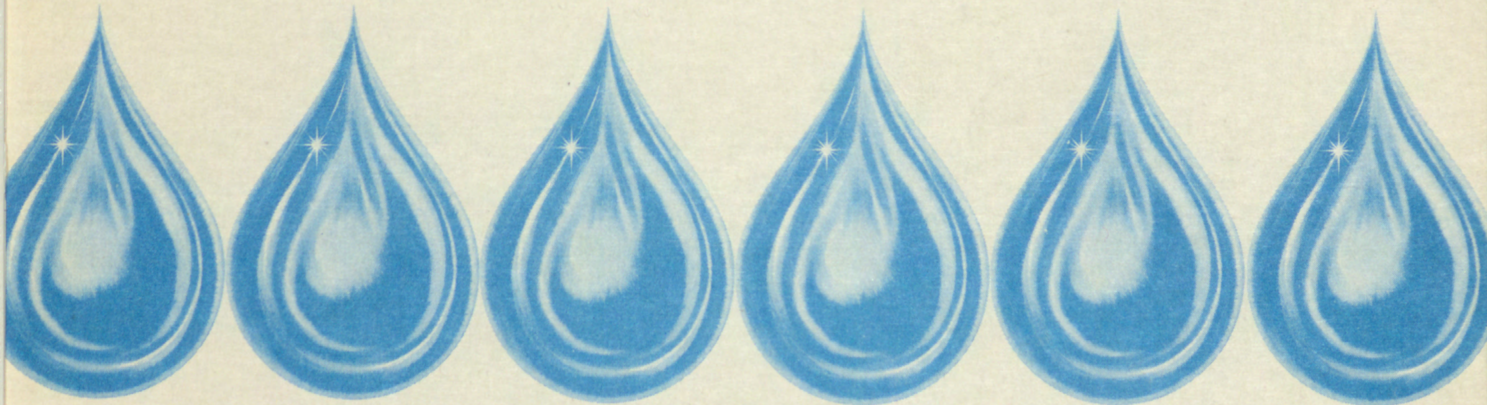

# WATER RESOURCES OF THE LOWER ELWHA INDIAN RESERVATION, WASHINGTON

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations
Open-File Report 79-82



Prepared in Cooperation With
Lower Elwha Tribal Council

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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By Kenneth L. Walters, William L. Haushild, and
Leonard M. Nelson

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Tacoma, Washington
1979

UNITED STATES DEPARTMENT OF THE INTERIOR
CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY
H. William Menard, Director

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U.S. Geological Survey, WRD
1201 Pacific Avenue - Suite 600
Tacoma, Washington 98402

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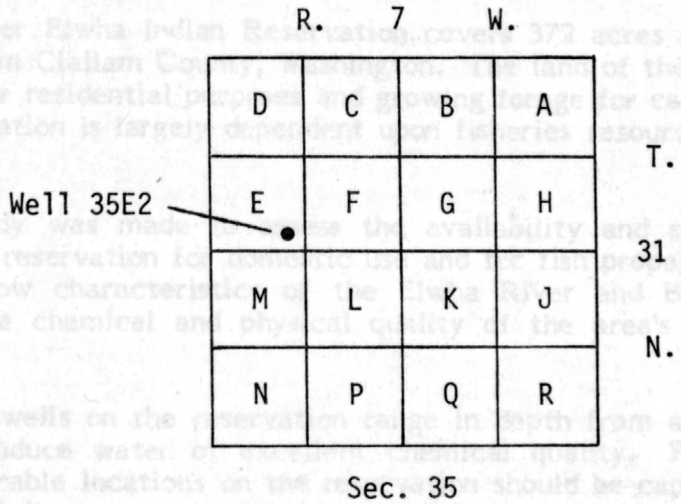
## METRIC CONVERSION FACTORS

| Multiply | By | To obtain |
|---|---|---|
| foot | 0.3048 | meter (m) |
| mile | 1.609 | kilometer (km) |
| acre | 4047. | square meter ($m^2$) |
| acre-foot (acre-ft) | 1233. | cubic meter ($m^3$) |
| cubic foot per second ($ft^3/s$) | 28.32 | liter per second (L/s) |
| | .02832 | cubic meter per second ($m^3/s$) |
| gallon per minute (gal/min) | .06309 | liter per second (L/s) |
| degrees Fahrenheit (°F) | Subtract 32, multiply remainder by .5556 | degree Celsius (°C) |

## WELL-NUMBERING SYSTEM

The well numbers used in this report give the location of wells according to the official rectangular public-land survey. Because all the wells mentioned in the report are in Township 31 North and Range 7 West of the Willamette base line and meridian, respectively, this information is omitted from the well number. For example, in well number 35E2 the number 35 indicates the section, and the letter E indicates the 40-acre subdivision of the section as shown in the sketch below. The last number is a sequence number used to distinguish wells in the same 40-acre tract. Thus, well 35E2 is in the SW¼ of the NW¼ of sec. 35, T.31 N., R.7 W.



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## ABSTRACT

The Lower Elwha Indian Reservation covers 372 acres at the mouth of the Elwha River in Clallam County, Washington. The land of the reservation is used principally for residential purposes and growing forage for cattle. The population of the reservation is largely dependent upon fisheries resources for its economic health.

This study was made to assess the availability and suitability of ground water on the reservation for domestic use and for fish propagation, to determine the streamflow characteristics of the Elwha River and Bosco Creek, and to determine the chemical and physical quality of the area's surface and ground waters.

Existing wells on the reservation range in depth from about 30 to about 80 feet, and produce water of excellent chemical quality. Properly constructed wells in favorable locations on the reservation should be capable of large yields, up to 5,000 gallons per minute. Intrusion of seawater into the aquifers of the reservation has not occurred. However, if massive quantities of ground water are withdrawn, intrusion could occur.

The Elwha River, which flows along the western margin of the reservation has a mean annual flow of about 1,500 cubic feet per second ($ft^3/s$). The recorded minimum daily discharge was 10 $ft^3/s$, and the maximum was 41,600 $ft^3/s$. The river floods the lower parts of the reservation annually, and extensive flooding is common. Water in the Elwha River is of excellent chemical quality, and its recorded temperature has ranged from 36° to 64°F. Bosco Creek, the only other stream on or adjacent to the reservation, has an estimated mean annual flow of 1.1 $ft^3/s$.

## INTRODUCTION

### Location, Extent, and Description of the Reservation

The Lower Elwha Indian Reservation of the Klallam Tribe is located principally on the floor of the Elwha River Valley in Clallam County, Wash. (fig. 1). Most of the reservation is east of the Elwha River, and includes nearly a mile of frontage on the Strait of Juan de Fuca. A small part of the reservation that lies on the upland west of the river was not included in this study. The 372 acres that compose the reservation were purchased with funds made available under the Indian Reorganization Act of 1934, and the land was designated as an Indian Reservation in 1968. As shown in figure 1, the land of the reservation is not in a single distinct parcel, but rather is interspersed with non-Indian holdings.

The reservation is almost entirely on a delta built into the Strait of Juan de Fuca by the Elwha River, and former channels of the river are indicated by numerous depressions, sloughs, and ponds. The change in the position of the river channel between 1950 and 1977 in relation to the reservation is illustrated by comparing figures 1 and 3. The floor of the valley is separated from the adjacent uplands by steep bluffs.

The land of the reservation is used chiefly for residential purposes, grazing of cattle, and growing of hay crops. Some of the land is timbered, but little marketable timber remains.

### Purpose and Scope

The Klallam Indian Tribe is dependent in large measure upon its natural fisheries resource for its economic health. This natural resource has been closely dependent on the Elwha River. In the future a fisheries resource could be tied to other sources of water supplies that might be developed to start salmon-rearing facilities on the reservation. Because all domestic water supplies on the reservation are from individual wells, and much of the reservation is subject to flooding by the Elwha River, the health and welfare of all residents of the reservation are highly dependent upon the surface and ground water of the reservation.

Prior to this study the water resources of the reservation had not been documented in sufficient detail for the tribe to assess the extent of the resource in order to estimate the potential for development. To be able to do this, the tribe entered into a cooperative agreement with the U.S. Geological Survey in 1975 authorizing a study of the water resources of the reservation. Items specifically designated for study included:

1. Ground-water availability for domestic use.
2. Delineation of areas subject to seawater intrusion.
3. The potential availability of large supplies of ground water for fish rearing.

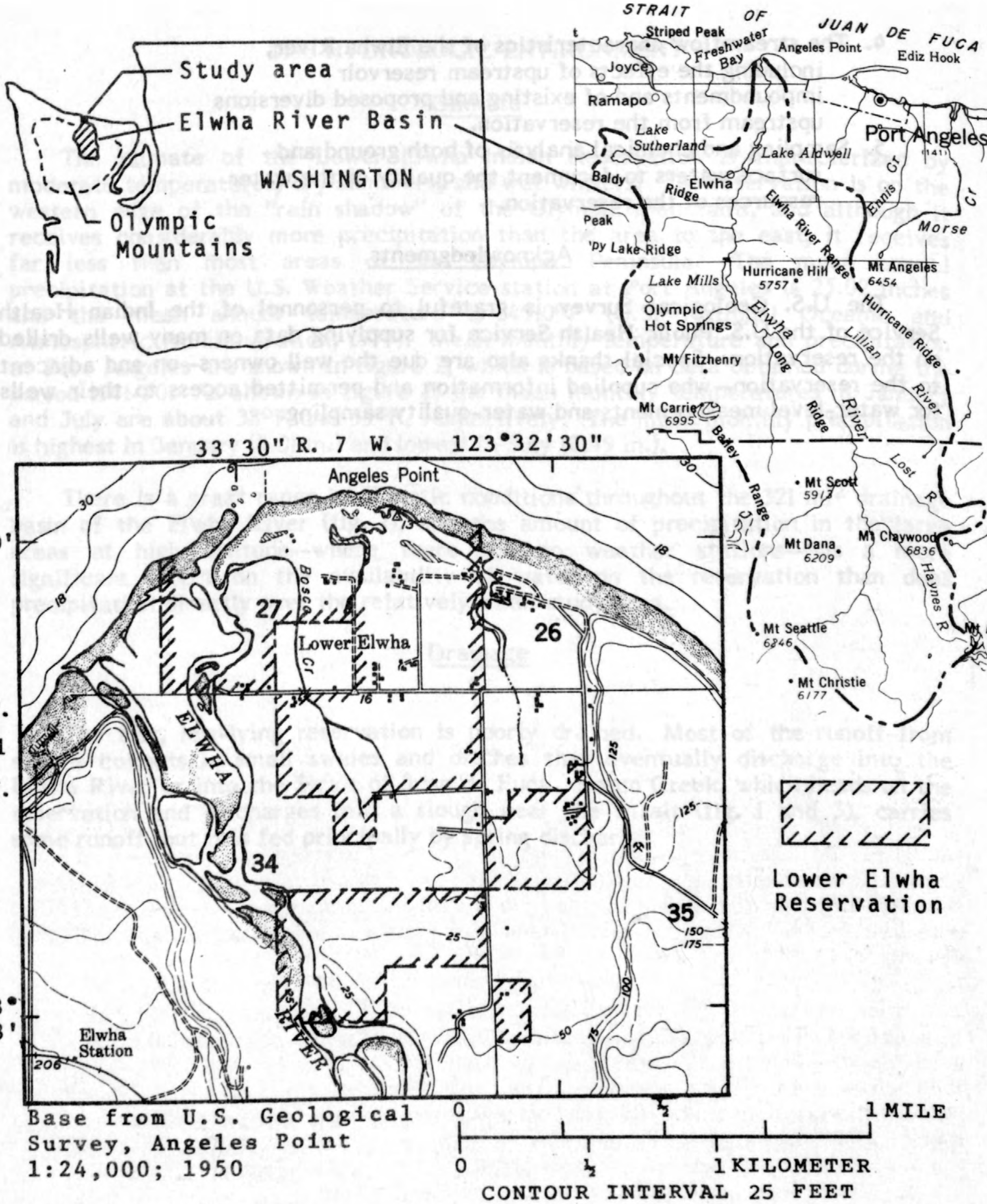



FIGURE 1.--Location of the Lower Elwha Indian Reservation, and the Elwha River basin.

4. The streamflow characteristics of the Elwha River, including the effects of upstream reservoir impoundments and of existing and proposed diversions upstream from the reservation.
5. Sampling and chemical analysis of both ground and surface waters to document the quality of the water resources of the reservation.

## Acknowledgments

The U.S. Geological Survey is grateful to personnel of the Indian Health Service of the U.S. Public Health Service for supplying data on many wells drilled on the reservation. Special thanks also are due the well owners--on and adjacent to the reservation--who supplied information and permitted access to their wells for water-level measurements and water-quality sampling.

## THE HYDROLOGIC ENVIRONMENT

### Climate

The climate of the Lower Elwha Indian Reservation is characterized by moderate temperatures, dry summers, and wet winters. The reservation is on the western edge of the "rain shadow" of the Olympic Mountains, and although it receives considerably more precipitation than the area to the east, it receives far less than most areas of the Olympic Peninsula. The mean annual precipitation at the U.S. Weather Service station at Port Angeles is 25.02 inches and the mean annual temperature is 49.0°F (U.S. National Oceanic and Atmospheric Administration, 1977). Mean monthly temperature and precipitation at Port Angeles are shown in figure 2, which is based on data obtained during the period 1941-70. As shown in figure 2, the mean monthly temperatures in January and July are about 38°F and 59°F, respectively. The mean monthly precipitation is highest in January (4.01 in.) and lowest in July (0.49 in.).

There is a great range in climatic conditions throughout the 321 $mi^2$ drainage basin of the Elwha River (fig. 1), and the amount of precipitation in the large areas at high altitude--where there are no weather stations--has a more significant effect on the availability of water on the reservation than does precipitation directly over the relatively small study area.

### Drainage

The flat, low-lying reservation is poorly drained. Most of the runoff from storms collects in small swales and ditches that eventually discharge into the Elwha River or into the Strait of Juan de Fuca. Bosco Creek, which heads on the reservation and discharges into a slough near the Strait (fig. 1 and 3), carries some runoff, but it is fed principally by spring discharge.

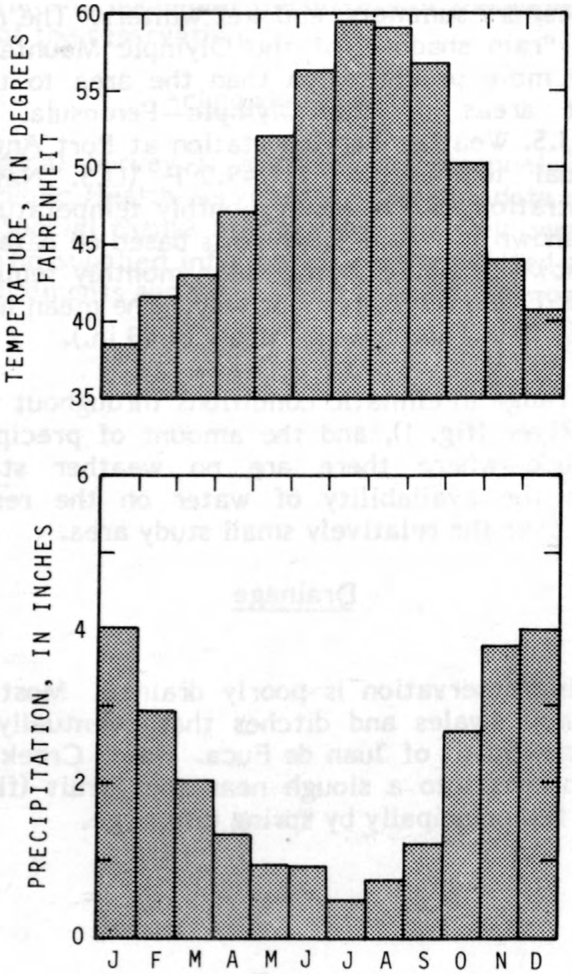



FIGURE 2.--Mean monthly temperature and precipitation at Port Angeles, Wash., during 1941-70. Based on data from U.S. National Oceanic and Atmospheric Administration.

