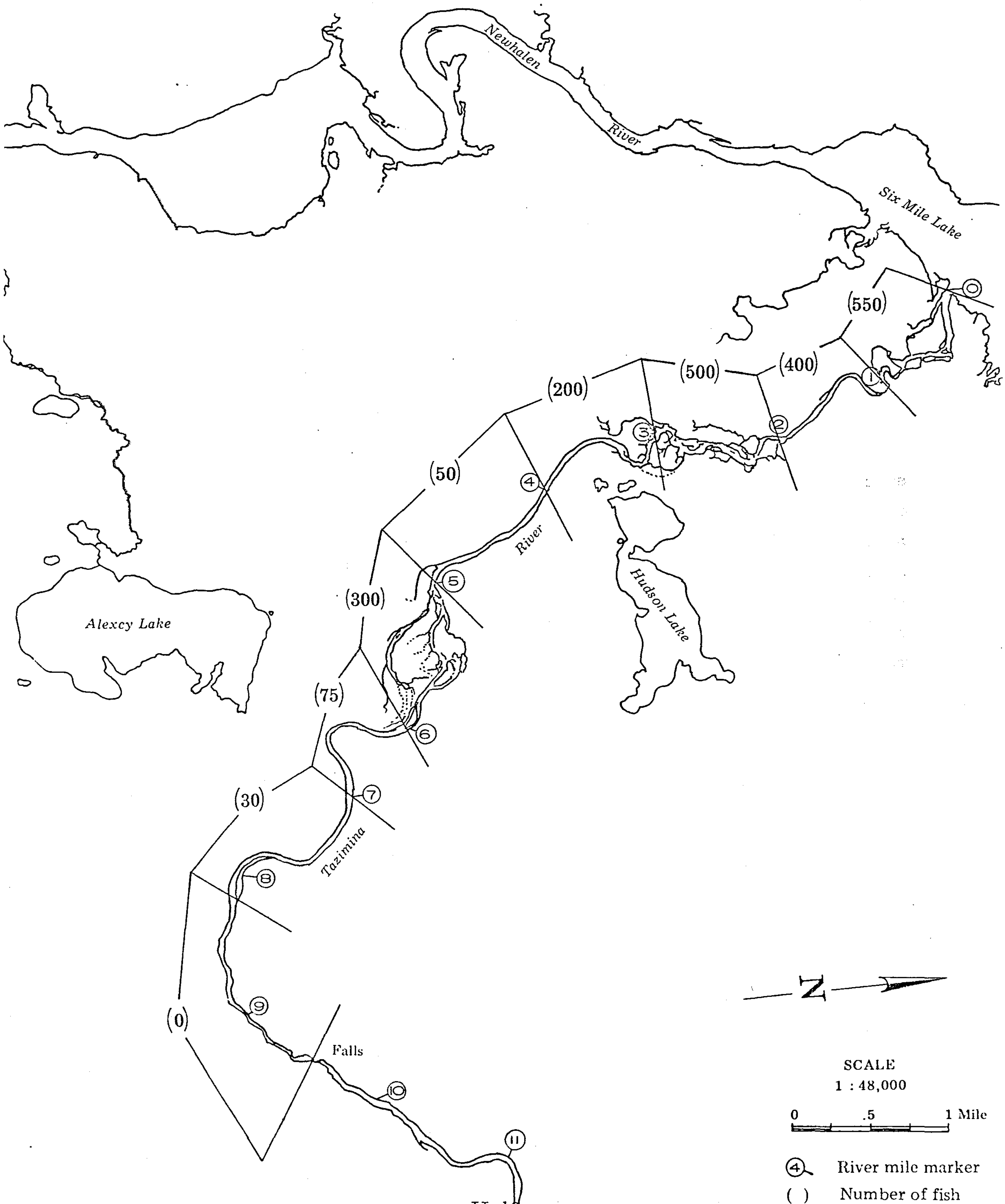
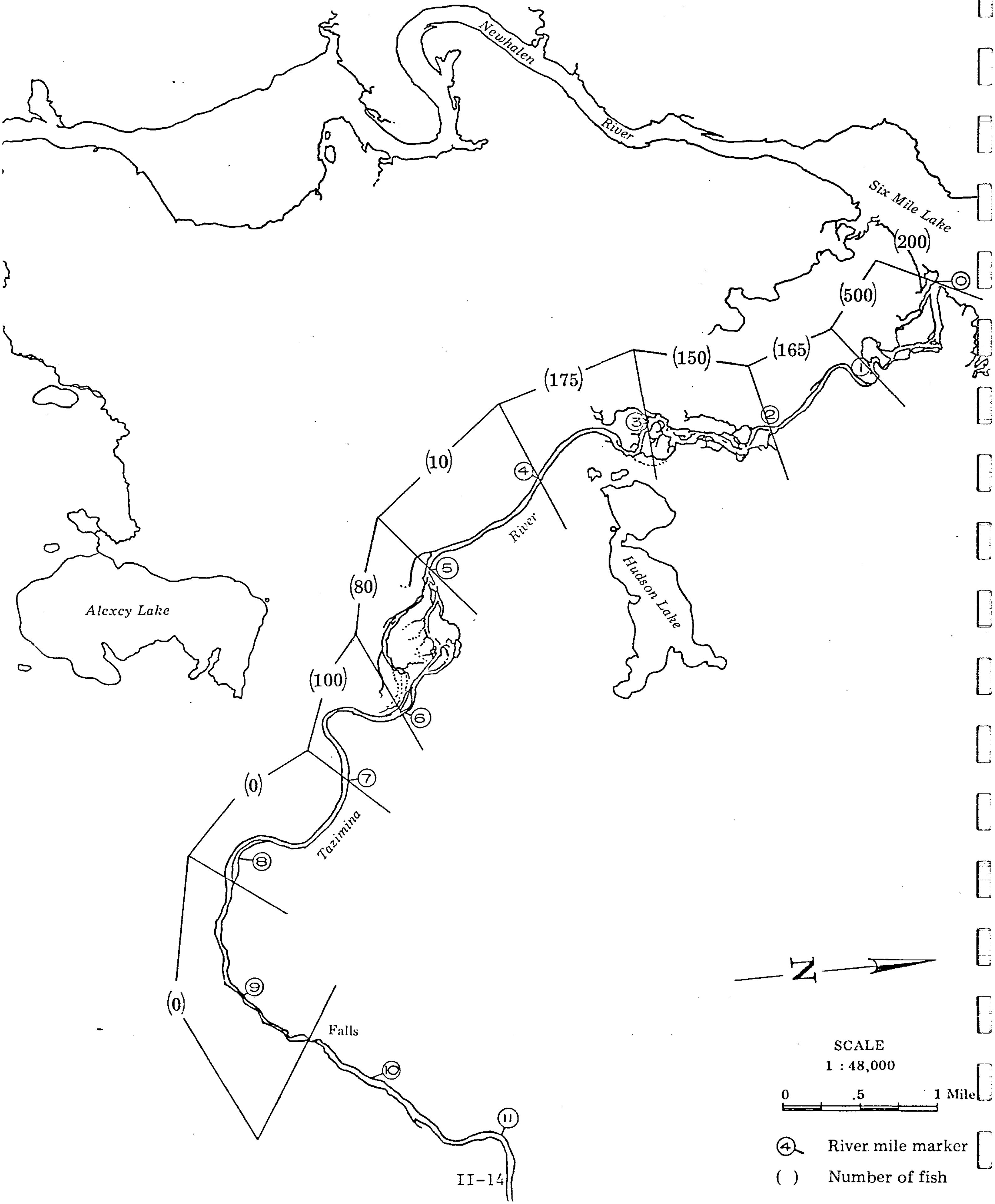


Figure II-6. Distribution and abundance of resident fish in the lower Tazimina River from aerial survey on October 14, 1981.



investigations conducted in other drainages in the Iliamna area which reported that most fish leave the streams in the fall and seek lake environments for overwintering (Russell 1974; Siedelman, Cunningham, and Russell 1973; Siedelman and Engle 1972).

