WATER RESOURCES OF THE MAKAH INDIAN RESERVATION, WASHINGTON

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 80-15

Prepared in Cooperation With
Makah Indian Tribal Council

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Ground water is known to occur only in sand and gravel layers that underlie the lowlands of the reservation. Individual wells are capable of yielding as much as 90 gallons per minute. Several wells in the Neah Bay area have been abandoned because of inferior water quality. In coastal areas, an individual domestic well on each 10-acre allotment should provide sufficient water for the occupants without danger of seawater intrusion.

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1980

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

GEOLOGICAL SURVEY
H. William Menard, Director

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U.S. Geological Survey
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Tacoma, Washington 98402

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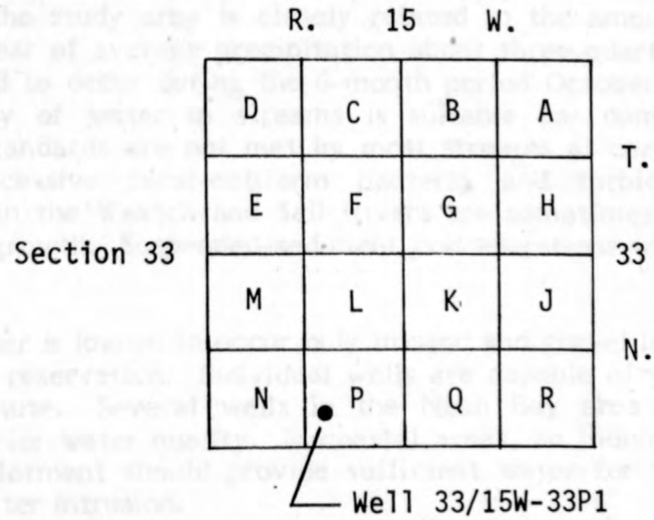
METRIC CONVERSION TABLE

Multiply	By	To obtain
inch	25.4	millimeter (mm)
	2.54	centimeter (cm)
	0.0254	meter (m)
foot (ft)	0.3048	meter (m)
mile	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	4047.	square meter (m^2)
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
	0.02832	cubic meter per second (m^3/s)
ton (2,000 lbs)	907.185	kilogram (kg)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
to convert degrees Fahrenheit (°F) to degrees Celsius (°C)	subtract 32 and multiply remainder by 0.5556	

WELL-NUMBERING SYSTEM

Wells in Washington have been assigned numbers by the U.S. Geological Survey, identifying them by location within a section, township, and range. For example, in the symbol 33/15W-33P1, the part preceding the hyphen indicates, successively, the township and range (T.33 N., R.15 W.) north and west of the Willamette base line and meridian. Because the entire State lies north of the base line, the letter indicating the direction north is omitted. The first number following the hyphen indicates the section (sec. 33), and the letter "P" gives the 40-acre subdivision of the section, as shown in the sketch below. The numeral "1" indicates that this well is the first one inventoried within the 40-acre subdivision.



WATER RESOURCES OF THE MAKAH INDIAN RESERVATION, WASHINGTON

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ABSTRACT

The residents of the Makah Indian Reservation depend on the streams of the area for their fisheries and domestic water supply. The temporal distribution of streamflow in the study area is closely related to the amount and distribution of rainfall. In a year of average precipitation about three-quarters of the streamflow can be expected to occur during the 6-month period October-March. Although the chemical quality of water in streams is suitable for domestic purposes, State water-quality standards are not met by most streams at certain times of the year because of excessive fecal-coliform bacteria and turbidity levels. Nutrient concentrations in the Waatch and Sail Rivers are sometimes high enough to cause nuisance-plant growth. Suspended-sediment concentrations were low in all streams sampled.

Ground water is known to occur only in sand and gravel layers that underlie the lowlands of the reservation. Individual wells are capable of yielding as much as 90 gallons per minute. Several wells in the Neah Bay area have been abandoned because of inferior water quality. In coastal areas, an individual domestic well on each 10-acre allotment should provide sufficient water for the occupants without danger of seawater intrusion.

INTRODUCTION

Background

Historically, the Makah Indians have relied on the fisheries resource of streams on the reservation as a significant source of livelihood. In addition, streams serve as the primary sources of domestic water supply for the town of Neah Bay and the surrounding area. Thus, the tribe is dependent, both directly and indirectly, on the quantity and quality of water in the streams of the reservation. In the past, members of the tribe have expressed interest in the following aspects of the water resources of the reservation:

Streamflow distribution.--Very little information is available on the flow characteristics of the major streams. The tribe would like this information in order to manage and develop several water-related operations. The Waatch River is presently the source of domestic supply for the town of Neah Bay and the surrounding area. Water from Village Creek, once the main source of domestic supply, is not being diverted at present (1979) but could supplement that now obtained from the Waatch River. A large fish hatchery is under construction along the lower Sooes River and another hatchery is contemplated along the Sail River. The tribe also hopes to establish a run of sockeye salmon up the Ozette River to Ozette Lake.

Ground-water availability.--The tribe would like to know the availability of ground water near the site of the fish hatchery on the Sooes River, as an alternative supply for the hatchery, and in the vicinity of Anderson Point near the lower Sooes River, where future land development is anticipated.