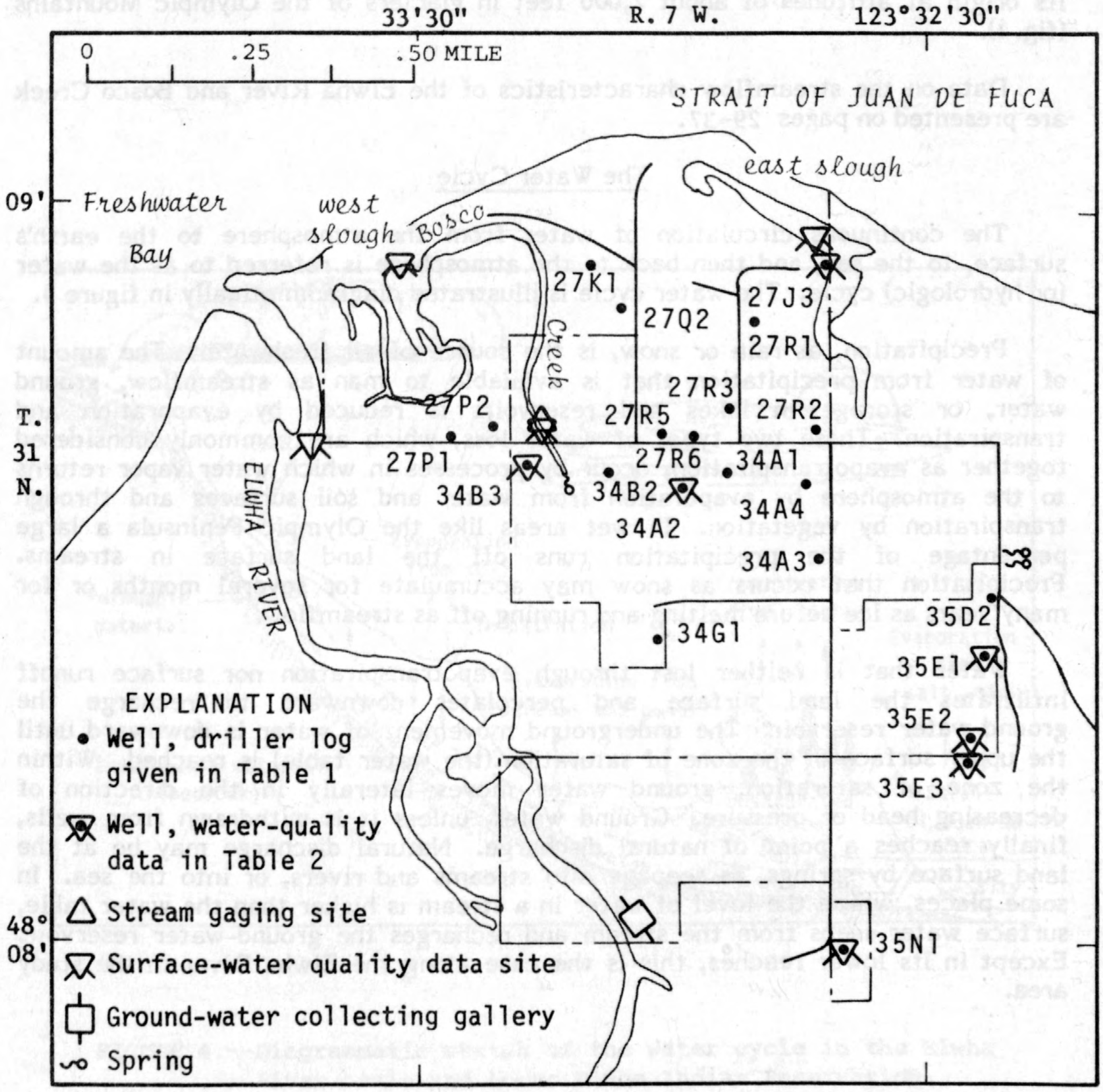



FIGURE 3.--Surface-water and ground-water data-collection sites.

The Elwha River flows past the western margin of the reservation, and has its origin at altitudes of about 7,000 feet in glaciers of the Olympic Mountains (fig. 1).

Data on the streamflow characteristics of the Elwha River and Bosco Creek are presented on pages 29-37.

## The Water Cycle

The continuous circulation of water from the atmosphere to the earth's surface, to the sea, and then back to the atmosphere is referred to as the water (or hydrologic) cycle. The water cycle is illustrated diagrammatically in figure 4.

Precipitation, as rain or snow, is the source of all freshwater. The amount of water from precipitation that is available to man as streamflow, ground water, or storage in lakes and reservoirs is reduced by evaporation and transpiration. These two types of water loss, which are commonly considered together as evapotranspiration, occur by processes in which water vapor returns to the atmosphere by evaporation from water and soil surfaces and through transpiration by vegetation. In wet areas like the Olympic Peninsula a large percentage of the precipitation runs off the land surface in streams. Precipitation that occurs as snow may accumulate for several months or for many years as ice before melting and running off as streamflow.

Water that is neither lost through evapotranspiration nor surface runoff infiltrates the land surface and percolates downward to recharge the ground-water reservoir. The underground movement of water is downward until the upper surface of the zone of saturation (the water table) is reached. Within the zone of saturation, ground water moves laterally in the direction of decreasing head or pressure. Ground water, unless it is withdrawn from wells, finally reaches a point of natural discharge. Natural discharge may be at the land surface by springs, as seepage into streams and rivers, or into the sea. In some places, where the level of water in a stream is higher than the water table, surface water seeps from the stream and recharges the ground-water reservoir. Except in its lower reaches, this is the case along the Elwha River in the study area.

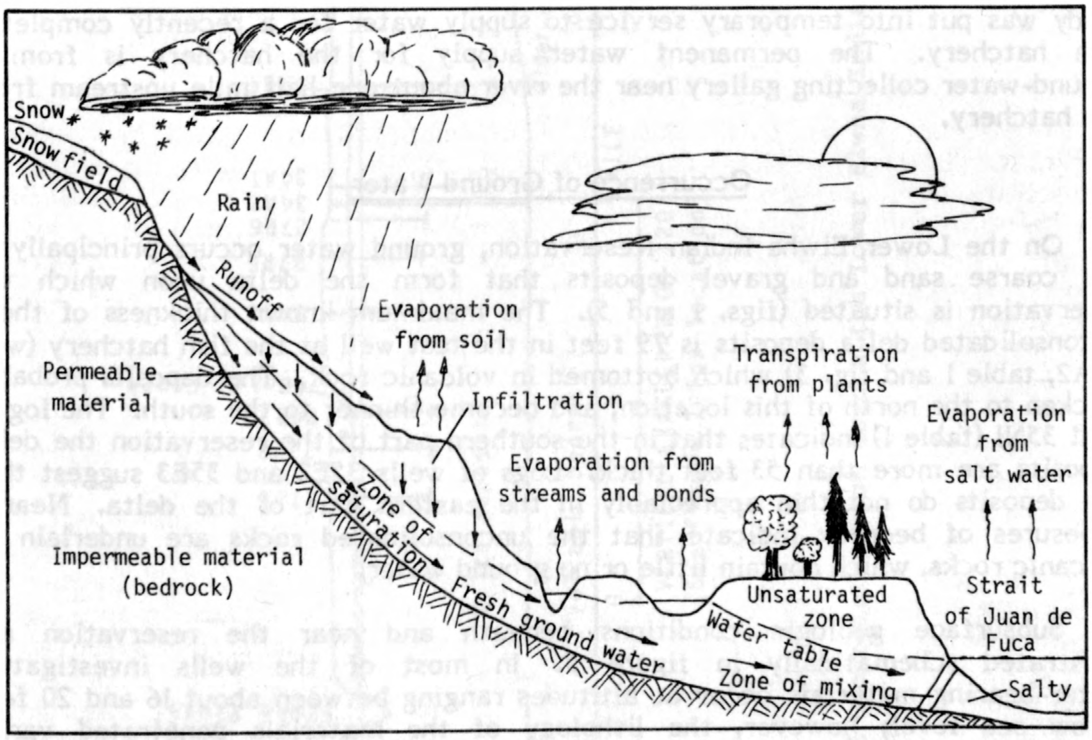



FIGURE 4.--Diagrammatic sketch of the water cycle in the Elwha River basin and Lower Elwha Indian Reservation.

## GROUND-WATER RESOURCES

The convenient accessibility to a reliable source of ground water may be one of the more valuable features of the Lower Elwha Indian Reservation. Ground water has several advantages over surface water, including the following: (1) It is available everywhere beneath the reservation; (2) it is somewhat less subject to contamination; and (3) the temperature, turbidity, and available quantity of ground water does not fluctuate greatly with seasonal changes.

Prior to 1977, the only use of ground water on the reservation was for individual domestic supplies. Early in 1977, a test well drilled as a part of this study was put into temporary service to supply water for a recently completed fish hatchery. The permanent water supply for the hatchery is from a ground-water collecting gallery near the river about one-half mile upstream from the hatchery.

### Occurrence of Ground Water

On the Lower Elwha Indian Reservation, ground water occurs principally in the coarse sand and gravel deposits that form the delta upon which the reservation is situated (figs. 1 and 5). The maximum known thickness of these unconsolidated delta deposits is 79 feet in the test well at the fish hatchery (well 34A2, table 1 and fig. 3) which bottomed in volcanic rock. The deposits probably thicken to the north of this location, and become thinner to the south. The log of well 35N1 (table 1) indicates that in the southern part of the reservation the delta deposits are more than 53 feet thick. Logs of wells 35E2 and 35E3 suggest that the deposits do not thin appreciably in the eastern part of the delta. Nearby exposures of bedrock indicate that the unconsolidated rocks are underlain by volcanic rocks, which contain little or no ground water.

Subsurface geologic conditions beneath and near the reservation are illustrated schematically in figure 5. In most of the wells investigated, water-bearing materials occur at altitudes ranging between about 16 and 20 feet below sea level; however, the lithology of the materials penetrated varies considerably from well to well, as is typical of deltaic deposits. The older unconsolidated deposits that are exposed in the valley walls do not underlie the reservation.

Ground water moves continuously from points of recharge to points of discharge. When the amount of recharge is equal to the amount of discharge the system is in balance. When recharge is reduced, ground-water levels decline, the gradient or slope of the water table is decreased, and the discharge is reduced. On the Lower Elwha Indian Reservation, recharge during the winter months is from precipitation on the land surface and by seepage from the Elwha River; during the drier summer months recharge is from the river only. Seasonal fluctuations in water levels in seven wells are shown in figure 6 and the locations of these wells are shown in figure 3.

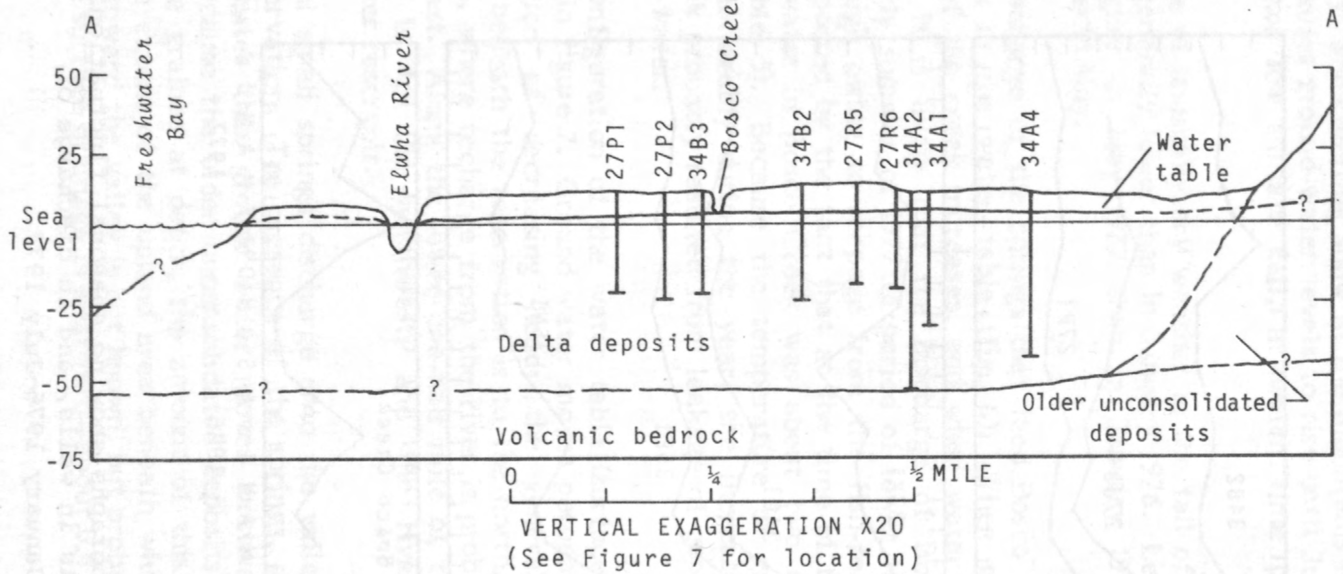



FIGURE 5.--Generalized geologic section across the Lower Elwha Indian Reservation.

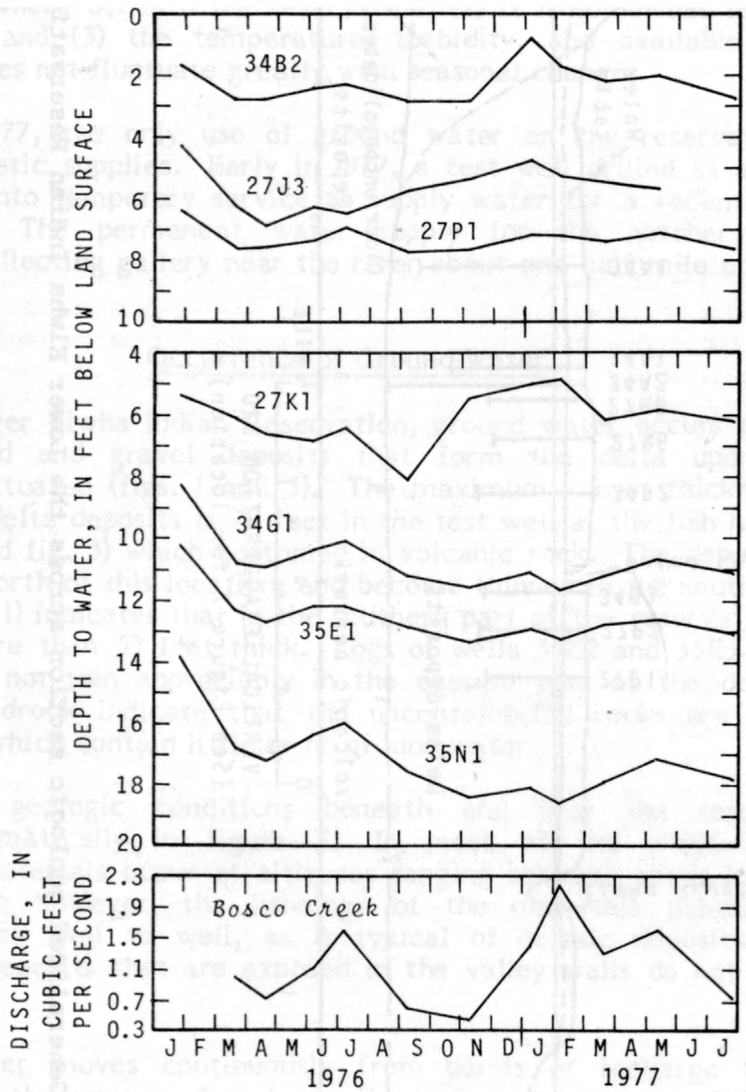



FIGURE 6.--Hydrographs showing seasonal fluctuations in water levels in wells, and in discharge of Bosco Creek, January 1976-July 1977.

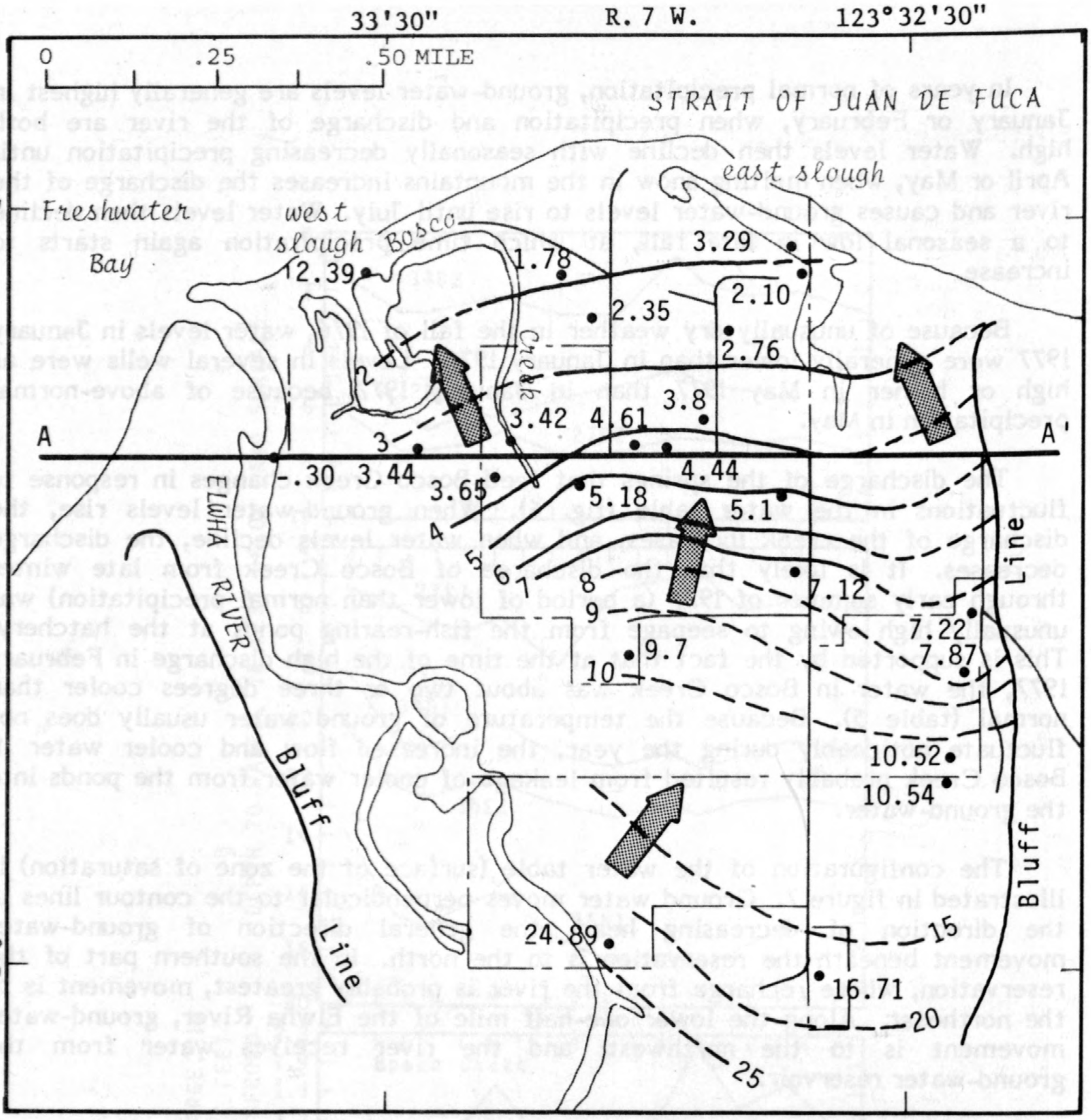
In years of normal precipitation, ground-water levels are generally highest in January or February, when precipitation and discharge of the river are both high. Water levels then decline with seasonally decreasing precipitation until April or May, when melting snow in the mountains increases the discharge of the river and causes ground-water levels to rise until July. Water levels then decline to a seasonal low in late fall, at which time precipitation again starts to increase.