Young rainbow trout were numerous in the lower Tazimina River. Although no systematic sample program was undertaken, trout were observed in slow, shallow water along stream margins, in side channels, and in backwater areas. A few young were captured in the canyon just below the rapids, indicating that the entire length of the lower river is utilized by juvenile rainbow trout. Most of the good rearing habitat is located in the braided reaches and side channels. Outside of these areas young fish appear to be restricted to stream margins.

No data are available for Arctic grayling spawning activities in the Tazimina River. Most of the available data in the literature was collected in interior and arctic streams. Krueger (in press) synthesized available data on grayling life history and habitat requirements. The following information is summarized from this report.

In interior Alaska, grayling generally spawn during breakup. Grayling spawn in the Iliamna area in May and June (Russell, pers. comm.). Upstream migration and spawning activity may be related to water temperature. Tack (1980) reported that spawning activity commenced when stream temperatures reached 4°C. Males generally establish and defend territories prior to the arrival of the females. Spawning has been observed in a wide variety of habitats, including shallow backwater areas to lake margins and riffles and runs.

No redds are constructed. The slightly adhesive eggs sink to the stream bottom and become attached to the substrate. Spawning activity generally covers the eggs with a layer of substrate. Embryo development is rapid and eggs generally hatch in 13 to 32 days. Development time is influenced by water temperatures. Fry generally remain in their natal stream during the summer. Young grayling occupy similar habitat to that of young salmonids, selecting shallow, low-velocity areas with cover. Only one young grayling was collected by Dames and Moore in the lower Tazimina River. However, side-channel habitats below Alexcy Braid were not sampled.

Few observations of Arctic char were made during the 1981 field season. Char reportedly move into the Tazimina River to feed on salmon eggs and remain to spawn in late September through October. Spawners were captured by sportsmen near RM 6.2 in September. A school of fish was observed in this location during the September aerial survey and an even larger school was observed during the October aerial survey. Since most resident fish appeared to be leaving the system, the October increase would seem to indicate an influx of spawners to this river segment; however, none of the fish was captured during October to verify species or state of sexual maturity. No young Arctic char were found in the Lower Tazimina River during the 1981 field season. The eggs incubate in the stream gravels until hatching in March and April. Emergence probably occurs in May and June. The young fish may move downstream to the lake to rear. No juvenile arctic char were captured in the lower river during the 1981 field season.

METHODOLOGY FOR ESTIMATING PREPROJECT STREAMFLOWS IN THE TAZIMINA RIVER, ALASKA

Appendix III

E. Woody Trihey, P.E.
Hydraulic Engineer

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Average monthly streamflows for the Tazimina River have been estimated on the basis of a systematic review and extrapolation of the Newhalen River streamflow record. In general, both river systems are influenced by the same regional climatic conditions, drain similar topography, and are influenced by relatively large lake systems. The Tazimina River, a tributary to the Newhalen, drains approximately 10 percent of the Newhalen River basin.

The U.S. Geological Survey (USGS) maintained a continuous recording station on the Newhalen River, approximately 9 miles downstream from the mouth of the Tazimina River from July 1951 through September 1967. Annual crest-stage data (annual flood peaks) were recorded from 1968 through 1977.

The USGS installed a continuous recording gage near River Mile (RM) 11.6 on the Tazimina River on June 19, 1981. The USGS also obtained several winter-spring base flow measurements during the 1980, 1981, and 1982 water years near RM 13.6. Additional streamflow data were periodically obtained by AEIDC and Dames and Moore personnel in the lower eight miles of the Tazimina River from late July through mid-October 1981.

On July 25, 1981 AEIDC installed a staff gage at RM 1.7 to supplement the USGS recording station at RM 11.6. In addition, the USGS gage on the Newhalen River, which was maintained from 1951 to 1967, was visited and AEIDC found the stilling well and staff gage to be communicating with the river at gage heights above 5.4 ft.

Throughout the late summer and fall of 1981, periodic observations were made of the staff gages at these three locations (Figure III-1). USGS and AEIDC personnel also measured streamflows to confirm the reliability of the existing rating curve for the Newhalen River gage and to develop preliminary rating curves for the two installations on the Tazimina River. (The rating tables are presented in Appendix III-A.)

Figure III-1. 1981 staff gage readings and corresponding streamflows for the Newhalen and Tazimina rivers.

Date	Tazimina River RM 1.7 G.H.	Tazimina River RM 1.7 Flow	Tazimina River RM 11.6 G.H.	Tazimina River RM 11.6 Flow	Newhalen River RM 11.95 G.H.	Newhalen River RM 11.95 Flow
July 24	Not installed		3.34	2380	7.08	25,260
July 25	2.89	2540	3.35	2390	7.14	25,570
July 25	2.91	2550	3.36	2400	7.15	25,600
Aug 4	4.05	4550	3.89	3190	--	--
Aug 11	2.82	2415*	3.34	2380	--	--
Aug 12	--	--	1.40	2460	7.49	27,250
Aug 17	3.24	3130	3.66	2840	7.40	26,800
Aug 19	2.96	2670	3.42	2470	7.25	26,080
Aug 28	2.21	1600	0.66	1500	6.32	21,660
Aug 29	2.20	1582*	0.61	1450	6.29	21,520
Sept 21	1.54	860	1.81	720	#	
Sept 25	1.49	800	1.72	650	#	
Oct 2	1.36	660	1.54	530	--	--
Oct 10	1.22	540	1.31	380	--	--
Oct 13	1.35	664*	1.49	601*	3.21**	8,630

G.H. Gage height.

-- No observations made.

* Measured value as compared to other streamflows obtained from rating curve.

The staff gage was read, but it was later determined that the stilling well was not communicating with the river at gage heights less than 5.4 feet.

** Equivalent gage height determined by differential leveling.

Monthly flow duration curves were plotted for the Newhalen River based on the 16 years of daily streamflow record available for the 1951-67 period (Appendix III-A). The annual peak flows observed between 1968 and 1977 were excluded from this analysis. Using 50 percent exceedance as an index, average monthly streamflows were determined from the monthly flow duration curves for the Newhalen River (Figure III-2). Monthly streamflow values obtained in this manner are unlikely to agree with the monthly arithmetic averages for the 16 years of record. There is greater certainty that the monthly streamflow values derived from the 50 percent exceedance index will occur at least half of the time; whereas the arithmetic average may not occur at this frequency.

Figure III-2. Average monthly streamflow in the Newhalen River.

Month	Streamflow cfs	Month	Streamflow cfs
January	2,700	July	21,000
February	2,100	August	22,000
March	1,900	September	18,000
April	1,900	October	11,000
May	4,700	November	6,300
June	14,000	December	3,600

Some question exists regarding the degree of accuracy of the flow duration curves during the winter months. However, the low-flow data available for the Newhalen River were judged sufficient for the purpose of estimating the order of magnitude of midwinter streamflows in the Tazimina River.