Because of unusually dry weather in the fall of 1976, water levels in January 1977 were generally lower than in January 1976. Levels in several wells were as high or higher in May 1977 than in January 1977 because of above-normal precipitation in May.

The discharge of the springs that feed Bosco Creek changes in response to fluctuations in the water table (fig. 6). When ground-water levels rise, the discharge of the creek increases, and when water levels decline, the discharge decreases. It is likely that the discharge of Bosco Creek from late winter through early summer of 1977 (a period of lower than normal precipitation) was unusually high owing to seepage from the fish-rearing ponds at the hatchery. This is supported by the fact that at the time of the high discharge in February 1977, the water in Bosco Creek was about two or three degrees cooler than normal (table 5). Because the temperature of ground water usually does not fluctuate noticeably during the year, the increased flow and cooler water in Bosco Creek probably resulted from leakage of cooler water from the ponds into the ground-water.

The configuration of the water table (surface of the zone of saturation) is illustrated in figure 7. Ground water moves perpendicular to the contour lines in the direction of decreasing head; the general direction of ground-water movement beneath the reservation is to the north. In the southern part of the reservation, where recharge from the river is probably greatest, movement is to the northeast. Along the lower one-half mile of the Elwha River, ground-water movement is to the northwest; and the river receives water from the ground-water reservoir.

Several small springs discharge onto the valley floor from the uplands east of the reservation. The presence of the springs, about 10 feet above the valley floor, indicates that ground water moves westward from the upland into the valley. Because the older unconsolidated deposits that underlie the upland are mostly fine grained at depth, the amount of this underground flow is probably small. The extent of the upland area beneath which ground-water movement is westward toward the valley is not known, but probably coincides roughly with the area where surface drainage is westward--about 0.4 mile wide and 2 miles long.




EXPLANATION

—5— Contour line showing altitude of water table above mean sea level

• Data control point, with altitude of water surface

General direction of ground-water movement

A——A' Line of section in Figure 5

FIGURE 7.--Contours on the water table beneath the study area, June 11, 1977.

The quantity of ground water that flows beneath the reservation and discharges into the Strait of Juan de Fuca can be calculated by the formula

$$Q = TIL,$$

where

Q = quantity of ground-water flow, in cubic feet per day;
T = transmissivity of the aquifer (water-bearing material), in feet squared per day;
I = ground-water gradient in feet per foot; and
L = length, in feet, of the section through which discharge occurs.

The transmissivity (T) of aquifer materials is a measure of the ability of the materials to transmit water. Interpretation of pumping-test data on test well 34A2 (table 3) indicates that the transmissivity of the principal water-bearing material at this well is high--about 56,000 $ft^2/d$. The ground-water gradient (I) in the vicinity of the test well is about 1 foot in 600 feet. The length of the section (L) through which discharge occurs--from the river east to the bluff line--is about 5,400 feet. Using these values, the discharge of ground water to the Strait can be estimated as follows:

$$Q = 56{,}000 \times 1/600 \times 5{,}400 = 500{,}000 \text{ ft}^3\text{/d (or 6 ft}^3\text{/s).}$$

This amount of ground-water underflow to the Strait is insignificant when compared with the discharge of the Elwha River, and is only three times larger than the maximum observed discharge of Bosco Creek. However, the rather small amount of ground-water underflow should not be regarded as the total amount of ground water available for use on the reservation. Rather, it represents the amount by which recharge exceeds discharge by evapotranspiration, pumpage, and seepage to streams. The ground water that is discharged into the Strait of Juan de Fuca as underflow is lost from the immediate hydrologic system, but it is not wasted because this seaward movement of ground water prevents the intrusion of salt water into aquifers beneath the reservation.

The amount of ground water that can be withdrawn from beneath the reservation depends on well locations and spacing. If high-yield wells, about 5,000 gal/min each, were drilled on or near the marine shoreline and were heavily pumped, the ground-water level in the vicinity of the wells would be lowered. Appreciable lowering of the ground-water level adjacent to the shoreline would cause a reversal of the normal seaward movement of ground water, and result in saltwater being drawn into the aquifer. However, if similar, high-yield wells were located adjacent to the Elwha River at some distance from the marine shoreline, lowering the ground-water level in the vicinity of the wells would steepen the ground-water gradient and increase the amount of water moving from the river into the ground-water body. The ground-water collecting gallery that was constructed as a water supply for the fish hatchery is an example of the latter arrangement. About 700 feet of perforated pipe was buried in a trench adjacent to, and roughly parallel to, the Elwha River in an area where the river normally looses water to the ground-water body. The buried pipe is below the water table and the river level. Water moves underground from the river to the buried pipe and is then carried to the hatchery by gravity pipeline. In this type of installation, the ground-water gradient that can be established is limited by the relative elevation of the water in the river and in the buried collecting pipe. A pumped deep well, located adjacent to the river, could establish a much steeper ground-water gradient and would yield much more water per unit of intake area.

Because of limitation on the size of the pump that was used to test the 8-inch hatchery test well, the well when completed was pumped at only 252 gal/min. The well has since been pumped continuously to supply the hatchery for as long as 2 months at a reported rate of 350 gal/min, but the water level in the well could not be measured while it was being pumped at the higher rate. The rate at which a properly constructed well could be pumped (if it penetrated the same materials as those penetrated by the test well) can be estimated from the test well's specific capacity.[1]

The specific capacity of the test well at the hatchery site was calculated to be 219 gal/min per foot of drawdown. This value was determined on the basis of the water level being drawn down 1.15 feet when pumped at 252 gal/min. If this specific capacity were constant at all pumping rates, a properly constructed well could be pumped at about 5,700 gal/min, with about 26 feet of drawdown. However, under the water-table conditions that exist here, the specific capacity decreases as the drawdown increases, and a pumping rate of about 4,400 gal/min would result in a drawdown of 26 feet (two-thirds of the distance from the static water level to the top of the perforations).

Such a high pumping rate and corresponding drawdown could not be sustained without increasing the danger of seawater intrusion, and reducing the yield of nearby wells. Continuous pumping of a well at the hatchery site at the rate of 1,100 gal/min would result in lowering of the ground-water level by about 5 feet--approximately to sea level.

---

[1]Specific capacity is defined as the yield of a well in gallons per minute per foot of drawdown of water level. For the maximum efficiency of a production well, the water level should not be drawn down more than about two-thirds of the distance from the static water level to the top of the perforations or well screen.

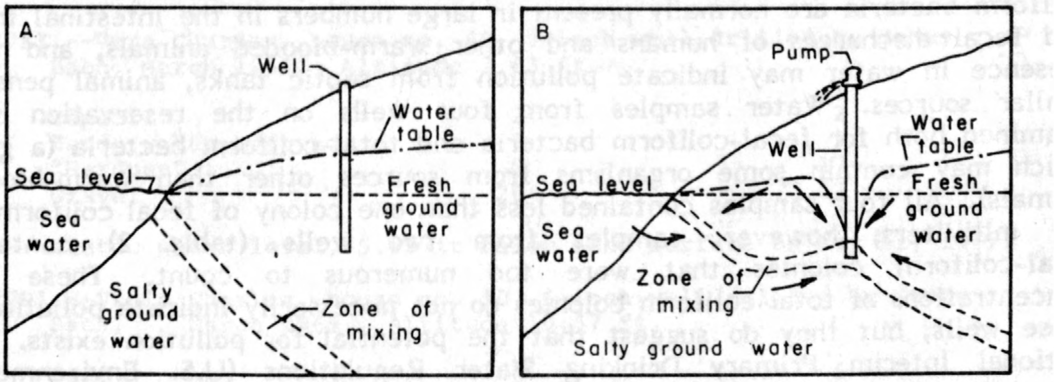
Seawater instrusion presently (1977) is not a problem beneath the reservation. However, if wells near the shoreline were pumped heavily for prolonged periods, intrusion could occur (fig. 8B). In general, seawater intrusion does not occur as long as the water levels in wells remain substantially above sea level. Because of the rather slow rate of movement of ground water, water levels in wells near the shoreline can be drawn down below sea level for short periods without causing significant seawater intrusion. However, because of the complex pattern of the movement of ground water in the zone where freshwater and salty water mix, intrusion can occur even where pumping levels are slightly above sea level. Because of the high transmissivity of the unconsolidated materials underlying most of the reservation, and because the aquifer is readily recharged from the river, seawater intrusion under foreseeable conditions of gradual ground-water development is not likely to be a problem.

Before wells with large yields are put into production, the extent to which water levels in neighboring wells may be affected should be determined. In addition to determing the probable effect on the yield of other wells on the reservation, this would also provide data that would be useful in more accurately assessing the potential for seawater instrusion under conditions of heavy ground-water withdrawal. This determination would involve drilling two wells that completely penetrate the unconsolidated deposits, pumping one at a high rate for a prolonged period, and observing changes in water levels in the neighboring unpumped well.

## Quality of Ground Water

The results of comprehensive analyses of water samples from five wells and partial analyses of samples from two wells (table 2), indicate that the ground water beneath the reservation is of excellent chemical quality and is suitable for such common uses as domestic supplies, livestock watering, and the irrigation of crops. None of the common chemical substances for which maximum recommended or allowable concentrations have been established by regulatory agencies were found to be present in excess. No ground-water samples were tested for insecticides or herbicides. Determinations of concentrations of heavy metals were made only on water samples from the ground-water collecting gallery that supplies the fish hatchery. The quality of water from the collecting gallery is described on page 43.

Observed ground-water temperatures ranged from 44° to 48°F. The total hardness of ground-water samples ranged from 42 to 60 mg/L (milligrams per liter). Under most systems of classifying the hardness of water, "soft water" is in the range from 0 to 60 mg/L.




**A. Simplified diagram of a well tapping an unconfined near-shore aquifer under conditions of equilibrium--no intrusion has occurred.**

**B. Diagram of the same well under conditions of intensive pumping--intrusion has reached the well.**

FIGURE 8.--Schematic sections showing nearshore aquifers without and with seawater intrusion. Adapted from Walters (1971).

The specific conductance of water is a convenient method of estimating the dissolved-solids concentration--the degree of mineralization. The specific conductance, which is a measure of the ability of water to conduct an electrical current, ranged from 89 to 114 micromhos per centimeter at 25°C in the samples collected, and indicated a range of dissolved-solids concentration from about 60 to 75 mg/L. The maximum dissolved-solids concentration proposed for drinking water in the National Secondary Drinking Water Regulations is 500 mg/L.

The concentrations of chemical substances such as iron, manganese, chloride, sulfate, and fluoride, which are present in many parts of the country in quantities large enough to make ground water undesirable for domestic use, were well below objectionable levels in all samples collected.

The sanitary quality of water is commonly evaluated on the basis of the number of colonies of coliform bacteria per 100 milliliters of water. Fecal coliform bacteria are normally present in large numbers in the intestinal tracts and fecal discharges of humans and other warm-blooded animals, and their presence in water may indicate pollution from septic tanks, animal pens, or similar sources. Water samples from four wells on the reservation were examined both for fecal-coliform bacteria and total-coliform bacteria (a group which may contain some organisms from sources other than warm-blooded animals). All four samples contained less than one colony of fecal coliform per 100 milliliters; however, samples from two wells (table 2) contained total-coliform colonies that were too numerous to count. These high concentrations of total-coliform colonies do not necessarily indicate pollution of these wells, but they do suggest that the potential for pollution exists. The National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1975) establishes maximum total-coliform levels in public drinking water systems at 1 to 4 colonies per 100 milliliters. However, these maximum levels are based on the arithmetic mean of several samples collected from the same source over a period of one month.

Successful irrigation depends not only on supplying irrigation water to the land but also on controlling the saline and alkaline conditions of the soil. In general, waters with specific conductance values below 750 micromhos/cm are satisfactory for irrigating most crops insofar as salt content is concerned. However, some salt-sensitive crops may be adversely affected by irrigation waters with specific-conductance values between 250 and 750 micromhos. The highest specific conductance value measured in ground water from the reservation was 114 micromhos/cm (table 2). The sodium-adsorption ratio of water, in conjunction with the specific conductance, is also used to evaluate the suitability of water for irrigation. Using this method of classification, all ground-water samples from the reservation are classified as being of low salinity hazard and low sodium (alkali) hazard.

TABLE 1.--Logs of wells

27J3.--Lavern Hepfer, house no. 70, 6-inch well drilled by James Bach, May 1969. Altitude 7.74 ft, casing perforated 13 to 33 ft.

| Materials | Thickness (ft) | Depth (ft) |
|---|---|---|
| Sand | 4 | 4 |
| "Hardpan" | 4 | 8 |
| Gravel | 22 | 30 |
| "Hardpan" | 11 | 41 |

static water level, 5.64 ft below land surface on May 11, 1977.

27K1.--Vera Charles, house no. 40, 6-inch well drilled by James Bach, March 1969. Altitude 7.63 ft.

| | | |
|---|---|---|
| Topsoil | 2 | 2 |
| Sand, water-bearing | 7 | 9 |
| "Hardpan" | 8 | 17 |
| Gravel | 20 | 37 |

static water level, 5.85 ft below land surface on May 11, 1977.

27P1.--Viola Charles, house no. 30, 6-inch well drilled by James Bach, March 1969. Altitude 10.57 ft.

| | | |
|---|---|---|
| Sand | 6 | 6 |
| Sand and boulders | 6 | 12 |
| "Hardpan" | 19 | 31 |
| Gravel and sand | 2 | 33 |

static water level, 7.13 ft below land surface on May 11, 1977.

27P2.--Ralph Charles, house no. 35, 6-inch well drilled by James Bach, March 1969. Altitude about 11 ft.

| | | |
|---|---|---|
| Topsoil | 2 | 2 |
| Sand and gravel | 8 | 10 |
| Gravel | 8 | 18 |
| "Hardpan" | 14 | 32 |
| Gravel and sand | 2 | 34 |

27Q2.--Foster Charles, house no. 45, 6-inch well drilled by James Bach, May 1969. Altitude 9.16 ft.

| | | |
|---|---|---|
| Clay | 3 | 3 |
| Clay and gravel | 10 | 13 |
| "Hardpan" | 19 | 32 |
| Sand and gravel | 2 | 34 |

static water level, 6.81 ft below land surface on May 11, 1977.

TABLE 1.--Logs of wells (continued)

27R1.--Charles Sampson, house no. 75, 6-inch well drilled by James Bach, March 1969. Altitude 11.40 ft, casing perforated 15 to 36 ft.

| Materials | Thickness (ft) | Depth (ft) |
|---|---|---|
| Topsoil | 2 | 2 |
| Sand | 4 | 6 |
| "Hardpan" | 5 | 11 |
| Gravel | 27 | 38 |
| "Hardpan" | 3 | 41 |

static water level, 8.64 ft below land surface on May 11, 1977.

27R2.--Larry Bennett, house no. 80, 6-inch well drilled by James Bach, April 1969. Altitude about 12 ft.

| | | |
|---|---|---|
| Topsoil | 2 | 2 |
| Clay | 4 | 6 |
| Gravel | 2 | 8 |
| Clay "hardpan" | 21 | 29 |
| Gravel and sandy clay | 5 | 34 |

27R3.--Phillip Charles, house no. 60, 6-inch well drilled by James Bach, March 1969. Altitude 13.45 ft, casing perforated 17 to 36 ft.

| | | |
|---|---|---|
| Topsoil | 5 | 5 |
| "Hardpan" | 7 | 12 |
| Gravel and clay | 29 | 41 |

static water level, 9.65 ft below land surface on May 11, 1977.

27R5.--Elmer Charles, house no. 50, 6-inch well drilled by James Bach, March 1969. Altitude 15.16 ft.

| | | |
|---|---|---|
| Topsoil | 5 | 5 |
| "Hardpan" | 26 | 31 |
| Coarse sand, then gravel | 2 | 33 |

static water level, 10.55 ft below land surface on May 11, 1977.

27R6.--Geneva Foster, house no. 55, 6-inch well drilled by James Bach, April 1969. Altitude 14.72 ft.

| Materials | Thickness (ft) | Depth (ft) |
|---|---|---|
| Topsoil | 5 | 5 |
| Gravel and clay | 6 | 11 |
| "Hardpan" | 10 | 21 |
| Gravel, some clay | 14 | 35 |

static water level, 10.28 ft below land surface on May 11, 1977.

34A1.--George Bolstrom, house no. 20, 6-inch well drilled by James Bach, April 1969 Altitude about 15 ft.

| | | |
|---|---|---|
| Topsoil | 3 | 3 |
| Clay, sandy | 7 | 10 |
| Boulders | 2 | 12 |
| "Hardpan" | 21 | 33 |
| Gravel and sand | 5 | 38 |
| "Hardpan" | 4 | 42 |
| Sand, coarse | 2 | 44 |

34A2.--Klallam Indian Tribe, fish hatchery test well, 8-inch well drilled by Stoican Drilling Co., July 1976. Altitude 19.61 ft prior to excavation, now 13.11 ft, casing perforated 51 to 76 ft.

| | | |
|---|---|---|
| Silt, sandy, brown | 8 | 8 |
| Clay, sandy, brown | 2 | 10 |
| Gravel, medium to coarse, water-bearing | 4 | 14 |
| Gravel, and medium to coarse sand, water-bearing | 10 | 24 |
| Gravel, medium to coarse water-bearing | 6 | 30 |
| Wood, appeared to be buried, cedar log | 1 | 31 |
| Sand, medium to coarse, some gravel, water-bearing | 5 | 36 |
| Gravel, some sand | 6 | 42 |
| Sand and gravel, some red-brown clay | 9 | 51 |
| Sand and gravel, less clay | 3 | 54 |
| Gravel, medium to coarse, some sand | 25 | 79 |
| Bedrock, very hard | | |

34A3.--Edward Sampson, house no. 15, 6-inch well drilled by James Bach, April 1969. Altitude 16.60 ft.

| Materials | Thickness (ft) | Depth (ft) |
|---|---|---|
| Topsoil | 2 | 2 |
| Clay | 5 | 7 |
| Gravel and boulders | 2 | 9 |
| "Hardpan" | 23 | 32 |
| Sand, coarse | 2 | 34 |

static water level 9.48 ft below land surface on May 11, 1977.

34B2.--Indian Fellowship Community Hall, 6-inch well drilled by James Bach, June 1969. Altitude 7.16 ft.

| | | |
|---|---|---|
| Boulders | 8 | 8 |
| Gravel | 24 | 32 |

static water level, 1.98 ft below land surface on May 11, 1977.

34B3.--Oliver Charles, house no. 25, 6-inch well drilled by James Bach, April 1969. Altitude 9.79 ft.

| | | |
|---|---|---|
| Sand | 8 | 8 |
| "Hardpan" | 10 | 18 |
| Gravel and sand | 15 | 33 |

static water level, 6.14 ft below land surface on May 11, 1977.

34G1.--Ernest Charles, house no. 10, 6-inch well drilled by James Bach, April 1969. Altitude 20.35 ft.

| | | |
|---|---|---|
| Topsoil | 2 | 2 |
| Gravel and boulders | 7 | 9 |
| "Hardpan" | 24 | 33 |
| Sand | 3 | 36 |

static water level, 10.70 ft below land surface on May 11, 1977.

35A4.--Klallam Indian Tribe, community center, 6-inch well drilled by Stoican Drilling Co., April 1977. Altitude 13.60 ft, .045 slot screen 51 to 56 ft.

| Materials | Thickness (ft) | Depth (ft) |
|---|---|---|
| Clay, brown | 4 | 4 |
| Clay, gravelly, brown | 7 | 11 |
| Clay, brown | 16 | 27 |
| Clay, brown, and rocks | 3 | 30 |
| Gravel, brown, water-bearing | 4 | 34 |
| Clay, brown, gravelly | 10 | 44 |
| Clay, sandy, brown, water-bearing | 5 | 49 |
| Sand, and gravel, water-bearing | 7 | 56 |
| Gravel, cemented, brown | 1 | 57 |

static water level 8.54 ft below land surface on May 11, 1977.

35D2.--Gilbert Charles, house no. 85, 6-inch well drilled by James Bach, April 1969. Altitude 19.27 ft.

| | | |
|---|---|---|
| Topsoil | 2 | 2 |
| Gravel and boulders | 5 | 7 |
| "Hardpan" | 8 | 15 |
| Gravel | 18 | 33 |
| Sand, coarse | 3 | 36 |

static water level, 12.05 ft below land surface on May 11, 1977.

35E1.--Virgil Johnson, house no. 90, 6-inch well drilled by James Bach, March 1969. Altitude 20.44 ft, casing perforated 16 to 26 ft.

| | | |
|---|---|---|
| Topsoil | 4 | 4 |
| "Hardpan" | 9 | 13 |
| Gravel | 20 | 33 |

static water level, 12.57 ft below land surface on May 11, 1977.

TABLE 1.--Logs of wells (continued)

35E2.--Klallam Indian Tribe, housing area well no. 2 (north well) 6-inch well drilled by Bartholomew Drilling Co., April 1976. Altitude 27.41 ft, .030 slot screen 45 to 50 ft.

| Materials | Thickness (ft) | Depth (ft) |
|---|---|---|
| Topsoil | 2 | 2 |
| Sand and gravel, dirty | 31 | 33 |
| Sand and gravel, clean | 16 | 49 |
| Sand and gravel, clay lenses | 1 | 50 |

static water level, 16.89 ft below land surface on May 11, 1977.

35E3.--Klallam Indian Tribe, housing area well no. 1 (south well), 6-inch well drilled by Bartholomew Drilling Co., April 1976. Altitude 26.99 ft., .030 slot screen 43 to 48 ft.

| | | |
|---|---|---|
| Topsoil | 2 | 2 |
| Gravel, dirty | 11 | 13 |
| Gravel and sand, cemented | 19 | 32 |
| Gravel, and coarse sand | 17 | 49 |
| Sand, fine, dirty | 3 | 52 |

static water level, 16.89 ft below land surface on May 11, 1977.

35N1.--James Charles, house no. 1, 6-inch well drilled by James Bach, March 1969. Altitude 33.89 ft, casing perforated 21 to 49 ft.

| | | |
|---|---|---|
| Topsoil | 2 | 2 |
| Clay, sandy | 11 | 13 |
| "Hardpan" | 8 | 21 |
| Gravel | 32 | 53 |

static water level, 17.18 ft below land surface on May 11, 1977.

TABLE 2.--Chemical quality of ground water, Lower Elwha Indian Reservation

| Well number | Owner | Date | Specific conductance field (micromhos/cm) | pH field (units) | Temperature (°F) | Color (units) | Dissolved oxygen (mg/L) | Total dissolved gas pressure (percent saturation) | Nitrogen plus argon (percent saturation) | Total coliform (col/100 mL) | Fecal coliform (col/100 mL) | Total hardness (mg/L) | Non-carbonate hardness (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27J3 | Laverne Hepfer | 5-11-77 | 104 | 6.6 | 48 | 1 | -- | -- | -- | [3]TNTC | <1 | 51 | 16 |
| 34A2 | Klallam Tribe Hatchery test well | 7-13-76 | 112 | 7.2 | 44 | 3 | -- | -- | -- | -- | -- | 42 | 2 |
| | do. | 2-2-77[1] | 92 | 7.0 | 47 | -- | 10.4 | 101 | 104 | -- | -- | -- | -- |
| | do. | 2-2-77[2] | 92 | 7.0 | 47 | -- | 9.6 | 100 | 105 | -- | -- | -- | -- |
| 34B3 | Oliver Charles | 5-11-77 | 89 | 6.8 | 47 | 1 | -- | -- | -- | TNTC | <1 | 42 | 8 |
| 35E1 | Virgil Johnson | 5-11-77 | 114 | 6.3 | 48 | 1 | -- | -- | -- | [4]<1 | <1 | 54 | 7 |
| 35E2 | Klallam Tribe Well 2 | 6-1-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 60 | -- |
| 35E3 | Klallam Tribe Well 1 | 6-1-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 60 | -- |
| 35N1 | James Charles | 5-11-77 | 94 | 6.5 | 48 | 1 | -- | -- | -- | <1 | <1 | 46 | 8 |

| Well number | Dissolved calcium (mg/L) | Dissolved magnesium (mg/L) | Dissolved sodium (mg/L) | Sodium (percent) | Sodium adsorption ratio | Milligrams per liter: Dissolved potassium | Bicarbonate | Carbonate | Total alkalinity | Dissolved sulfate | Dissolved chloride | Dissolved fluoride | Dissolved silica | Total nitrite plus nitrate (as N) | Iron (µg/L) | Manganese (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27J3--con. | 16 | 2.6 | 2.8 | 11 | 0.2 | 0.3 | 55 | 0 | 45 | 10 | 1.3 | 0.1 | 11 | 0.07 | 20 | 0 |
| 34A2--con. | 14 | 1.7 | 2.0 | 9 | .1 | .2 | 49 | 0 | 40 | 7.8 | 1.5 | .1 | 8.3 | .04 | -- | -- |
| Do. | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Do. | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 34B3--con. | 14 | 1.7 | 2.1 | 10 | .1 | .1 | 42 | 0 | 34 | 13 | 1.3 | .1 | 6.9 | .09 | 160 | 10 |
| 35E1--con. | 17 | 2.7 | 4.1 | 14 | .2 | .3 | 57 | 0 | 47 | 11 | 3.0 | .1 | 13 | .33 | 20 | 10 |
| 35E2--con. | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6 | 3.0 | .1 | -- | -- | 100 | <50 |
| 35E3--con. | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6 | 3.0 | .08 | -- | -- | 100 | <50 |
| 35N1--con. | 15 | 2.0 | 2.8 | 12 | .2 | .2 | 46 | 0 | 38 | 8.6 | 1.8 | .1 | 8.9 | .07 | 20 | 0 |

[1] Water collected from inside incubating box.

[2] Water collected from outside incubating box.

[3] TNTC - Too numerous to count.

[4] < - less than.

TABLE 3.--Data from pumping test at well 34A2 (fish hatchery test well), during period July 13-14, 1976

[Water levels are in feet below land surface]

| Time | Water level | Time | Water level |
|---|---|---|---|
| 7/13/76 | | | |
| 8:57 am | 12.00 | 2:03 | 12.14 |
| 9:00 | [a]Pump on | 2:04 | 12.14 |
| 9:02 | 12.96 | 2:05 | 12.14 |
| 9:04 | 12.98 | 2:06 | 12.13 |
| 9:06 | 12.98 | 2:07 | 12.13 |
| 9:08 | 13.00 | 2:08 | 12.13 |
| 9:10 | 12.97 | 2:09 | 12.13 |
| 9:12 | 12.98 | 2:10 | 12.13 |
| 9:15 | 12.99 | 2:12 | 12.13 |
| 9:20 | 13.01 | 2:14 | 12.13 |
| 9:25 | 13.01 | 2:16 | 12.13 |
| 9:30 | 13.01 | 2:18 | 12.13 |
| 9:35 | 13.02 | 2:20 | 12.13 |
| 9:40 | 13.02 | 2:25 | 12.13 |
| 9:45 | 13.03 | 2:30 | 12.13 |
| 9:50 | 13.04 | 3:26 | 12.12 |
| 9:55 | 13.04 | 3:50 | 12.09 |
| 10:00 | 13.05 | 4:35 | 12.11 |
| 10:05 | 13.06 | 5:00 | 12.11 |
| 10:10 | 13.06 | | |
| 10:15 | 13.06 | 7/14/76 | |
| 10:20 | 13.07 | | |
| 10:25 | 13.07 | 8:20 am | 11.98 |
| 10:30 | 13.07 | 10:15 | 12.03 |
| 10:35 | 13.08 | | |
| 10:40 | 13.08 | | |
| 10:50 | 13.08 | | |
| 11:00 | 13.08 | | |
| 11:10 | 13.09 | | |
| 11:20 | 13.09 | | |
| 11:30 | 13.10 | | |
| 11:40 | 13.10 | | |
| 11:50 | 13.10 | | |
| 12:00noon | 13.10 | | |
| 12:10 pm | 13.11 | | |
| 12:20 | 13.11 | | |
| 12:30 | 13.12 | | |
| 1:00 | 13.14 | | |
| 1:20 | 13.14 | | |
| 1:43 | 13.15 | | |
| 2:00 | 13.15 Pump off | | |
| 2:01 | 12.15 | | |
| 2:02 | 12.14 | | |

[a]Pump discharge was maintained at 252 gal/min.

## SURFACE-WATER RESOURCES

The surface-water resources pertinent to the Lower Elwha Indian Reservation are the Elwha River on the western margin of the area, and Bosco Creek and two sloughs or ponds on the reservation. Bosco Creek (fig. 3) is a small spring-fed stream about 1 mile long that is located east of, and flows parallel to the Elwha River. The two sloughs occupy abandoned channels of the Elwha River and are 3½ to 5 acres in area. The Elwha River drains generally rugged forested country in the northern part of the Olympic Mountains (fig. 1) and is fed by meltwater from snowfields and glaciers, some at altitudes of over 7,000 feet. The Elwha River begins at approximately 4,500 feet altitude, and flows in a curved pattern first southeasterly, then northwesterly and north--about 41 miles to Freshwater Bay of the Strait of Juan de Fuca.

Bosco Creek discharges into west slough in the northwestern part of the reservation. The other slough is near the northeastern corner of the reservation and is called east slough. The altitudes of the water surfaces of the two sloughs during March 1976-June 1977 are shown in figure 9. Water levels in the sloughs may fluctuate somewhat in response to daily changes in tide stage, but principally in response to changes in ground-water levels.

### Streamflow Characteristics

#### Elwha River

A record of daily mean flows from October 1897 to December 1901 and after October 1918 is available for the Elwha River at McDonald Bridge, near Port Angeles (station 12045500). However, only flow data for complete water years after storage of water in Lake Mills (fig. 1) began on April 1, 1927 were used to evaluate the partly-regulated flow characteristics of the Elwha River.

Monthly and annual flows.--The annual flow of the Elwha River at McDonald Bridge averaged 1,510 $ft^3/s$ during the period 1928-75; mean monthly data indicate a seasonal distribution of flow that generally has both a winter and spring peak with spring flows higher than winter flows. Snow accumulates at the higher elevations of the Elwha River basin from late fall to early spring, and runoff from rainfall and melting of accumulated snow causes the dual-peak distribution. Historically, maximum instantaneous flows each year usually occur in winter months (earliest recorded in mid-October and latest recorded in late April). The recorded maximum flow of 41,600 $ft^3/s$ occurred on November 18, 1897. Low flows of the Elwha River may occur as late as November or December; the minimum mean monthly flow occurs in November (fig. 10) and the minimum daily discharge of record was 10 $ft^3/s$ on October 3, 1938.

High and Low flows.--The maximum and minimum average flows during specified consecutive days are used in characterizing the high and low flows of streams. The probabilities that high or low flows for the specified number of days will or will not exceed a given flow in any year complete the characterization. These probabilities are expressed as a percentage. For example, if the 7-day low flow is 400 $ft^3/s$ for a nonexceedance probability of 50 percent, then the lowest average flow for any seven consecutive days in any year has a 50-percent probability (chance is 1 in 2, or equal) of being less than 400 $ft^3/s$. Similarily, a 30-day high flow of 6,000 $ft^3/s$ for an exceedance probability of 2 percent means that the highest average flow for any 30 consecutive days in any year has only a 2-percent probability (chance is 1 in 50) of exceeding 6,000 $ft^3/s$.

The characteristic low and high flows of the Elwha River at McDonald Bridge are given in table 4. These high and low flows were estimated from frequency distributions of the annual high and low flows for the various sets of consecutive days during the period 1928-75.

Floods.--The Elwha River floods the lower parts of the Lower Elwha Indian Reservation annually, and more extensive flooding occurs in many years. Some local flooding also occurs annually from small streams flowing from higher elevations east and south of the reservation. The peak discharges at gaging station 12046500 located 3 miles upstream of the mouth were correlated with concurrent peak discharges at the McDonald Bridge gage (12045500) (figure 11). The peak discharges for the Elwha River at McDonald Bridge for the 0.2, 1, 2, and 10 percent exceedance probabilities were determined using methods described by the United States Water Resources Council. By using these discharges, the peak discharges for the 0.2, 1, 2, and 10 percent exceedance probabilities (500, 100, 50, and 10 year recurrence intervals) for the Elwha River below diversion were determined from the curve shown in figure 11. These peak discharges were then used in the Geological Survey's E431 step-backwater program (Shearman, 1976) to obtain flood profiles. A plot of the profiles on a map (figure 12) shows the extent of flooding from the Elwha River.

TABLE 4.--Low-flow and high-flow frequencies of Elwha River at McDonald Bridge, near Port Angeles, 1928-75

| Number of consecutive days | Low flows ($ft^3/s$) for indicated probability of nonexceedance | | | | | High flows ($ft^3/s$) for indicated probability of exceedance | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 50% | 20% | 10% | 5% | 2% | 50% | 20% | 10% | 5% | 2% |
| 1 | 158 | 56 | 30 | 17 | 8 | 8080 | 11800 | 14400 | 18100 | 21000 |
| 3 | 320 | 160 | 94 | 56 | 28 | 6300 | 9010 | 10900 | 13400 | 15400 |
| 7 | 377 | 279 | 230 | 194 | 156 | 4840 | 6520 | 7650 | 9100 | 10200 |
| 14 | 417 | 324 | 281 | 248 | 214 | | | | | |
| 15 | | | | | | 3800 | 4860 | 5540 | 6370 | 6980 |
| 30 | 470 | 374 | 329 | 295 | 260 | 3160 | 3900 | 4340 | 4860 | 5230 |
| 60 | 557 | 441 | 392 | 356 | 321 | 2630 | 3180 | 3490 | 3840 | 4070 |
| 90 | 651 | 512 | 456 | 416 | 376 | 2360 | 2810 | 3060 | 3320 | 3490 |
| 183 | 1060 | 832 | 734 | 661 | 587 | 1890 | 2230 | 2410 | 2620 | 2750 |

Water storage.--In the lower reaches of the Elwha River and upstream from the reservation, water is impounded behind two hydroelectric power dams built by Crown Zellerbach Corporation to form Lake Mills and Lake Aldwell (fig. 1). These structures have little effect on downstream floods or low flows because for efficient operation their contents must be maintained at about a constant level. A small control structure, with no storage capacity, 3¼ miles upstream from the mouth of the river is used to divert as much as 115 $ft^3/s$ of water for industrial use at Port Angeles.

Water stored in an upstream reservoir could be released to supplement Elwha River flows on the reservation during low-flow periods, or water could be stored in the reservoir to reduce downstream river flows during high-flow periods. The storage volume required for these purposes can be approximated by using the low- and high-flow characteristics of the Elwha River. As guides to the approximate amount of water storage required to produce an outflow to be specified by the user, the storage analyses in this report provide data that are usable in more complete analyses. Because a specific water-storage development is not being considered, only uniform drafts or releases of water are used and losses from evaporation and seepage are not included in the analyses. Also, only the rates of water drafts or releases obtainable from within-year storage (that is, no carryover storage of water from year to year) are considered in the analyses.