A comparison of 1981 daily streamflows (gage height observations) at the Newhalen gage with their respective monthly flow duration curves indicated that Newhalen River streamflows were abnormally high from late July to early August (Figure III-3). Rainstorms which influenced runoff in the Newhalen River during the 1981 July-August field season were persistent regionwide storms that also influenced Tazimina River flows. Thus, it was concluded that the streamflows observed during July and August in the Tazimina River would represent a higher-than-average summer runoff. Local residents confirmed that the streamflows in the Tazimina River in July and August were higher than normal (Sims; Baluta, pers. comm.).

A U.S. Fish and Wildlife Service scientific report on spawning ground conditions in the Kvichak River system refers to a 1,400 cfs discharge (September 10, 1962) in the Tazimina River as a "normal summer flow" (Demory, Orrell, and Heinle 1964). The monthly streamflows recorded at the USGS gage on the Tazimina River during July and August 1981 were 2,560 and 2,280 cfs (USGS provisional streamflow record in Appendix III-A).

Long-term average monthly streamflow estimates provided by R.W. Retherford and Associates (Gropp, Steeby, and Bettine 1980) for the Tazimina River during July and August are 2,712 and 2,659 cfs, respectively, (Figure III-4). A comparison between the Retherford streamflow estimates and the 1981 USGS provisional streamflow data indicated that the forecasted long-term average monthly preproject flows for July and August are 6 and 17 percent greater than observed monthly streamflows during a year recognized for its abnormally high summer runoff. Hence, it was concluded that the estimated average monthly uncontrolled river flows provided in the 1980 Retherford report should be revised.

Although several glaciers exist in the headwaters of the Newhalen River, they have entirely receded from the Tazimina River basin. During winter, glaciers store precipitation as snowfall that eventually becomes incorporated into the glacier ice. Glaciers are likely to carry over one winter's snowfall for several years before releasing it as meltwater. When receding, a glacier's meltwater augments basin input; when advancing the glacier retains precipitation. These phenomena are cyclic and have a notable effect on annual basin outflow.

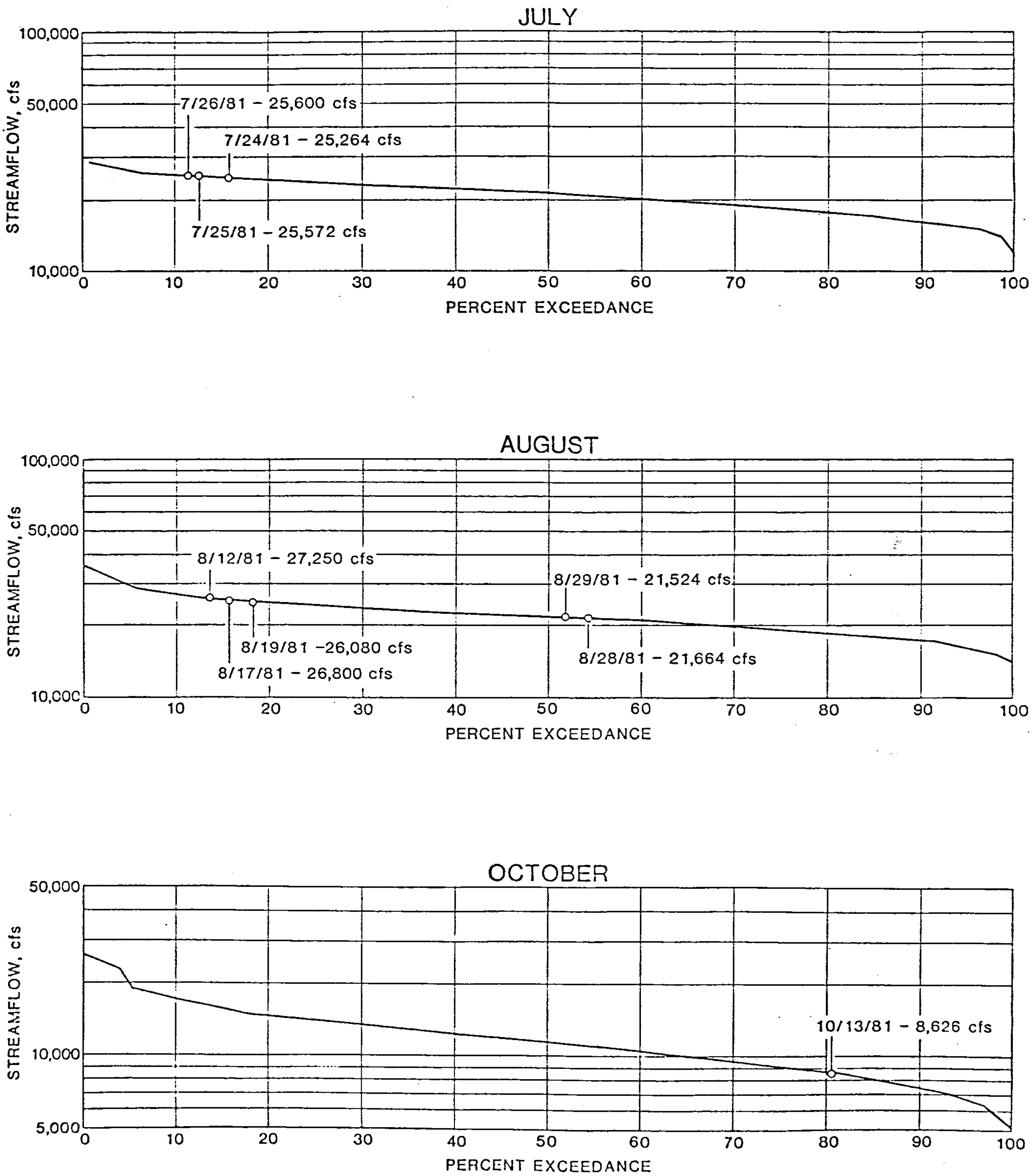


Figure III-3. Comparison of 1981 daily streamflow observations at the Newhalen River gage with the respective monthly flow duration curve.

Figure III-4. Estimated average monthly uncontrolled river flow for the Tazimina River.

Month	Streamflow (cfs)	Month	Streamflow (cfs)
January	280	July	2,712
February	406	August	2,659
March	554	September	2,253
April	1,253	October	1,498
May	1,917	November	877
June	2,456	December	225

Source: Adapted from Gropp, Steeby, and Bettine 1980.

Glaciers also alter the seasonal streamflow patterns of their watersheds. Meltwater flow from a glacier increases slowly as summer advances, with little response to rainfall. In the fall, heat which has been stored in the glacier during summer months maintains meltwater flow, extending the high-flows period well past the normal runoff period of nonglacial systems.

Generally, it is inadvisable to estimate basin yield or monthly streamflows for nonglacial rivers using streamflow records from a glacial system. However, the headwater conditions of the Newhalen and Tazimina Rivers appeared to be similar enough to justify an attempt at estimating average monthly streamflows for the Tazimina River from the 16 years of record on the Newhalen River.