The frequency-mass-curve method, as described by Riggs and Hardison (1973) for determining a draft-storage-frequency relation, was used to determine both draft-storage and release-storage frequency data for the Elwha River. The data used in the analyses are the characteristic low and high flows given in table 4; the results of the analyses are shown in figure 13. The following are examples of using the graphs of figure 13. The probability is 80 percent (chance of 4 in 5) that 2,000 acre-feet of storage volume (within-year type) would ensure a uniform low flow of 400 $ft^3/s$ in any year at McDonald Bridge. For a storage volume of 9,200 acre-feet, the probability of maintaining low flows of 400 $ft^3/s$ in any year increases to 98 percent. If a within-year storage volume of 5,000 acre-feet were available, the probabilities are 50 percent and 98 percent that water would have to be released during high-flow periods in any year at uniform rates of 5,600 $ft^3/s$ and 22,000 $ft^3/s$, respectively. A few thousand acre-feet of upstream storage of water would be beneficial toward sustaining low flows at McDonald Bridge but would not provide much alleviation of the high flows that may cause flooding downstream of the bridge.

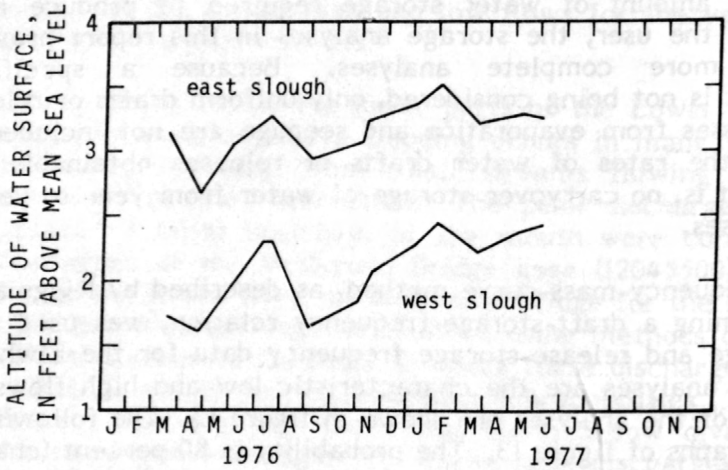



FIGURE 9.--Water-level fluctuations in east and west sloughs, March 1976 to June 1977.

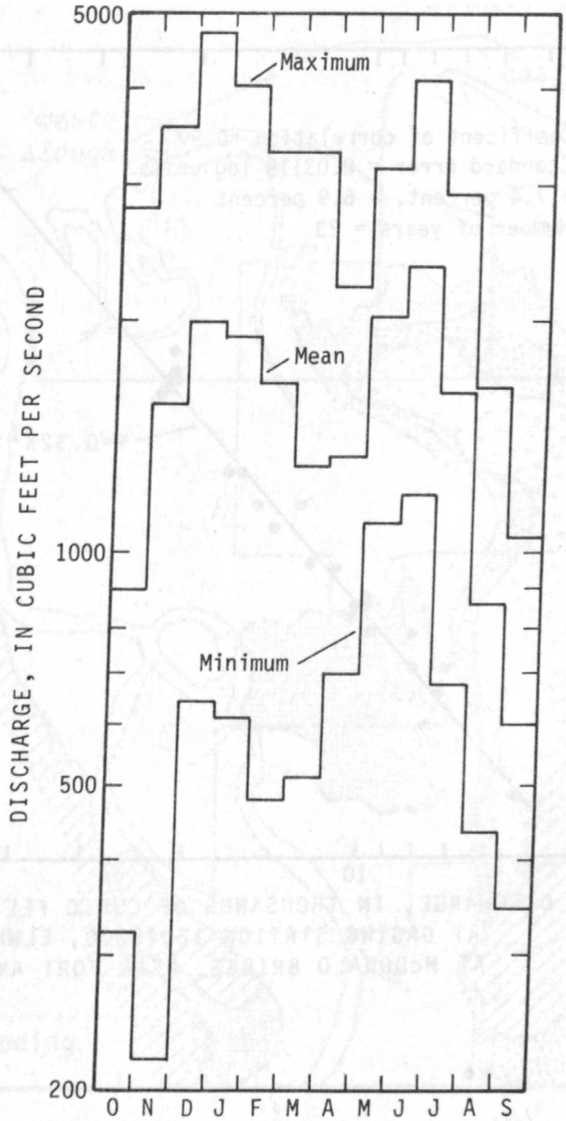



FIGURE 10.--Means and extremes of monthly discharges of Elwha River at McDonald Bridge, near Port Angeles (station 12045500), 1928-75.

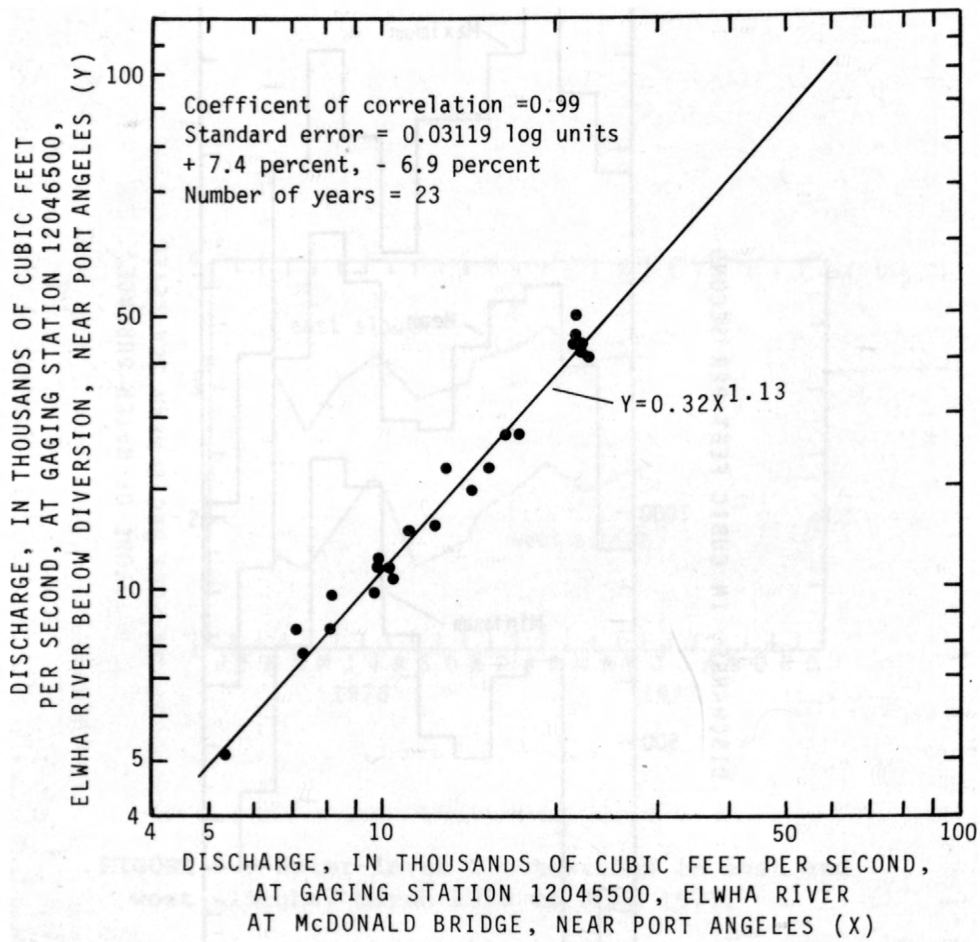



**FIGURE 11.--Relation between annual peak discharges at two sites on the Elwha River.**

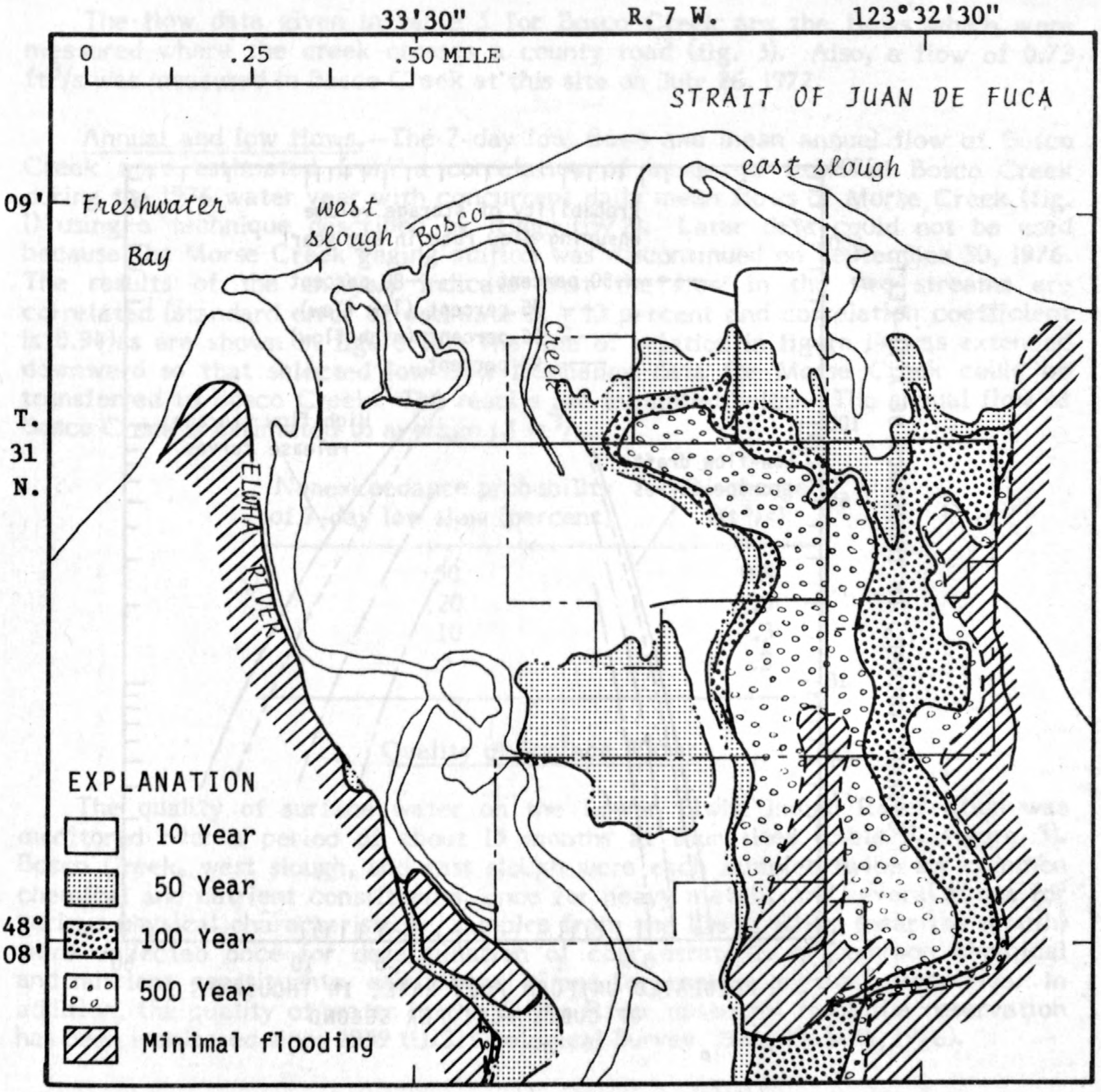



FIGURE 12.--Flood boundaries on the Lower Elwha Indian Reservation.

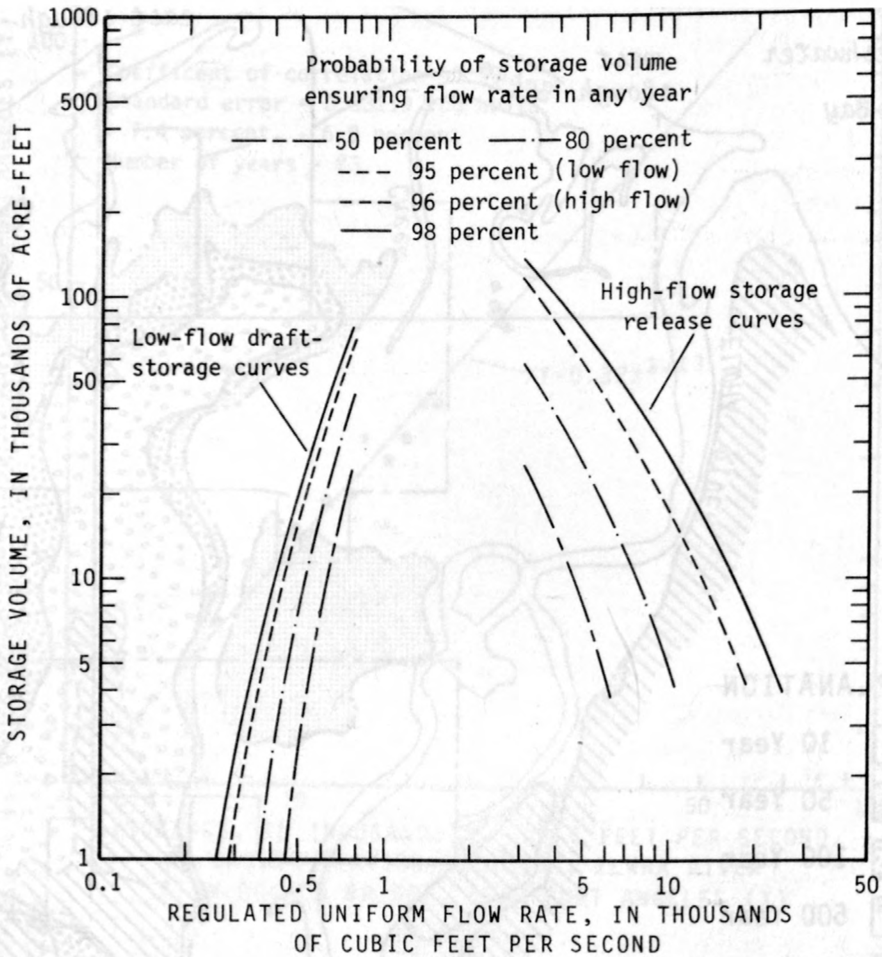



FIGURE 13.--Frequency curves of storage-volume requirements for sustaining uniform low flows or high flows of the Elwha River at McDonald Bridge near Port Angeles. Based on data for period 1928-75.

## Bosco Creek

The flow data given in table 5 for Bosco Creek are the flows which were measured where the creek crosses a county road (fig. 3). Also, a flow of 0.73 $ft^3/s$ was measured in Bosco Creek at this site on July 26, 1977.

Annual and low flows.--The 7-day low flows and mean annual flow of Bosco Creek were estimated from a correlation of measured flows of Bosco Creek during the 1976 water year with concurrent daily mean flows of Morse Creek (fig. 1) using a technique described by Riggs (1972). Later data could not be used because the Morse Creek gaging station was discontinued on September 30, 1976. The results of the analysis indicate that the flow in the two streams are correlated (standard error of estimate is $\pm$ 13 percent and correlation coefficient is 0.94)as are shown in figure 14. The line of relation in figure 14 was extended downward so that selected low-flow frequency data for Morse Creek could be transferred to Bosco Creek. The results are tabulated below. The annual flow of Bosco Creek is estimated to average 1.1 $ft^3/s$.

| Nonexceedance probability of 7-day low flow (percent) | Discharge ($ft^3/s$) |
|---|---|
| 50 | 0.4 |
| 20 | .3 |
| 10 | .3 |
| 5 | .2 |

## Quality of Surface Water

The quality of surface water on the Lower Elwha Indian Reservation was monitored over a period of about 15 months at four sites (table 5, figure 3). Bosco Creek, west slough, and east slough were each sampled twice for common chemical and nutrient constituents, once for heavy metals, and several times for various physical characterisitcs. Samples from the Elwha River (near the mouth) were collected once for determination of concentrations of common chemical and nutrient constituents, and several times for various physical properties. In addition, the quality of water in the Elwha River upstream from the reservation has been monitored since 1959 (U.S. Geological Survey, 1964, 1965-74, 1976).

TABLE 5.--Chemical quality of surface water

[Values in milligrams per liter unless otherwise indicated]

| Date of collection | Stream discharge ($ft^3/s$) | Specific conductance (micromhos/cm) | pH (units) | Water temperature (°F) | Turbidity (NTU) | Dissolved oxygen | Total dissolved gas pressure (percent saturation) | Nitrogen plus argon (percent saturation) |
|---|---|---|---|---|---|---|---|---|
| Bosco Creek (station 12046523) | | | | | | | | |
| 3-18-76 | 0.94 | 73 | 6.3 | 46 | 0 | 8.8 | 104 | 112 |
| 4-28-76 | .74 | 220 | 6.8 | 49 | -- | -- | -- | -- |
| 6-01-76 | 1.15 | 99 | 6.6 | 45 | 0 | 10.0 | 101 | 106 |
| 6-03-76 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7-08-76 | 1.61 | 103 | 6.8 | 46 | -- | -- | 98 | 105 |
| 7-14-76 | -- | -- | -- | 45 | 0 | 8.7 | -- | -- |
| 9-02-76 | .61 | 96 | 6.4 | 46 | 0 | 7.6 | 96 | 105 |
| 11-02-76 | .43 | 77 | 7.1 | 48 | -- | 7.8 | 94 | 101 |
| 11-18-76 | -- | -- | -- | 46 | 1 | -- | -- | -- |
| 1-06-77 | 1.42 | 90 | 6.9 | 46 | -- | 8.8 | 97 | 103 |
| 2-02-77 | 2.27 | 148 | 6.8 | 43 | -- | 11.5 | 100 | 102 |
| 3-23-77 | 1.29 | 67 | 7.2 | 48 | 1 | 10.9 | 105 | 107 |
| 5-10-77 | 1.60 | -- | 6.5 | 48 | -- | 10.7 | 102 | 105 |
| West Slough (station 12046520) | | | | | | | | |
| 3-18-76 | -- | 81 | 7.2 | 48 | 1 | 13.2 | 106 | 103 |
| 4-28-76 | -- | 380 | 7.6 | 55 | -- | -- | -- | -- |
| 6-01-76 | -- | 89 | 6.6 | 53 | 0 | 11.5 | 104 | 104 |
| 6-03-76 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7-07-76 | -- | 98 | 7.1 | 59 | -- | -- | 102 | 104 |
| 7-14-76 | -- | -- | -- | 54 | 0 | 10.9 | -- | -- |
| 9-02-76 | -- | 93 | 6.7 | 59 | 0 | 9.8 | 100 | 101 |
| 11-02-76 | -- | 280 | 7.2 | 46 | -- | 9.2 | 97 | 102 |
| 11-18-76 | -- | -- | -- | -- | 5 | -- | -- | -- |
| 1-06-77 | -- | 127 | 7.2 | 37 | -- | 11.3 | 96 | 99 |
| 2-02-77 | -- | 136 | 6.9 | 42 | -- | 11.8 | 99 | 101 |
| 3-23-77 | -- | 105 | 7.5 | 48 | 1 | 13.0 | 104 | 102 |
| 5-10-77 | -- | 91 | 6.8 | 54 | -- | 11.0 | 103 | 104 |
| East Slough (station 12046526) | | | | | | | | |
| 3-18-76 | -- | 136 | 7.2 | 48 | 0 | 13.0 | 107 | 105 |
| 4-28-76 | -- | 537 | 7.3 | 55 | -- | -- | -- | -- |
| 6-01-76 | -- | 114 | 6.8 | 55 | 0 | 13.2 | 104 | 99 |
| 6-03-76 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7-08-76 | -- | 118 | 7.2 | 62 | -- | -- | 102 | 104 |
| 7-14-76 | -- | -- | -- | 59 | 0 | 9.4 | -- | -- |
| 9-02-76 | -- | 107 | 7.2 | 61 | 0 | 10.0 | 103 | 104 |
| 11-02-76 | -- | 90 | 7.5 | 48 | -- | 9.7 | 97 | 100 |
| 11-18-76 | -- | 116 | -- | 45 | 0 | -- | -- | -- |
| 1-06-77 | -- | 368 | 7.1 | 36 | -- | 9.1 | 94 | 101 |
| 2-02-77 | -- | 265 | 7.2 | 41 | -- | 10.4 | 98 | 102 |
| 3-23-77 | -- | 560 | 7.3 | 51 | 0 | 11.0 | 102 | 102 |
| 5-11-77 | -- | -- | 7.1 | 55 | -- | 10.6 | 101 | 101 |
| Elwha River at mouth (station 12046510) | | | | | | | | |
| 3-18-76 | 0 | 115 | 6.4 | 41 | 1 | 12.9 | 103 | 103 |
| 4-28-76 | -- | 111 | 7.4 | 49 | -- | -- | -- | -- |
| 6-01-76 | -- | 94 | 6.7 | 46 | 1 | 11.8 | 101 | 102 |
| 2-02-77 | -- | -- | 7.2 | 39 | -- | 13.2 | 101 | 101 |
| Collecting gallery | | | | | | | | |
| 7-26-77[1] | -- | 95 | 7.3 | 57 | -- | -- | -- | -- |
| 7-26-77[2] | -- | -- | -- | -- | -- | -- | -- | -- |

| Total coliform col/100 mL) | Fecal coliform (col/100 mL) | Total hard-ness | Non-car-bonate hard ness | Dis-solved calcium | Dis-solved magne-sium | Dis-solved sodium | Sodium (percent) | Sodium adsorp-tion ratio | Dis-solved potas-sium | Bicar-bonate |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | <1 | 44 | 3 | 14 | 2.1 | 2.3 | 10 | 0.2 | 0.1 | 49 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 36 | <1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 110 | 13 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | 170 | 44 | 5 | 15 | 1.5 | 2.1 | 9 | .1 | .2 | 47 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 160 | <1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 6 | <1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2 | <1 | 40 | 1 | 13 | 1.8 | 2.8 | 13 | .2 | .2 | 48 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 200 | <1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 100 | <1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | 10 | 42 | 4 | 14 | 1.6 | 2.2 | 10 | .1 | .3 | 46 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 450 | 3 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 3 | <1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| < 1 | <1 | 51 | 3 | 15 | 3.4 | 8.6 | 26 | .5 | .5 | 59 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 490 | <1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1800 | 4 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | <1 | 51 | 9 | 16 | 2.6 | 3.1 | 12 | .2 | .3 | 51 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 460 | <1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 5 | <1 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 3 | <1 | 47 | 1 | 15 | 2.2 | 5.1 | 19 | 0.3 | 0.3 | 55 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | 40 | 5 | 14 | 1.3 | 2.0 | 10 | ..1 | .2 | 43 |
| -- | -- | -- | -- | 14 | -- | -- | -- | -- | -- | -- |

TABLE 5.--Chemical quality of surface water--continued

[Values in milligrams per liter unless otherwise indicated]

| Date of collection | Carbonate | Total alkalinity | Dissolved sulfate | Dissolved chloride | Dissolved nitrate (as N) | Dissolved nitrite (as N) | Dissolved ammonia (as N) | Total Kjeldahl nitrogen (as N) | Total phosphate (as P) | Dissolved orthophosphate (as P) | Total aluminum (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bosco Creek (continued) | | | | | | | | | | | |
| 3-18-76 | 0 | 40 | 7.5 | 1.4 | 0.12 | 0.002 | 0.05 | 0.06 | 0.002 | 0.001 | 0 |
| 4-28-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 6-01-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 6-03-76 | -- | --- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7-08-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7-14-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 9-02-76 | 0 | 39 | 8.7 | .6 | .02 | .002 | .05 | .09 | .006 | .004 | -- |
| 11-02-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 11-18-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1-06-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-02-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 3-23-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 5-10-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| West Slough (continued) | | | | | | | | | | | |
| 3-18-76 | 0 | 39 | 7.4 | 1.8 | .02 | .002 | .05 | .21 | .016 | .006 | -- |
| 4-28-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 6-01-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 6-03-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7-07-67 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7-14-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 9-02-76 | 0 | 38 | 7.6 | .7 | .01 | .001 | .05 | .16 | .011 | .006 | -- |
| 11-02-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 11-18-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1-06-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-02-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 3-23-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 5-10-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| East Slough (continued) | | | | | | | | | | | |
| 3-18-76 | 0 | 48 | 8.7 | 11 | .04 | .001 | .03 | .16 | .006 | .001 | -- |
| 4-28-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 6-01-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 6-03-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7-08-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7-14-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 9-02-76 | 0 | 42 | 8.0 | 1.5 | .00 | .001 | .06 | .21 | .010 | .002 | -- |
| 11-02-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 11-18-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1-06-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-02-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 3-23-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 5-11-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Elwha River at mouth (continued) | | | | | | | | | | | |
| 3-18-76 | 0 | 45 | 9.3 | 4.3 | 0.01 | 0.002 | 0.05 | 0.22 | 0.007 | 0.005 | 0 |
| 4-28-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 6-01-76 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-02-77 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Collecting gallery (continued) | | | | | | | | | | | |
| 7-26-77[1] | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 60 |
| 7-26-77[2] | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

[1]Sample collected from incubation tank in fish hatchery.

[2]Sample collected from manhole at collecting gallery headworks.

| Total admium (ug/L) | Total chromium (ug/L) | Dis- solved chromium (ug/L) | Total copper (ug/L) | Dis- solved copper (ug/L) | Total iron (ug/L) | Total lead (ug/L) | Dis- solved lead (ug/L) | Total manga- nese (ug/L) | Total mercury (ug/L) | Total molyb- denum (ug/L) | Total zinc (ug/L) | Dis- solved zinc (ug/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | 10 | -- | 1 | -- | -- | 1 | -- | -- | -- | -- | 10 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | 0 | -- | 1 | -- | -- | 0 | -- | -- | -- | -- | 20 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
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| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | 0 | -- | 5 | -- | -- | 0 | -- | -- | -- | -- | 0 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| <10 | 0 | -- | <10 | -- | 240 | <100 | -- | 0 | 0 | 0 | 10 | -- |
| -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

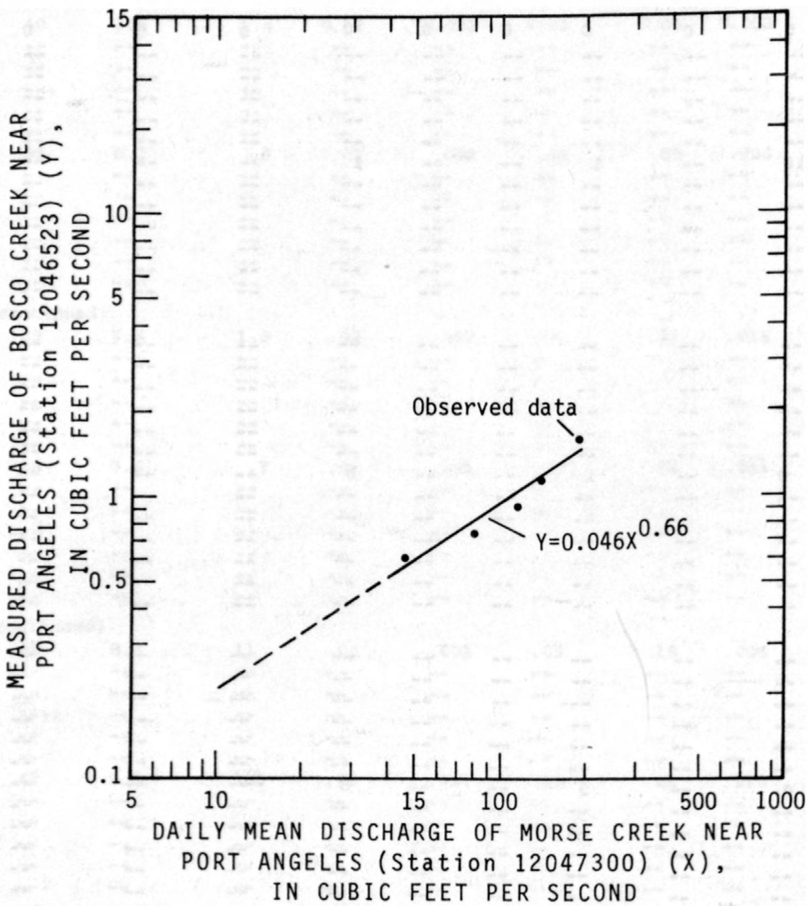


FIGURE 14.--Relation of measured discharge of Bosco Creek to daily mean discharge of Morse Creek.

Because of the excellent hydraulic connection between the ground-water body and the streams, the quality of ground and surface water on the reservation is almost identical in most respects. However, relative to those of ground water, values of specific conductance were high for at least one sample from each sampled surface-water body. The high values in the Elwha River and the two sloughs were for samples collected at high tide or after a storm when seawater may have mixed with the normally fresh water. The high specific conductance of the Bosco Creek samples of April 28, 1976 and February 2, 1977 cannot be explained.

With the exception of coliform bacteria concentration (table 5), all of the analyses of surface-water samples indicated that the water is satisfactory for domestic purposes. Concentrations of both total and fecal-coliform bacteria were occasionally high enough at all sampling sites, except in the Elwha River, to suggest that some pollution by animal wastes may have occurred.

Trace-metal determinations for chromium, copper, lead, and zinc were made in September 1976 on water samples from Bosco Creek, west slough and east slough (fig. 3). In addition, determinations for the above metals and also for mercury were made in July 1977 on a water sample collected from an incubating tank in the fish hatchery. At the time of sampling, the hatchery was being supplied from the ground-water collecting gallery (see p.16). However, because water from the river moves only a short distance underground before entering the collecting gallery, the quality of the water from the gallery is probably more similar to surface water than to ground water. None of the samples analyzed had trace-metal concentrations exceeding the recommended limits for drinking water established by the safe drinking water act (U.S. Environmental Protection Agency, 1977), or concentrations hazardous to fish (National Academy of Sciences and National Academy of Engineering, 1973).

A nutrient as used here is any element or compound that is required for the growth and reproduction of aquatic plants, including algae. Compounds of nitrogen and phosphorus however, are ususally considered the limiting nutrients for aquatic plant growth. The nutrients considered in this study include nitrate, nitrite, ammonia, organic nitrogen, total phosphorus, and orthophosphate. Excessive concentrations of nutrients--and the resulting proliferation of algae--may harm fish if the dissolved oxygen necessary to support fish life is depleted when large amounts of algae decay. The nutrient levels in all surface-water samples analyzed were well below the levels commonly regarded as high enough to stimulate the growth of aquatic plants in lakes. The concentrations likely to cause nuisance plant growth in streams are probably higher than those in lakes.

Determinations of the dissolved-oxygen concentration, percent saturation of total dissolved gases, and the percent saturation of nitrogen plus argon were made on a quarterly basis at surface-water data-collection sites. The dissolved-oxygen content of water is critical to the well being of fish. The optimum dissolved-oxygen concentration depends upon such factors as the species and age of fish involved. In general, dissolved-oxygen concentrations within the range of 4.7 to 9.3 mg/L will afford high levels of protection to most species of fish under most common environmental conditions (U.S. Environmental Protection Agency, 1973). The range in dissolved-oxygen concentrations in surface-water samples taken on the Lower Elwha Indian Reservation was from 7.6 to 13.2 mg/L (table 5). Excessive dissolved-nitrogen gas and excessive total dissolved gas pressure are commonly regarded as causes of gas bubble disease in fish. Many authorities (U.S. Environmental Protection Agency, 1973) formerly believed that the disease was caused by excessive dissolved-nitrogen gas alone. The percent saturation of nitrogen plus argon in water samples from the four surface-water-sampling sites ranged from 99 to 112 percent. The argon content of water is normally very small and is not believed to be significant in evaluating the suitability of water for fish culture. Commonly used analytical determinations do not differentiate between the two gases. The total dissolved-gas pressure of water is expressed in percent of the existing atmospheric pressure, and for salmonoid fish should not exceed 110 percent (U.S. Environmental Protection Agency, 1973). The range in total dissolved-gas pressure of the four surface-water-sampling sites was from 94 to 107 percent.

Temperature of Surface Water

Water-temperature-recording devices (thermographs) were operated on the Elwha River from April 1976 through August 1977 at the McDonald Bridge site and at the State Department of Fisheries facility (NE¼NE¼sec. 10, T.30 N., R.7 W). These two sites are about 4½ miles apart and, because one is upstream from Lake Aldwell and one is downstream, they were selected in part to provide data on the possible effect of Lake Aldwell on the temperature of water in the river.

The extremes of water temperature at the two sites were within one degree of one another. The highest water temperature recorded at the McDonald Bridge site was 64°F (table 6), while at the site below Lake Aldwell the highest temperature was 63°F. The lowest recorded water temperatures were 36°F at both sites. Although the average daily water temperatures at both sites were similar, the differences in daily water temperature fluctuations at each site were pronounced. The greatest daily fluctuation in water temperature at the McDonald Bridge site was 10°F, and at the site below Lake Aldwell it was 3°F. Average daily water temperature fluctuations were about 2.7°F at the McDonald Bridge site and about 1.0°F at the site below Lake Aldwell.

Observed water temperatures ranged from about 43° to 49°F in Bosco Creek, from 37° to 59° in west slough, and from 36° to 62° in east slough.

# SUMMARY AND CONCLUSIONS

Large ground-water supplies can be obtained almost anywhere on the reservation. The most favorable locations for high-yield wells are near the Elwha River--where recharge conditions are most favorable, and at the greatest practical distance from the marine shoreline to minimize the likelihood of saltwater intrusion. No saltwater intrusion now exists beneath the reservation, and none is likely to occur unless large quantities of ground water are withdrawn. If large quantities are to be withdrawn, plans should include a program of monitoring ground-water levels and chloride content in wells situated between the heavily pumped wells and the marine shoreline.

Ground water beneath the reservation is of excellent chemical quality, and, except possibly for a few local exceptions near septic tanks, is unpolluted. However, the materials between the land surface and the water table are permeable, and any pollutant that is discharged onto the land surface of the reservation could easily reach the water table. East of the reservation, an upland area about 0.4 mile wide and 2 miles long drains westward toward the reservation. Ground-water movement in this area is toward the reservation. Because only a small quantity of ground water moves westward onto the reservation, minor pollution of the ground water in this upland area would have little or no effect on the quality of surface or ground water on the reservation. However, surface runoff from any possible future concentration of polluting industries in the upland area could adversely effect the quality of both surface and ground water near the eastern margin of the reservation.

The annual flow of the Elwha River averages 1,510 $ft^3/s$, and that of Bosco Creek averages 1.1 $ft^3/s$. The recorded maximum flow of the Elwha River is 41,600 $ft^3/s$ and the minimum daily discharge is 10 $ft^3/s$. A low flow of the Elwha River of 377 $ft^3/s$ for 7 consecutive days has a 50 percent nonexceedance probability.

With the exception of coliform bacteria concentration, all analyses of surface water samples indicated that the water is satisfactory for domestic purposes. Concentrations of trace metals, nutrients, dissolved oxygen, dissolved nitrogen, and total dissolved gases in all surface water samples analyzed were at levels that are classified as nonhazardous to fish.