The surface area of Lake Clark is approximately 960 square miles, or 28 percent of the total drainage area for the Newhalen River system. A lake this large probably mutes the influence of seasonal variations in runoff of the relatively small glacial streams entering the lake on Newhalen River streamflows. The Tazimina River headwaters in a 12-square-mile lake system overlying exceptionally deep deposits of glacial outwash contained by a volcanic intrusion (Abbott, pers. comm.). This lake/groundwater system was thought to significantly dampen variations in Tazimina River streamflows. Thus, enough similarity was thought to exist between Tazimina and Newhalen river streamflows to warrant the investment in obtaining periodic streamflow data from both rivers on corresponding dates for use in a correlation analysis.

The ratio between average daily streamflows at the Newhalen and Tazimina River stream gages was computed for each day that corresponding data were available (Figure III-5). This comparison indicated that during late July through mid-August 1981 the Tazimina River provided approximately 9.5 percent of the Newhalen River flow, and approximately 7 percent of the Newhalen flow was supplied by the Tazimina River during the period of late August through October.

The drainage area upstream from the USGS gage on the Tazimina River is 327 square miles and that for the Newhalen River gage is 3,478 square miles. The drainage area ratio for the Tazimina/Newhalen gage sites is 0.094. This ratio compares favorably with the daily streamflow ratios presented in Figure III-5 for the July-August period. This is to be expected for the 1981 dates since persistent regional rainstorms had saturated the Newhalen River drainage, and its sub-basins were contributing to streamflow at the Newhalen gage in direct relation to their size.

In general, base flows are more strongly influenced by the size and geology of a basin than by other factors. Taken collectively, the lakes and geologic structure of the upper Tazimina drainage were also accepted as functioning somewhat similar to the large lakes which maintain base flow in the Newhalen River during winter months. In fact it is quite likely that Tazimina River base flows are greater than those for the Newhalen River on a square mile basis during January to April due to the inability of cold winter temperatures to effect groundwater outflow from the upper Tazimina basin to the same degree cold winter temperatures retard outflow from the glaciers and Lake Clark. However, for lack of data to indicate otherwise, it was assumed that Tazimina River base flows would be proportional to Newhalen River winter flows. Therefore, average monthly winter streamflows at the USGS gaging station on the Tazimina River have been estimated by multiplying the

Figure III-5. Comparison of coincident daily streamflows at the USGS gaging stations on the Newhalen and Tazimina rivers.

Date of Observation 1981	Newhalen Streamflow cfs	Tazimina Streamflow cfs	Ratio QTZ/QNH
July 24	25,264	2,376	0.094
July 25	25,572	2,390	0.093
July 26	25,600	2,400	0.094
August 12	27,250	2,460	0.090
August 17	26,800	2,870	0.107
August 19	26,080	2,530	0.097
August 28	21,664	1,530	0.070
October 13	8,626	601	0.070
January 18, 1982	2,320	247	0.106

Note: The drainage area above the USGS gage (RM 11.6) on the Tazimina River is 327 square miles, that for the Newhalen River is 3,478 square miles; drainage area ratio is 0.094.

long-term average monthly winter flows for the Newhalen River by a drainage area ratio of 0.095. Snowmelt runoff in the Tazimina River during May and June is anticipated to reflect a somewhat higher value for runoff per square mile than would be indicated by average monthly streamflows during the same period for the Newhalen River. Hence, a runoff ratio of 0.12 was used for estimating Tazimina River streamflows during May and June (Figure III-6).

Figure III-6. Estimated average monthly streamflows for the Tazimina River at the USGS gaging station, RM 11.6.

Month	Average Monthly Streamflow for Newhalen River (cfs)	Ratio	Average Monthly Streamflow for Tazimina River (cfs)
January	2,700	0.095	255
February	2,100	0.095	200
March	1,900	0.095	180
April	1,900	0.095	180
May	4,700	0.12	565
June	14,000	0.12	1,680
July	21,000	0.095	1,995
August	22,000	0.095	2,090
September	18,000	0.070	1,260
October	11,000	0.070	770
November	6,300	0.095	600
December	3,600	0.095	340
Average Annual	9,100		843

The USGS has made several miscellaneous discharge measurements for the Tazimina River during the winters of 1980, 1981, and 1982 at a location approximately 2 miles upstream from the gagehouse (Figure III-7). A corresponding streamflow measurement for the Newhalen River was only obtained in 1982. The streamflow ratio for the January 1982 USGS measurements on the Tazimina and Newhalen rivers is 0.11.

The USGS base flow measurements are consistently 20 to 30 percent higher than the estimated monthly winter streamflows presented for the Tazimina River in Figure 5. These measurements are not viewed as contradicting the general order of magnitude of the estimates. In fact, they tend to confirm that winter low flows are approximately 200 cfs.

Figure III-7. Miscellaneous USGS winter base flow measurements at RM 13.6 on the Tazimina River.

Date	Streamflow (cfs)
January 11, 1981	290
January 7, 1982*	246
February 27, 1980	302
April 8, 1981	224

*Corresponding flow measured in Newhalen River = 2,320 cfs.

Average monthly streamflows for the Tazimina River have been estimated on the basis of a systematic review of basin characteristics and extrapolation of sixteen years of streamflow records for the Newhalen River. The nearest weather station is located in Iliamna but its low elevation and close proximity to Iliamna Lake are not representative of physical conditions found in the Tazimina River basin. The only streamflow data which exits in the Newhalen Drainage for a basin similar in size to the Tazimina was collected on the Tanalian River. Runoff patterns for the Tanalian River are dominated by glacial melt. No glaciers exist in the Tazimina River basin.

Tazimina River streamflows have also been estimated by various engineering firms. Due to the absence of precipitation, climate, and streamflow data for the Tazimina River basin, a variety of assumptions have been made. The significance of these assumptions is reflected in the variability among the various streamflow estimates presented in Figure III-8.

Figure III-8. Comparison between various average monthly streamflow estimates for the Tazimina River.

Month	Estimated Average Monthly Streamflows in cfs 1	2	3	4	5	USGS Record
January	280	130	240	255	197	250
February	406	130	190	200	115	N.R.
March	554	130	170	180	113	N.R.
April	1,253	130	170	180	110	N.R.
May	1,917	770	420	565	761	N.R.
June	2,456	2,050	1,260	1,680	2,889	2,560*
July	2,712	2,850	1,890	1,995	3,254	2,560
August	2,659	2,780	1,980	2,090	2,737	2,340
September	2,253	1,930	1,620	1,260	1,844	863
October	1,498	800	990	770	1,388	635
November	877	230	570	600	350	638
December	225	130	320	340	350	342
Average Annual	1,424	1,005	820	843	1,175	N.A.

1 Retherford projections (Gropp, Steeby, and Bettine 1980)

2 Stone and Webster estimates (Critikos, pers. comm. 1981)

3 Preliminary AEIDC estimates (Trihey 1982)

4 AEIDC Final estimates

5 Dames and Moore estimates (Dames and Moore 1982)

6 USGS provisional record (USGS unpublished data)

* June 18-30, 1981

APPENDIX III-A

9-210
(Nov. 1957)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

File No. Washington 30-3000.00
Field........................

Rating table for Newhalen River near Iliamna, Alaska

from Oct. 1, 19 61, *to* Sept 30, 1964, *from* May 1, 19 66, *to* ...., 19......

Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference
Feet	*Cfs*	*Cfs*	*Feet*	*Cfs*	*Cfs*	*Feet*	*Cfs*	*Cfs*	*Feet*	*Cfs*	*Cfs*	*Feet*	*Cfs*	*Cfs*	*Feet*	*Cfs*	*Cfs*	*Feet*	*Cfs*	*Cfs*
0 .00			2 .00	4,970	260	4 .00	11,590	400	6 .00	20,190	460	8 .00	29,800	500	10 .00	40,400	560	.00		
.10			.10	5,230	270	.10	11,990	400	.10	20,650	460	.10	30,300	500	.10	40,960		.10		
.20			.20	5,500	280	.20	12,390	400	.20	21,110	460	.20	30,800	520	.20	41,520		.20		
.30			.30	5,780	280	.30	12,790	410	.30	21,570	470	.30	31,320		.30	42,080		.30		
.40			.40	6,060	290	.40	13,200	410	.40	22,040		.40	31,840		.40	42,640		.40		
.50			.50	6,350	290	.50	13,610	410	.50	22,510		.50	32,360		.50	43,200		.50		
.60	2,180	150	.60	6,640	300	.60	14,020	420	.60	22,980		.60	32,880		.60	43,760	560	.60		
.70	2,330	160	.70	6,940	310	.70	14,440	420	.70	23,450	470	.70	33,400	520	.70	44,320		.70		
.80	2,490	170	.80	7,250	320	.80	14,860	430	.80	23,920	480	.80	33,920	540	.80			.80		
.90	2,660	170	.90	7,570	330	.90	15,290	430	.90	24,400		.90	34,460		.90			.90		
1 .00	2,830	180	3 .00	7,900	340	5 .00	15,720	430	7 .00	24,880		9 .00	35,000		.00			.00		
.10	3,010	180	.10	8,240	350	.10	16,150	440	.10	25,360		.10	35,540		.10			.10		
.20	3,190	190	.20	8,590	360	.20	16,590	440	.20	25,840		.20	36,080		.20			.20		
.30	3,380	200	.30	8,950	360	.30	17,030	440	.30	26,320	480	.30	36,620		.30			.30		
.40	3,580	210	.40	9,310	370	.40	17,470	450	.40	26,800	500	.40	37,160		.40			.40		
.50	3,790	220	.50	9,680	370	.50	17,920	450	.50	27,300		.50	37,700		.50			.50		
.60	4,010	230	.60	10,050	380	.60	18,370	450	.60	27,800		.60	38,240		.60			.60		
.70	4,240	240	.70	10,430	380	.70	18,820	450	.70	28,300		.70	38,780		.70			.70		
.80	4,480	240	.80	10,810	390	.80	19,270	460	.80	28,800		.80	39,320		.80			.80		
.90	4,720	250	.90	11,200	390	.90	19,730	460	.90	29,300	500	.90	39,860	540	.90			.90		

This table is applicable for open-channel conditions. It is based on 53 discharge measurements made during 1951-62 .... and is .... well defined between 2,200 cfs and 30,000 cfs. Comp by MJS date ....
Ch'd by EDH ... 12/6/62

III-13

9-210
(Rev. 2-67)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

Sta. No. 15277900
Table No. 01
Begin __ __ __ __ (YR. MO. D. HR.)

Rating table for TAZIMINIA RIVER NEAR NONDALTON, AK

from ________ to ________, from ________ to ________, from ________ to ________

Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference
Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs
.00			.00			0.00			2.00			.00			.00			.00		
.10			.10			.10	960	90	.10			.10			.10			.10		
.20			.20			.20	1050	100	.20			.20			.20			.20		
.30			.30			.30	1150	100	.30			.30			.30			.30		
.40			.40			.40	1250	100	.40			.40			.40			.40		
.50			.50			.50	1350	110	.50			.50			.50			.50		
.60			.60			.60	1460	110	.60			.60			.60			.60		
.70			.70			.70	1570	110	.70			.70			.70			.70		
.80			.80			.80	1680	120	.80			.80			.80			.80		
.90			.90			.90	1800	120	.90			.90			.90			.90		
.00			.00			1.00	1920	130	.00			.00			.00			.00		
.10			.10			.10	2050	130	.10			.10			.10			.10		
.20			.20			.20	2180	140	.20			.20			.20			.20		
.30			.30			.30	2320	140	.30			.30			.30			.30		
.40			.40			.40	2460	140	.40			.40			.40			.40		
.50			.50			.50	2600	150	.50			.50			.50			.50		
.60			.60			.60	2750	150	.60			.60			.60			.60		
.70			.70			.70	2900	150	.70			.70			.70			.70		
.80			.80			.80	3050	160	.80			.80			.80			.80		
.90			.90			.90	3210		.90			.90			.90			.90		

PROVISIONAL DATA SUBJECT TO REVISION

This table is applicable for open-channel conditions. It is based on 3 discharge measurements made during 1981 WY