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TABLE 6.--Temperature data at two stations on the Elwha River (April 1, 1976 - August 31, 1977)

[Temperatures in degrees Fahrenheit]

| | April 1976 | | | | | | May 1976 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | McDonald Bridge | | | Below Lake Aldwell | | | McDonald Bridge | | | Below Lake Aldwell | | |
| Day | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | | | | | | | A | A | A | 47 | 46 | 46 |
| 2 | | | | | | | A | A | A | 47 | 46 | 46 |
| 3 | | | | | | | A | A | A | 47 | 45 | 46 |
| 4 | | | | | | | A | A | A | 47 | 45 | 46 |
| 5 | | | | | | | A | A | A | 47 | 45 | 46 |
| 6 | 44 | A | A | 44 | 43 | 44 | A | A | A | 47 | 45 | 46 |
| 7 | 43 | 41 | 42 | 44 | 43 | 44 | A | A | A | 47 | 45 | 46 |
| 8 | 43 | 41 | 42 | 44 | 43 | 44 | A | A | A | 47 | 46 | 46 |
| 9 | 44 | 40 | 42 | 44 | 44 | 44 | A | A | A | 47 | 46 | 46 |
| 10 | 45 | 41 | 43 | 45 | 43 | 44 | A | A | A | 47 | 47 | 47 |
| 11 | 43 | 41 | 42 | 45 | 44 | 44 | A | A | A | 47 | 46 | 46 |
| 12 | 43 | 41 | 42 | 45 | 44 | 44 | A | A | A | 47 | 45 | 46 |
| 13 | 45 | 41 | 43 | 45 | 44 | 44 | A | A | A | 47 | 45 | 46 |
| 14 | 42 | 41 | 42 | 45 | 44 | 44 | A | A | A | 47 | 45 | 46 |
| 15 | 43 | 41 | 42 | 45 | 43 | 44 | A | A | A | 47 | 45 | 46 |
| 16 | 44 | 41 | 42 | 45 | 43 | 44 | A | A | A | 47 | 46 | 46 |
| 17 | 42 | 41 | 42 | 44 | 43 | 44 | A | A | A | 47 | 46 | 46 |
| 18 | 43 | 41 | 42 | 44 | 43 | 44 | A | A | A | 47 | 46 | 46 |
| 19 | 43 | 41 | 42 | 45 | 43 | 44 | 46 | 44 | 45 | 47 | 46 | 46 |
| 20 | 44 | 41 | 42 | 45 | 42 | 44 | 46 | 44 | 45 | 47 | 45 | 46 |
| 21 | 45 | 41 | 43 | 45 | 42 | 44 | 47 | 44 | 46 | 47 | 46 | 46 |
| 22 | 43 | 41 | 42 | A | A | A | 46 | 44 | 45 | 47 | 46 | 46 |
| 23 | 43 | 41 | 42 | A | A | A | 47 | 45 | 46 | 47 | 46 | 46 |
| 24 | 43 | 41 | 42 | A | A | A | 47 | 45 | 46 | 47 | 46 | 46 |
| 25 | 44 | 41 | 42 | A | A | A | 47 | 45 | 46 | 47 | 46 | 46 |
| 26 | 45 | 41 | 43 | A | A | A | 46 | 45 | 46 | 47 | 46 | 46 |
| 27 | 45 | 41 | 43 | A | A | A | 47 | 45 | 46 | 47 | 46 | 46 |
| 28 | 46 | 42 | 44 | A | A | A | 46 | 44 | 45 | 47 | 46 | 46 |
| 29 | 46 | 42 | 44 | 47 | 44 | 46 | 46 | 44 | 45 | 47 | 46 | 46 |
| 30 | 45 | 43 | 44 | 47 | 46 | 46 | 46 | 43 | 44 | 47 | 46 | 46 |
| 31 | -- | -- | -- | -- | -- | -- | 45 | 43 | 44 | 46 | 46 | 46 |

A--no record

TABLE 6.--Temperature data at two stations on the Elwha River (April 1, 1976 - August 31, 1977)--Continued

[Temperatures in degrees Fahrenheit]

| | June 1976 | | | | | | July 1976 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | McDonald Bridge | | | Below Lake Aldwell | | | McDonald Bridge | | | Below Lake Aldwell | | |
| Day | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | 46 | 43 | 44 | 46 | 45 | 46 | 48 | 45 | 46 | 50 | 49 | 50 |
| 2 | 46 | 43 | 44 | 46 | 45 | 46 | 49 | 45 | 47 | 49 | 49 | 49 |
| 3 | 47 | 43 | 45 | 46 | 45 | 46 | 48 | 46 | 47 | 49 | 49 | 49 |
| 4 | 48 | 44 | 46 | 47 | 45 | 46 | 48 | 46 | 47 | 49 | 49 | 49 |
| 5 | 48 | 44 | 46 | 47 | 46 | 46 | 49 | 46 | 48 | 50 | 49 | 50 |
| 6 | 48 | 45 | 46 | 48 | 46 | 47 | 49 | 47 | 48 | 50 | 49 | 50 |
| 7 | 48 | 46 | 47 | 48 | 47 | 48 | 48 | 47 | 48 | 50 | 49 | 50 |
| 8 | 49 | 46 | 48 | 48 | 48 | 48 | 49 | 47 | 48 | 50 | 50 | 50 |
| 9 | 48 | 46 | 47 | 48 | 47 | 48 | 48 | 46 | 47 | 50 | 49 | 50 |
| 10 | 47 | 46 | 46 | 48 | 48 | 48 | 49 | 46 | 48 | 49 | 48 | 48 |
| 11 | 47 | 46 | 46 | 48 | 47 | 48 | 49 | 46 | 48 | 49 | 48 | 48 |
| 12 | 48 | 46 | 47 | 48 | 47 | 48 | 48 | 46 | 47 | 50 | 49 | 50 |
| 13 | 48 | 45 | 46 | 48 | 47 | 48 | 49 | 46 | 48 | 50 | 49 | 50 |
| 14 | 49 | 45 | 47 | 48 | 47 | 48 | 50 | 47 | 48 | 50 | 49 | 50 |
| 15 | 48 | 46 | 47 | 48 | 47 | 48 | 50 | 47 | 48 | 50 | 49 | 50 |
| 16 | 48 | 46 | 47 | 49 | 48 | 48 | 50 | 48 | 49 | 51 | 50 | 50 |
| 17 | 49 | 46 | 48 | 49 | 48 | 48 | 50 | 48 | 49 | 51 | 51 | 51 |
| 18 | 49 | 46 | 48 | 49 | 48 | 48 | 50 | 48 | 49 | 52 | 51 | 52 |
| 19 | 49 | 46 | 48 | 49 | 48 | 48 | 50 | 48 | 49 | 52 | 51 | 52 |
| 20 | 49 | 46 | 48 | 49 | 48 | 48 | 51 | 48 | 50 | 52 | 51 | 52 |
| 21 | 49 | 47 | 48 | 50 | 48 | 49 | 50 | 48 | 49 | 52 | 51 | 52 |
| 22 | 49 | 46 | 48 | 49 | 48 | 48 | 49 | 48 | 48 | 51 | 50 | 50 |
| 23 | 49 | 47 | 48 | 49 | 48 | 48 | 51 | 48 | 50 | 51 | 50 | 50 |
| 24 | 49 | 47 | 48 | 49 | 48 | 48 | 51 | 48 | 50 | 51 | 50 | 50 |
| 25 | 50 | 46 | 48 | 49 | 49 | 49 | 51 | 49 | 50 | 52 | 51 | 52 |
| 26 | 49 | 46 | 48 | 50 | 49 | 50 | 51 | 49 | 50 | 52 | 51 | 52 |
| 27 | 50 | 47 | 48 | 50 | 49 | 50 | 51 | 49 | 50 | 52 | 51 | 52 |
| 28 | A | A | A | 50 | 49 | 50 | 52 | 49 | 50 | 52 | 51 | 52 |
| 29 | A | A | A | 50 | 49 | 50 | 52 | 49 | 50 | 52 | 51 | 52 |
| 30 | 48 | 46 | 47 | 50 | 49 | 50 | 52 | 49 | 50 | 52 | 51 | 52 |
| 31 | -- | -- | -- | -- | -- | -- | 52 | 49 | 50 | 52 | 51 | 52 |

A--no record

TABLE 6.--Temperature data at two stations on the Elwha River (April 1, 1976 - August 31, 1977)--Continued

[Temperatures in degrees Fahrenheit]

| | August 1976 | | | | | | September 1976 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | McDonald Bridge | | | Below Lake Aldwell | | | McDonald Bridge | | | Below Lake Aldwell | | |
| Day | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | 51 | 50 | 50 | 53 | 52 | 52 | 52 | 49 | 50 | 54 | 53 | 54 |
| 2 | 52 | 50 | 51 | 52 | 52 | 52 | 53 | 50 | 52 | 54 | 53 | 54 |
| 3 | 51 | 50 | 50 | 52 | 52 | 52 | 53 | 50 | 52 | 55 | 53 | 54 |
| 4 | 53 | 50 | 52 | 53 | 52 | 52 | 52 | 50 | 51 | 55 | 54 | 54 |
| 5 | 52 | 50 | 51 | 53 | 52 | 52 | 51 | 50 | 50 | 54 | 54 | 54 |
| 6 | 53 | 50 | 52 | 53 | 52 | 52 | 52 | 50 | 51 | 54 | 53 | 54 |
| 7 | 52 | 50 | 51 | 53 | 52 | 52 | 53 | 50 | 52 | 54 | 53 | 54 |
| 8 | 53 | 50 | 52 | 53 | 52 | 52 | 53 | 50 | 52 | 54 | 52 | 53 |
| 9 | 53 | 50 | 52 | 53 | 52 | 52 | 54 | 50 | 52 | 54 | 53 | 54 |
| 10 | 53 | 50 | 52 | 54 | 53 | 54 | 54 | 50 | 52 | 54 | 53 | 54 |
| 11 | 53 | 50 | 52 | 54 | 53 | 54 | 52 | 50 | 51 | 54 | 53 | 54 |
| 12 | 53 | 50 | 52 | 54 | 53 | 54 | 52 | 50 | 51 | 54 | 53 | 54 |
| 13 | 51 | 51 | 51 | 54 | 53 | 54 | 52 | 49 | 50 | 54 | 53 | 54 |
| 14 | 53 | 51 | 52 | 53 | 53 | 53 | 53 | 50 | 52 | 53 | 53 | 53 |
| 15 | 51 | 50 | 50 | 54 | 53 | 54 | 53 | 50 | 52 | 54 | 53 | 54 |
| 16 | 51 | 50 | 50 | 53 | 53 | 53 | 53 | 50 | 52 | 54 | 53 | 54 |
| 17 | 52 | 49 | 50 | 53 | 52 | 52 | 52 | 50 | 51 | 54 | 53 | 54 |
| 18 | 52 | 49 | 50 | 53 | 52 | 52 | 53 | 50 | 52 | 54 | 53 | 54 |
| 19 | 50 | 50 | 50 | 52 | 52 | 52 | 54 | 50 | 52 | 55 | 53 | 54 |
| 20 | 52 | 49 | 50 | 53 | 52 | 52 | 54 | 50 | 52 | 54 | 53 | 54 |
| 21 | 52 | 49 | 50 | 53 | 52 | 52 | 54 | 50 | 52 | 54 | 53 | 54 |
| 22 | 51 | 50 | 50 | 53 | 52 | 52 | 51 | 51 | 51 | 54 | 53 | 54 |
| 23 | 51 | 50 | 50 | 53 | 52 | 52 | 53 | 51 | 52 | 54 | 53 | 54 |
| 24 | 52 | 50 | 51 | 53 | 52 | 52 | 54 | 50 | 52 | 54 | 53 | 54 |
| 25 | 52 | 50 | 51 | 53 | 52 | 52 | 54 | 50 | 52 | 54 | 53 | 54 |
| 26 | 52 | 50 | 51 | 53 | 52 | 52 | 54 | 51 | 52 | 55 | 53 | 54 |
| 27 | 51 | 50 | 50 | 52 | 52 | 52 | 53 | 51 | 52 | 55 | 54 | 54 |
| 28 | 53 | 50 | 52 | 53 | 52 | 52 | 54 | 51 | 52 | 55 | 54 | 54 |
| 29 | 53 | 50 | 52 | 53 | 52 | 52 | A | A | A | 55 | 54 | 54 |
| 30 | 53 | 49 | 51 | 53 | 52 | 52 | A | A | A | 55 | 54 | 54 |
| 31 | 53 | 50 | 52 | 54 | 52 | 53 | -- | -- | -- | -- | -- | -- |

A--no record

TABLE 6.--Temperature data at two stations on the Elwha River (April 1, 1976 - August 31, 1977)--Continued

[Temperatures in degrees Fahrenheit]

| | October 1976 | | | | | | November 1976 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | McDonald Bridge | | | Below Lake Aldwell | | | McDonald Bridge | | | Below Lake Aldwell | | |
| Day | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | A | A | A | A | A | A | A | A | A | 48 | 47 | 48 |
| 2 | A | A | A | A | A | A | A | A | A | 48 | 47 | 48 |
| 3 | A | A | A | 53 | 52 | 52 | 49 | 47 | 48 | 48 | 47 | 48 |
| 4 | A | A | A | 53 | 52 | 52 | 49 | 47 | 48 | 48 | 47 | 48 |
| 5 | A | A | A | 52 | 52 | 52 | 48 | 47 | 48 | 47 | 47 | 47 |
| 6 | A | A | A | 52 | 51 | 52 | 48 | 47 | 48 | 47 | 46 | 46 |
| 7 | A | A | A | 52 | 51 | 52 | 49 | 47 | 48 | 47 | 46 | 46 |
| 8 | A | A | A | 52 | 51 | 52 | 48 | 47 | 48 | 47 | 46 | 46 |
| 9 | 53 | 51 | 52 | 52 | 51 | 52 | 48 | 47 | 48 | 47 | 46 | 46 |
| 10 | 53 | 51 | 52 | 52 | 52 | 52 | 48 | 46 | 47 | 47 | 46 | 46 |
| 11 | 54 | 50 | 52 | 53 | 51 | 52 | 48 | 46 | 47 | 47 | 46 | 46 |
| 12 | A | A | A | 52 | 52 | 52 | 48 | 46 | 47 | 47 | 46 | 46 |
| 13 | A | A | A | 52 | 51 | 52 | 47 | 46 | 46 | 46 | 46 | 46 |
| 14 | A | A | A | 52 | 51 | 52 | 47 | 46 | 46 | 46 | 46 | 46 |
| 15 | A | A | A | 52 | 51 | 52 | 48 | 46 | 47 | 46 | 46 | 46 |
| 16 | A | A | A | 52 | 50 | 51 | 49 | 47 | 48 | 47 | 46 | 46 |
| 17 | A | A | A | 51 | 50 | 50 | 49 | 47 | 48 | 46 | 46 | 46 |
| 18 | A | A | A | 51 | 50 | 50 | 48 | 47 | 48 | 46 | 46 | 46 |
| 19 | A | A | A | 51 | 50 | 50 | 48 | 47 | 48 | 46 | 45 | 46 |
| 20 | A | A | A | 50 | 49 | 50 | 48 | 46 | 47 | 46 | 45 | 46 |
| 21 | A | A | A | 50 | 49 | 50 | 48 | 46 | 47 | 46 | 45 | 46 |
| 22 | A | A | A | 49 | 49 | 49 | 47 | 46 | 46 | 45 | 44 | 44 |
| 23 | A | A | A | 49 | 48 | 48 | 47 | 46 | 46 | 45 | 44 | 44 |
| 24 | A | A | A | 49 | 48 | 48 | 47 | 46 | 46 | 45 | 44 | 44 |
| 25 | A | A | A | 49 | 48 | 48 | 47 | 45 | 46 | 44 | 43 | 44 |
| 26 | A | A | A | 49 | 48 | 48 | 46 | 44 | 45 | 44 | 43 | 44 |
| 27 | A | A | A | 49 | 48 | 48 | 45 | 43 | 44 | 43 | 42 | 42 |
| 28 | A | A | A | 49 | 48 | 48 | 45 | 43 | 44 | 43 | 42 | 42 |
| 29 | A | A | A | 48 | 48 | 48 | A | A | A | 43 | 42 | 42 |
| 30 | A | A | A | 48 | 48 | 48 | A | A | A | 44 | 42 | 43 |
| 31 | A | A | A | 48 | 47 | 48 | -- | -- | -- | -- | -- | -- |

A--no record

TABLE 6.--Temperature data at two stations on the Elwha River (April 1, 1976 - August 31, 1977)--Continued