________ and is ________ well defined between 1000 cfs and 2600 cfs.

Comp. by CSS date 9-18-81

Ckd. by ______ date ______

$Q = 226(GH + 2.0)^{1.95}$

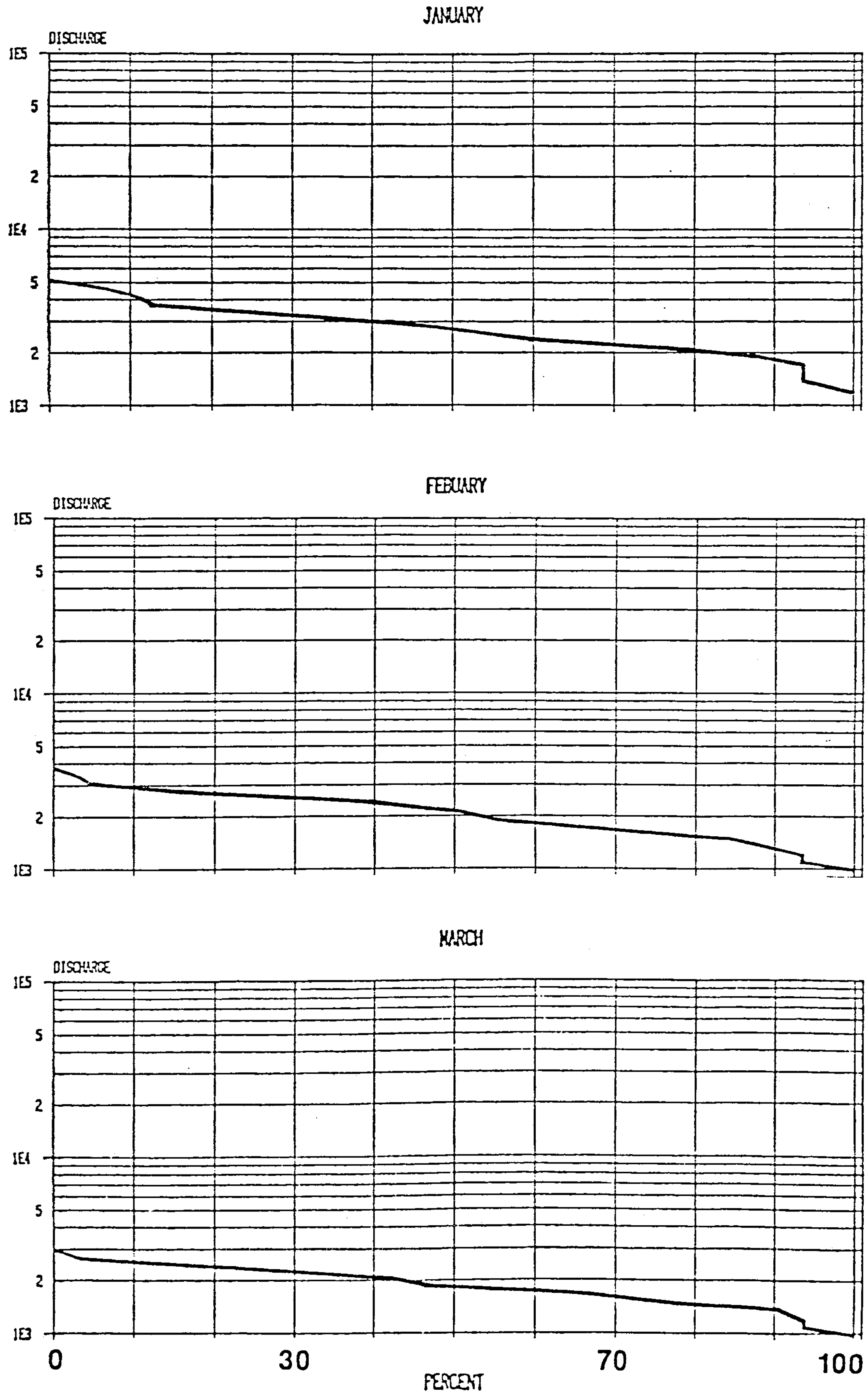
III-14

Rating table for staff gage at Tazimina River
above the mouth (RM 1.7)

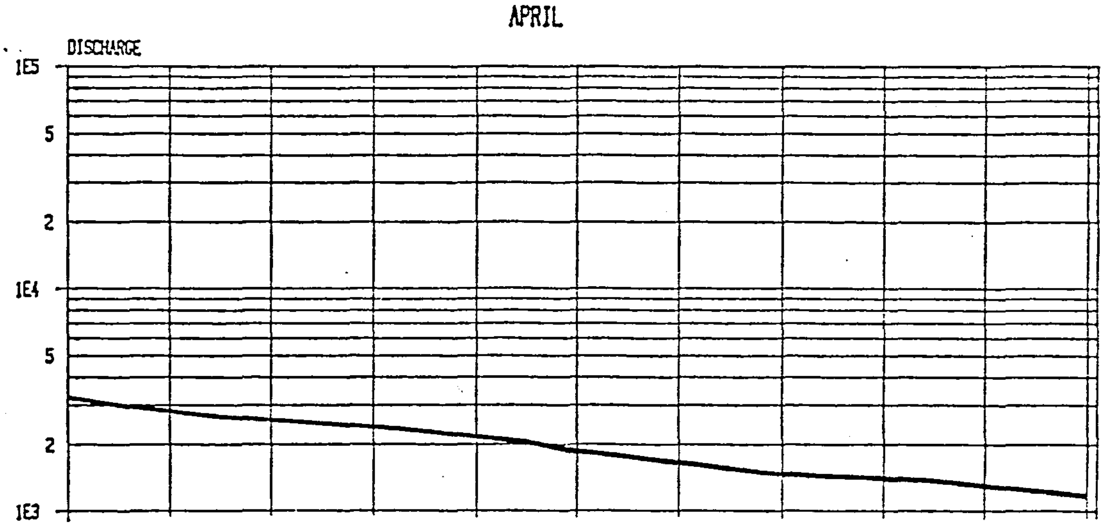
Stage (ft)	Discharge (cfs)
1.17	500
1.23	550
1.29	600
1.35	650
1.41	700
1.47	750
1.52	800
1.57	850
1.62	900
1.67	950
1.72	1000
1.82	1100
1.91	1200
2.00	1300
2.08	1400
2.16	1500
2.24	1600
2.32	1700
2.39	1800
2.47	1900
2.54	2000
2.68	2200
2.81	2400
2.94	2600
3.07	2800
3.19	3000
3.31	3200
3.42	3400
3.53	3600

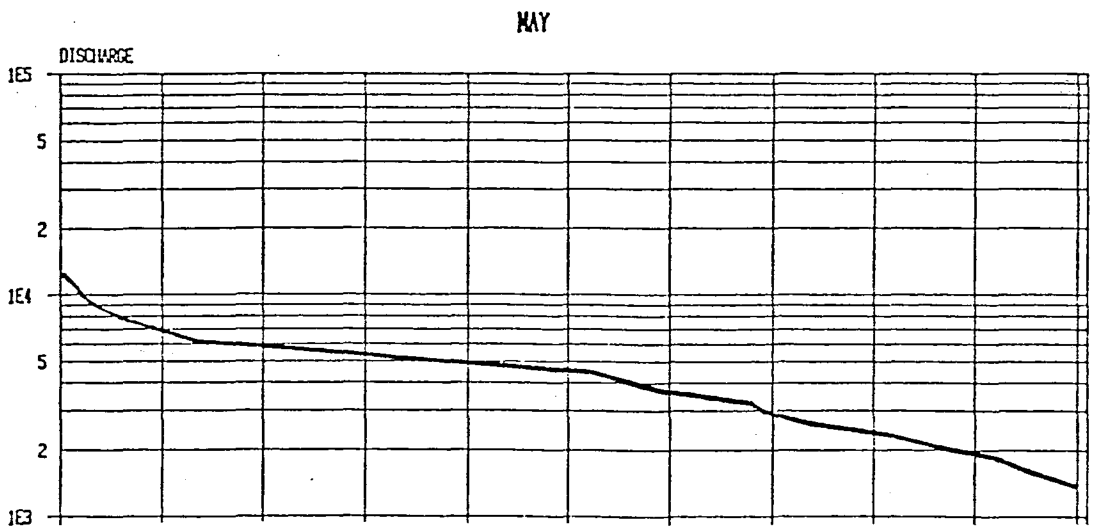
$\text{Stage} = 0.036\ Q^{.56}$

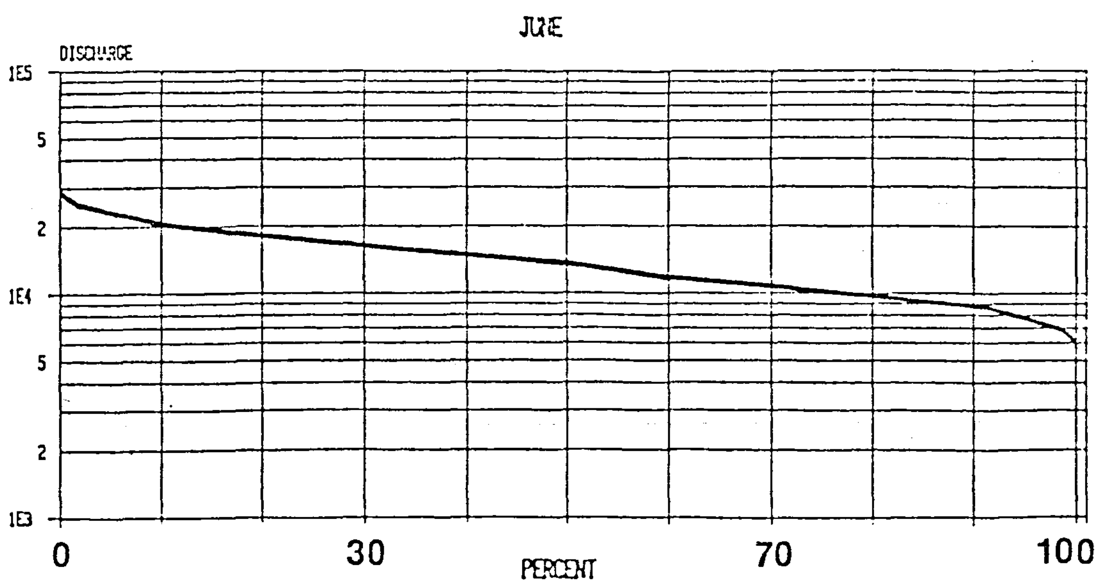
FLOW DURATION NEWHALEN RIVER



FLOW DURATION NEWHALEN RIVER







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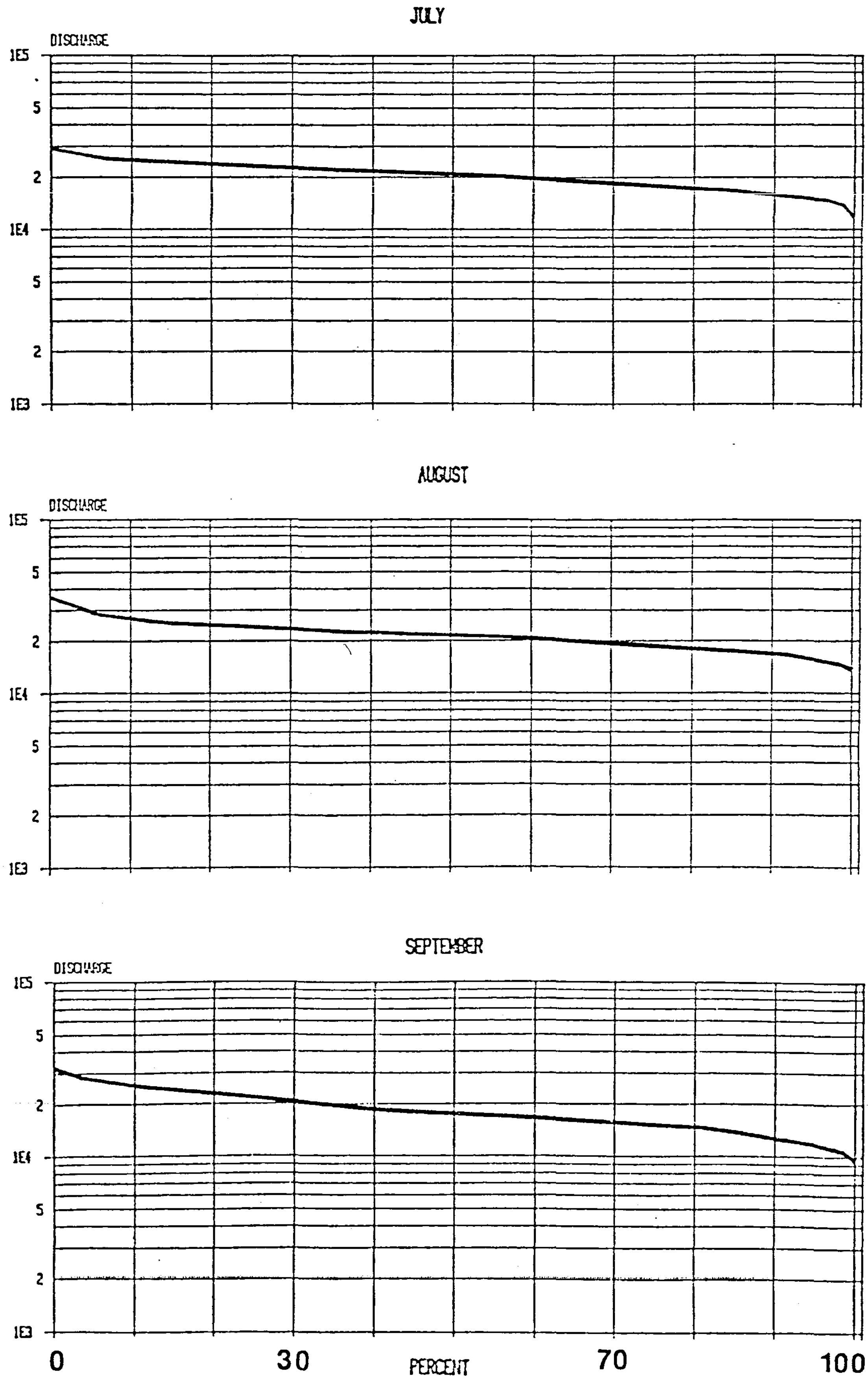
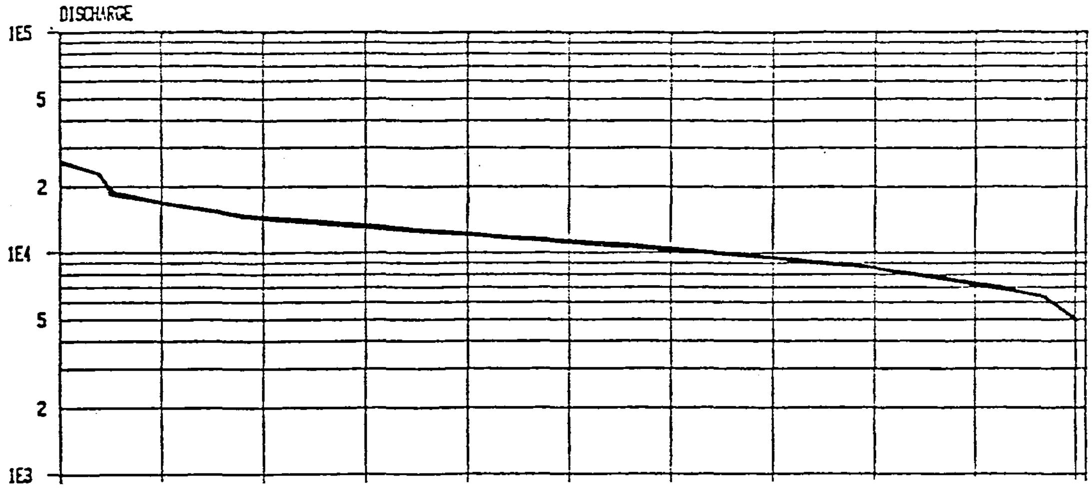
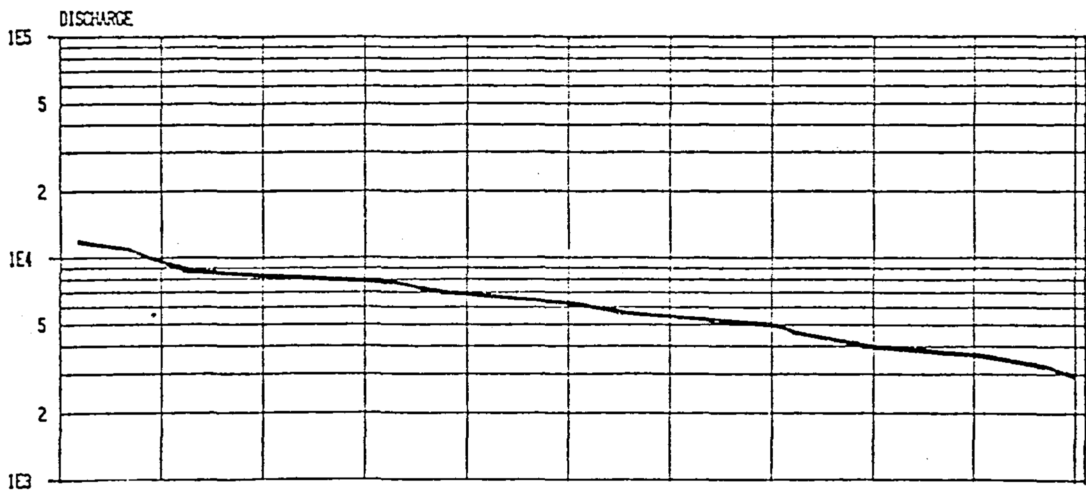