[Temperatures in degrees Fahrenheit]

| | December 1976 | | | | | |
|---|---|---|---|---|---|---|
| | McDonald Bridge | | | Below Lake Aldwell | | |
| Day | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | A | A | A | 43 | 42 | 42 |
| 2 | A | A | A | 43 | 42 | 42 |
| 3 | A | A | A | 43 | 42 | 42 |
| 4 | A | A | A | 43 | 42 | 42 |
| 5 | A | A | A | 42 | 42 | 42 |
| 6 | A | A | A | 42 | 42 | 42 |
| 7 | A | A | A | 43 | 42 | 42 |
| 8 | A | A | A | 42 | 42 | 42 |
| 9 | A | A | A | 42 | 42 | 42 |
| 10 | A | A | A | 42 | 42 | 42 |
| 11 | A | A | A | 42 | 42 | 42 |
| 12 | A | A | A | 42 | 42 | 42 |
| 13 | A | A | A | 42 | 42 | 42 |
| 14 | A | A | A | 42 | 42 | 42 |
| 15 | A | A | A | 42 | 41 | 42 |
| 16 | A | A | A | 42 | 41 | 42 |
| 17 | A | A | A | 42 | 41 | 42 |
| 18 | A | A | A | 42 | 41 | 42 |
| 19 | A | A | A | 41 | 41 | 41 |
| 20 | A | A | A | 42 | 41 | 42 |
| 21 | A | A | A | 42 | 41 | 42 |
| 22 | A | A | A | 41 | 41 | 41 |
| 23 | A | A | A | 41 | 40 | 40 |
| 24 | A | A | A | 41 | 40 | 40 |
| 25 | A | A | A | 41 | 40 | 40 |
| 26 | A | A | A | 41 | 40 | 40 |
| 27 | A | A | A | 41 | 40 | 40 |
| 28 | 40 | 40 | 40 | 41 | 40 | 40 |
| 29 | 40 | 39 | 40 | 41 | 40 | 40 |
| 30 | 39 | 38 | 38 | 40 | 40 | 40 |
| 31 | 39 | 38 | 38 | 40 | 39 | 40 |

| | January 1977 | | | | | |
|---|---|---|---|---|---|---|
| | McDonald Bridge | | | Below Lake Aldwell | | |
| Day | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | 39 | 38 | 38 | 40 | 39 | 40 |
| 2 | 39 | 39 | 39 | 40 | 39 | 40 |
| 3 | 39 | 38 | 38 | 39 | 39 | 39 |
| 4 | 38 | 37 | 38 | 39 | 39 | 39 |
| 5 | 38 | 37 | 38 | 39 | 38 | 38 |
| 6 | 38 | 37 | 38 | 39 | 38 | 38 |
| 7 | 38 | 36 | 37 | 39 | 38 | 38 |
| 8 | 37 | 36 | 36 | 39 | 37 | 38 |
| 9 | 37 | 36 | 36 | 37 | 37 | 37 |
| 10 | 37 | 36 | 36 | 37 | 36 | 36 |
| 11 | 37 | 37 | 37 | 37 | 36 | 36 |
| 12 | 38 | 37 | 38 | 37 | 36 | 36 |
| 13 | 37 | 36 | 36 | 37 | 36 | 36 |
| 14 | 37 | 36 | 36 | 37 | 36 | 36 |
| 15 | 37 | 36 | 36 | 37 | 37 | 37 |
| 16 | 37 | 36 | 36 | 38 | 37 | 38 |
| 17 | 37 | 36 | 36 | 38 | 37 | 38 |
| 18 | 37 | 37 | 37 | 38 | 38 | 38 |
| 19 | 37 | 36 | 36 | 39 | 38 | 38 |
| 20 | 38 | 36 | 37 | 39 | 38 | 38 |
| 21 | 38 | 37 | 38 | 39 | 38 | 38 |
| 22 | 38 | 37 | 38 | 39 | 38 | 38 |
| 23 | 38 | 37 | 38 | 38 | 38 | 38 |
| 24 | 38 | 37 | 38 | 38 | 37 | 38 |
| 25 | 38 | 37 | 38 | 38 | 37 | 38 |
| 26 | 38 | 37 | 38 | 38 | 37 | 38 |
| 27 | 38 | 37 | 38 | 37 | 37 | 37 |
| 28 | 38 | 37 | 38 | 37 | 37 | 37 |
| 29 | 38 | 37 | 38 | 37 | 37 | 37 |
| 30 | 38 | 36 | 37 | 37 | 37 | 37 |
| 31 | 38 | 36 | 37 | 38 | 37 | 38 |

A--no record

TABLE 6.--Temperature data at two stations on the Elwha River (April 1, 1976 - August 31, 1977)--Continued

[Temperatures in degrees Fahrenheit]

| | February 1977 | | | | | | March 1977 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | McDonald Bridge | | | Below Lake Aldwell | | | McDonald Bridge | | | Below Lake Aldwell | | |
| Day | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | 38 | 36 | 37 | 38 | 37 | 38 | 41 | 40 | 40 | 41 | 39 | 40 |
| 2 | 38 | 37 | 38 | 38 | 37 | 38 | 41 | 39 | 40 | 40 | 39 | 40 |
| 3 | 39 | 37 | 38 | 38 | 37 | 38 | 42 | 39 | 40 | 40 | 39 | 40 |
| 4 | 39 | 37 | 38 | 38 | 37 | 38 | 41 | 39 | 40 | 40 | 39 | 40 |
| 5 | 39 | 37 | 38 | 38 | 37 | 38 | 42 | 39 | 40 | 40 | 39 | 40 |
| 6 | 39 | 37 | 38 | 38 | 37 | 38 | 40 | 39 | 40 | 40 | 39 | 40 |
| 7 | 39 | 37 | 38 | 39 | 38 | 38 | 40 | 40 | 40 | 40 | 39 | 40 |
| 8 | 39 | 38 | 38 | 39 | 38 | 38 | 40 | 40 | 40 | 41 | 40 | 40 |
| 9 | 40 | 38 | 39 | 39 | 38 | 38 | 40 | 39 | 40 | 41 | 40 | 40 |
| 10 | 40 | 39 | 40 | 39 | 38 | 38 | 41 | 39 | 40 | 41 | 40 | 40 |
| 11 | 40 | 39 | 40 | 39 | 38 | 38 | 41 | 39 | 40 | 41 | 40 | 40 |
| 12 | 40 | 39 | 40 | 39 | 39 | 39 | 40 | 39 | 40 | 41 | 40 | 40 |
| 13 | 40 | 39 | 40 | 40 | 39 | 40 | 40 | 38 | 39 | 41 | 40 | 40 |
| 14 | 41 | 39 | 40 | 40 | 39 | 40 | 40 | 39 | 40 | 41 | 40 | 40 |
| 15 | 41 | 39 | 40 | 40 | 39 | 40 | 40 | 38 | 39 | 40 | 40 | 40 |
| 16 | 42 | 39 | 40 | 40 | 39 | 40 | 41 | 38 | 40 | 41 | 40 | 40 |
| 17 | 41 | 39 | 40 | 40 | 39 | 40 | 41 | 38 | 40 | 41 | 39 | 40 |
| 18 | 40 | 39 | 40 | 40 | 39 | 40 | 41 | 39 | 40 | 41 | 39 | 40 |
| 19 | 41 | 39 | 40 | 41 | 40 | 40 | 41 | 39 | 40 | 41 | 39 | 40 |
| 20 | 41 | 40 | 40 | 41 | 40 | 40 | 41 | 39 | 40 | 41 | 40 | 40 |
| 21 | 41 | 40 | 40 | 41 | 40 | 40 | 42 | 39 | 40 | 41 | 40 | 40 |
| 22 | 41 | 40 | 40 | 41 | 40 | 40 | 44 | 40 | 42 | 43 | 41 | 42 |
| 23 | 41 | 39 | 40 | 41 | 40 | 40 | 42 | 40 | 41 | 43 | 41 | 42 |
| 24 | 42 | 39 | 40 | 41 | 40 | 40 | 43 | 40 | 42 | 43 | 42 | 42 |
| 25 | 40 | 40 | 40 | 40 | 40 | 40 | 43 | 39 | 41 | 43 | 42 | 42 |
| 26 | 41 | 40 | 40 | 40 | 40 | 40 | 42 | 40 | 41 | 43 | 42 | 42 |
| 27 | 41 | 40 | 40 | 40 | 40 | 40 | 43 | 40 | 42 | 43 | 42 | 42 |
| 28 | 42 | 40 | 41 | 40 | 40 | 40 | 44 | 40 | 42 | 43 | 42 | 42 |
| 29 | -- | -- | -- | -- | -- | -- | 43 | 40 | 42 | 44 | 42 | 43 |
| 30 | -- | -- | -- | -- | -- | -- | 44 | 39 | 42 | 44 | 42 | 43 |
| 31 | -- | -- | -- | -- | -- | -- | 43 | 40 | 42 | 44 | 42 | 43 |

A--no record

TABLE 6.--Temperature data at two stations on the Elwha River (April 1, 1976 - August 31, 1977)--Continued

[Temperatures in degrees Fahrenheit]

| | April 1977 | | | | | | May 1977 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | McDonald Bridge | | | Below Lake Aldwell | | | McDonald Bridge | | | Below Lake Aldwell | | |
| Day | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | 45 | 40 | 42 | 44 | 42 | 43 | 47 | 45 | 46 | 47 | 47 | 47 |
| 2 | 44 | 40 | 42 | 44 | 42 | 43 | 47 | 45 | 46 | 48 | 47 | 48 |
| 3 | 45 | 40 | 42 | 45 | 43 | 44 | 47 | 45 | 46 | 48 | 47 | 48 |
| 4 | 45 | 41 | 43 | 45 | 43 | 44 | 46 | 44 | 45 | 48 | 47 | 48 |
| 5 | 47 | 41 | 44 | 46 | 44 | 45 | 46 | 43 | 44 | 48 | 46 | 47 |
| 6 | 47 | 42 | 44 | 46 | 44 | 45 | 47 | 44 | 46 | 47 | 46 | 46 |
| 7 | 47 | 42 | 44 | 46 | 44 | 45 | 48 | 44 | 46 | 48 | 46 | 47 |
| 8 | 44 | 42 | 43 | 46 | 45 | 46 | 48 | 44 | 46 | 48 | 46 | 47 |
| 9 | 45 | 42 | 44 | 46 | 45 | 46 | 48 | 43 | 46 | 48 | 46 | 47 |
| 10 | 45 | 42 | 44 | 46 | 45 | 46 | 46 | 44 | 45 | 48 | 47 | 48 |
| 11 | 45 | 41 | 43 | 46 | 45 | 46 | 46 | 43 | 44 | 48 | 47 | 48 |
| 12 | 45 | 42 | 44 | 46 | 44 | 45 | 46 | 43 | 44 | 48 | 47 | 48 |
| 13 | 45 | 42 | 44 | 46 | 44 | 45 | 45 | 44 | 44 | 48 | 47 | 48 |
| 14 | 45 | 42 | 44 | 46 | 44 | 45 | 46 | 44 | 45 | 48 | 47 | 48 |
| 15 | 45 | 42 | 44 | 45 | 44 | 44 | 47 | 44 | 46 | 48 | 47 | 48 |
| 16 | 45 | 41 | 43 | 45 | 44 | 44 | 45 | 44 | 44 | 47 | 46 | 46 |
| 17 | 45 | 41 | 43 | 46 | 44 | 45 | 47 | 43 | 45 | 48 | 47 | 48 |
| 18 | 45 | 41 | 43 | 46 | 44 | 45 | 48 | 44 | 46 | 48 | 47 | 48 |
| 19 | 45 | 41 | 43 | 46 | 44 | 45 | 47 | 44 | 46 | 48 | 47 | 48 |
| 20 | 46 | 41 | 44 | 46 | 44 | 45 | 47 | 44 | 46 | 49 | 47 | 48 |
| 21 | 45 | 42 | 44 | 46 | 44 | 45 | 47 | 45 | 46 | 49 | 48 | 48 |
| 22 | 47 | 43 | 45 | 46 | 45 | 46 | 48 | 45 | 46 | 49 | 48 | 48 |
| 23 | 47 | 43 | 45 | 46 | 45 | 46 | 46 | 45 | 46 | 49 | 48 | 48 |
| 24 | 47 | 44 | 46 | 47 | 45 | 46 | 47 | 45 | 46 | 49 | 48 | 48 |
| 25 | 46 | 44 | 45 | 47 | 46 | 46 | 48 | 45 | 46 | 49 | 48 | 48 |
| 26 | 46 | 44 | 45 | 47 | 46 | 46 | A | A | A | 49 | 48 | 48 |
| 27 | 47 | 43 | 45 | 47 | 46 | 46 | A | A | A | 49 | 48 | 48 |
| 28 | 47 | 43 | 45 | 47 | 46 | 46 | A | A | A | 49 | 48 | 48 |
| 29 | 47 | 44 | 46 | 47 | 46 | 46 | A | A | A | 49 | 48 | 48 |
| 30 | 47 | 44 | 46 | 47 | 46 | 46 | A | A | A | 49 | 48 | 48 |
| 31 | -- | -- | -- | -- | -- | -- | A | A | A | 49 | 48 | 48 |

A--no record

TABLE 6.--Temperature data at two stations on the Elwha River (April 1, 1976 - August 31, 1977)--Continued

[Temperatures in degrees Fahrenheit]

| | June 1977 | | | | | | July 1977 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | McDonald Bridge | | | Below Lake Aldwell | | | McDonald Bridge | | | Below Lake Aldwell | | |
| Day | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | 48 | 46 | 47 | 49 | 48 | 48 | 54 | 51 | 52 | 56 | 54 | 55 |
| 2 | 48 | 45 | 46 | 49 | 48 | 48 | 54 | 51 | 52 | 56 | 55 | 56 |
| 3 | 47 | 45 | 46 | 49 | 48 | 48 | 53 | 51 | 52 | 56 | 55 | 56 |
| 4 | 47 | 45 | 46 | 49 | 48 | 48 | 54 | 50 | 52 | 56 | 55 | 56 |
| 5 | 49 | 46 | 48 | 49 | 48 | 48 | 53 | 51 | 52 | 56 | 55 | 56 |
| 6 | 49 | 46 | 48 | 50 | 49 | 50 | 55 | 50 | 52 | 56 | 54 | 55 |
| 7 | 49 | 47 | 48 | 50 | 49 | 50 | 55 | 51 | 53 | 56 | 54 | 55 |
| 8 | 49 | 47 | 48 | 51 | 50 | 50 | 54 | 51 | 52 | 56 | 55 | 56 |
| 9 | 50 | 47 | 48 | 51 | 50 | 50 | 55 | 51 | 53 | 56 | 55 | 56 |
| 10 | 50 | 47 | 48 | 51 | 50 | 50 | 55 | 51 | 53 | 56 | 55 | 56 |
| 11 | A | A | A | 51 | 50 | 50 | 54 | 52 | 53 | 56 | 55 | 56 |
| 12 | A | A | A | 52 | 50 | 51 | 56 | 52 | 54 | 56 | 55 | 56 |
| 13 | A | A | A | 52 | 51 | 52 | 57 | 52 | 54 | 56 | 55 | 56 |
| 14 | A | A | A | 52 | 51 | 52 | 57 | 52 | 54 | 57 | 55 | 56 |
| 15 | A | A | A | 53 | 51 | 52 | 57 | 52 | 54 | 58 | 56 | 57 |
| 16 | 53 | 50 | 52 | 53 | 52 | 52 | 54 | 53 | 54 | 58 | 57 | 58 |
| 17 | 53 | 50 | 52 | 53 | 52 | 52 | 57 | 53 | 55 | 57 | 57 | 57 |
| 18 | 53 | 50 | 52 | 53 | 52 | 52 | 57 | 52 | 54 | 57 | 56 | 56 |
| 19 | 53 | 51 | 52 | 53 | 53 | 53 | 57 | 52 | 54 | 58 | 56 | 57 |
| 20 | 53 | 51 | 52 | 54 | 54 | 54 | 58 | 52 | 55 | 58 | 57 | 58 |
| 21 | 54 | 51 | 52 | 55 | 54 | 54 | 58 | 53 | 56 | 58 | 57 | 58 |
| 22 | 54 | 51 | 52 | 55 | 54 | 54 | 58 | 52 | 55 | 59 | 58 | 58 |
| 23 | 54 | 51 | 52 | 55 | 54 | 54 | 59 | 53 | 56 | 59 | 57 | 58 |
| 24 | 52 | 51 | 52 | 55 | 54 | 54 | 59 | 53 | 56 | 60 | 58 | 59 |
| 25 | 54 | 51 | 52 | 55 | 54 | 54 | 58 | 53 | 56 | 60 | 57 | 58 |
| 26 | 54 | 51 | 52 | 55 | 54 | 54 | 58 | 52 | 55 | 59 | 57 | 58 |
| 27 | 54 | 51 | 52 | 55 | 54 | 54 | 58 | 53 | 56 | 59 | 58 | 58 |
| 28 | 53 | 51 | 52 | 55 | 54 | 54 | 55 | 53 | 54 | 59 | 58 | 58 |
| 29 | 54 | 51 | 52 | 55 | 54 | 54 | 57 | 53 | 55 | 59 | 57 | 58 |
| 30 | 55 | 51 | 53 | 55 | 54 | 54 | 62 | 53 | 58 | 59 | 57 | 58 |
| 31 | -- | -- | -- | -- | -- | -- | 59 | 53 | 56 | 60 | 58 | 59 |

A--no record

TABLE 6.--Temperature data at two stations on the Elwha River (April 1, 1976-August 31, 1977)--Continued

[Temperatures in degrees Fahrenheit]

August 1977

| Day | McDonald Bridge Max. | Min. | Mean | Below Lake Aldwell Max. | Min. | Mean |
|---|---|---|---|---|---|---|
| 1 | 60 | 54 | 57 | 60 | 58 | 59 |
| 2 | 60 | 54 | 57 | 60 | 59 | 60 |
| 3 | 64 | 54 | 59 | 61 | 59 | 60 |
| 4 | 64 | 54 | 59 | 61 | 59 | 60 |
| 5 | 60 | 55 | 58 | 61 | 60 | 60 |
| 6 | 60 | 55 | 58 | 61 | 60 | 60 |
| 7 | 60 | 55 | 58 | 61 | 60 | 60 |
| 8 | 61 | 54 | 58 | 62 | 60 | 61 |
| 9 | 62 | 55 | 58 | 62 | 60 | 61 |
| 10 | 61 | 55 | 58 | 63 | 61 | 62 |
| 11 | 61 | 56 | 58 | 62 | 61 | 62 |
| 12 | 62 | 56 | 59 | 62 | 60 | 61 |
| 13 | 61 | 56 | 58 | 62 | 61 | 62 |
| 14 | 61 | 56 | 58 | 63 | 61 | 62 |
| 15 | 62 | 56 | 59 | 62 | 61 | 62 |
| 16 | 62 | 56 | 59 | 63 | 61 | 62 |
| 17 | 64 | 56 | 60 | 63 | 61 | 62 |
| 18 | 60 | 56 | 58 | 62 | 61 | 62 |
| 19 | 62 | 57 | 60 | 62 | 61 | 62 |
| 20 | 62 | 56 | 59 | 62 | 61 | 62 |
| 21 | 59 | 57 | 58 | 62 | 61 | 62 |
| 22 | 62 | 56 | 59 | 62 | 61 | 62 |
| 23 | 58 | 57 | 58 | 61 | 61 | 61 |
| 24 | 59 | 57 | 58 | 61 | 60 | 60 |
| 25 | 58 | 57 | 58 | 60 | 59 | 60 |
| 26 | 59 | 56 | 58 | 59 | 58 | 58 |
| 27 | 58 | 56 | 57 | 59 | 58 | 58 |
| 28 | 58 | 56 | 57 | 59 | 58 | 58 |
| 29 | 57 | 55 | 56 | 59 | 58 | 58 |
| 30 | 59 | 55 | 57 | 59 | 58 | 58 |
| 31 | A | A | A | | | |

A--no record