FLOW DURATION NEWHALEN RIVER

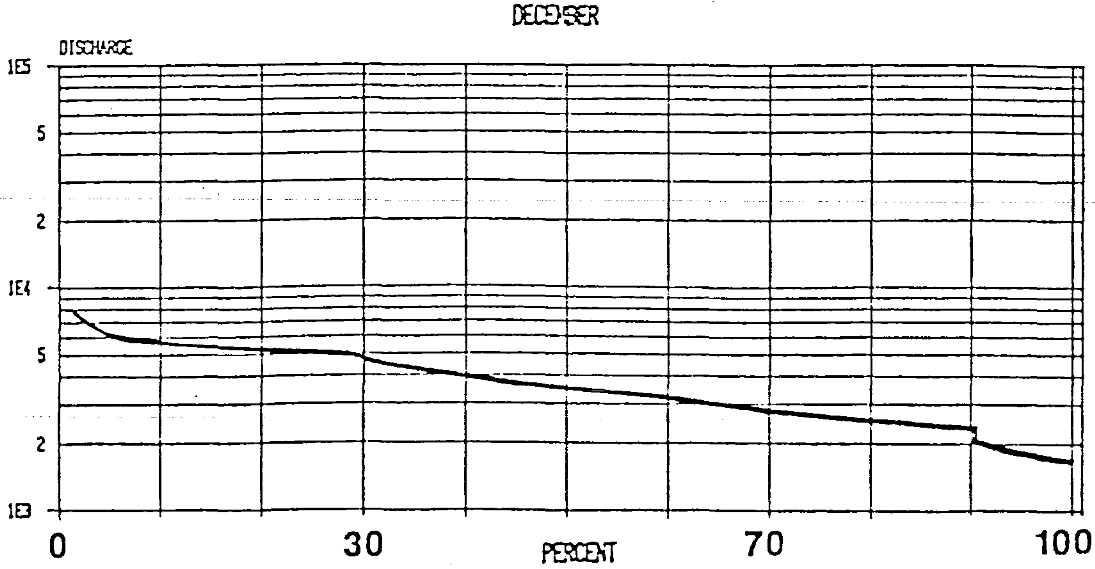
OCTOBER



NOVEMBER



DECEMBER



IHEIMINA RIVER NEAR NONDALTON

1981 WY

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Station Number 15299900

Used rating table dated

Gage Read to .... Once / Twice a Day by ....

Gage heights used to half tenths between ____ and ____ feet; hundredths below and tenths above these limits.

PROVISIONAL RECORDS SUBJECT TO REVISION

April		May		June		July		August		September		
Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Day
						3.30	3050	3.10	2050	2.43	1280	1
						3.72	2930	3.56	2690	2.39	1240	2
						3.59	2740	3.88	3180	2.35	1200	3
						3.48	2570	3.89	3190	2.35	1200	4
						3.36	2400	3.78	3020	2.33	1180	5
						3.28	2290	3.64	2810	2.28	1130	6
						3.24	2240	3.51	2620	2.23	1080	7
						3.21	2190	3.38	2430	2.19	1040	8
						3.24	2240	3.32	2350	2.16	1010	9
						3.40	2460	3.35	2390	2.12	987	10
						3.66	2840	3.34	2320	2.09	951	11
						3.77	3000	3.40	2460	2.06	924	12
						3.75	2980	3.47	2560	2.05	915	13
						3.65	2820	3.63	2800	1.99	854	14
						3.66	2840	3.82	3080	1.92	806	15
						3.77	3000	3.78	3220	1.87	766	16
						3.76	2990	3.66	2840	1.82	734	17
				3.19 f	2170	3.69	2880	3.55	2620	1.81	718	18
				3.29	2310	3.63	2800	3.41	2470	1.78	696	19
				3.44	2520	3.56	2690	3.31	2330	1.79	703	20
				3.59	2740	3.49	2590	3.19	2170	1.81	718	21
				3.67	2860	3.40	2460	3.06	2000	1.77	689	22
				3.62	2780	3.34	2380	2.92	1820	1.73	661	23
				3.56	2690	3.33	2360	2.82	1700	1.73	661	24
				3.51	2620	3.36	2400	2.75	1620	1.72	654	25
				3.45	2530	3.36	2400	2.70	1570	1.70	640	26
				3.40	2460	3.30	2320	2.66	1530	1.69	633	27
				3.35	2390	3.21	2190	2.64	1560	1.68	626	28
				3.34	2380	3.16	2130	2.59	1450	1.65	605	29
				3.63	2800	3.12	2080	2.54	1390	1.62	584	30
						3.05	1980	2.50	1350			31
							2560		2340		863	

PROVISIONAL RECORDS SUBJECT TO REVISION

	Fourth	Third	Second	First	Quarter
					Computed
					Checked
					Disch. applied
					Disch. checked
					G. H. copied
					G. H. checked

Period

Year

-192-a. (Rev. May 1971)

Daily Gage Height, in Feet, and Discharge, in Cubic Feet, per Second, of Tuolumne

Near [illegible] for the Year Ending September 30, 19 82

Drainage Area ______ Square Miles. Water-Stage Recorder ______ Ratio 1 : 6

Day	October Gage height	October Discharge	November Gage height	November Discharge	December Gage height	December Discharge	January Gage height	January Discharge	February Gage height	February Discharge	March Gage height	March Discharge
1	1.59	563		850		470		260				
2	1.54	523		830		450						
3	1.53	521		810		440						
4	1.52	514		800		420						
5	1.50	500		800		410		260				
6	1.46	472		790		400		250				
7	1.42	444		780		390						
8	1.38	418		760		380						
9	1.35	400		740		330						
10	1.31	376		720		350						
11	1.33	418		700								
12	1.46	472		680								
13	1.49	493		660								
14	1.49	493		630								
15	1.50	500		610		350						
16	1.56	542		590		320						
17	1.61	577		570								
18	1.61	577		560				250				
19	1.58	556		550								
20	1.57	549		540		320						
21	1.70	640		530		300						
22	1.80	710		520								
23	1.90	790										
24	2.07	933										
25	2.09	951				300						
26	2.15	1000				280						
27	2.16	1010										
28	2.15	1000		520								
29	2.11	969		510								
30	[illegible]	900		490								
31		[illegible]				280						
Total												
Mean		635		638		342						
Maximum												
Minimum												
Cfsm.												
Runoff in inches												
Acre-feet												

Max. G. H. ______ ft. at ______ on ______

Min. G. H. ______ ft. on ______

Max. Disch. ______ CFS at ______ on ______ (G. H. ______ ft.)

Min. Disch. ______ CFS on ______ (G. H. ______ ft.)

Calendar Year

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Appendix IV

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