Water quality.--The tribe is concerned with the chemical and bacterial quality of water in the Waatch River and Village Creek for domestic supplies, and in the Sail, Sooes, and Ozette Rivers for fish hatching and rearing. Seepage from a sewage lagoon recently constructed for the town of Neah Bay could affect the water quality of the lower Waatch River. In addition, there is concern that present logging activity by commercial interests--and future logging activity by tribal members--could increase the sediment load of streams on the reservation and adversely affect fish hatching and rearing operations. Residential and road construction in the Village Creek basin could also change the sediment-transport characteristics of that stream.

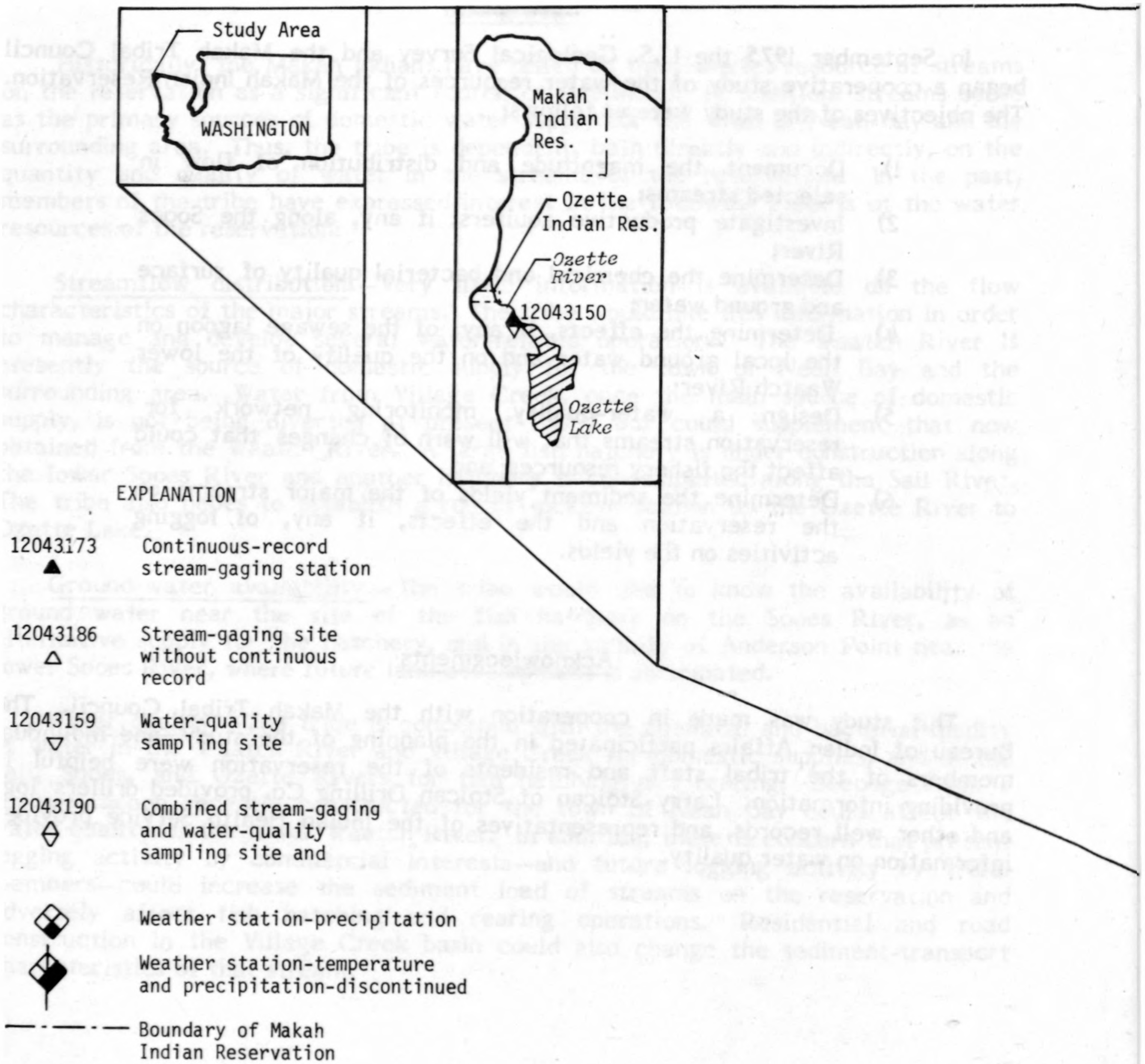
Objectives

In September 1975 the U.S. Geological Survey and the Makah Tribal Council began a cooperative study of the water resources of the Makah Indian Reservation. The objectives of the study were as follows:

1) Document the magnitude and distribution of flow in selected streams;
2) Investigate productive aquifers, if any, along the Sooes River;
3) Determine the chemical and bacterial quality of surface and ground water;
4) Determine the effects, if any, of the sewage lagoon on the local ground water and on the quality of the lower Waatch River;
5) Design a water-quality monitoring network for reservation streams that will warn of changes that could affect the fishery resources; and
6) Determine the sediment yields of the major streams on the reservation and the effects, if any, of logging activities on the yields.

Acknowledgments

This study was made in cooperation with the Makah Tribal Council. The Bureau of Indian Affairs participated in the planning of the study, and individual members of the tribal staff and residents of the reservation were helpful in providing information. Larry Stoican of Stoican Drilling Co. provided drillers' logs and other well records, and representatives of the Indian Health Service provided information on water quality.



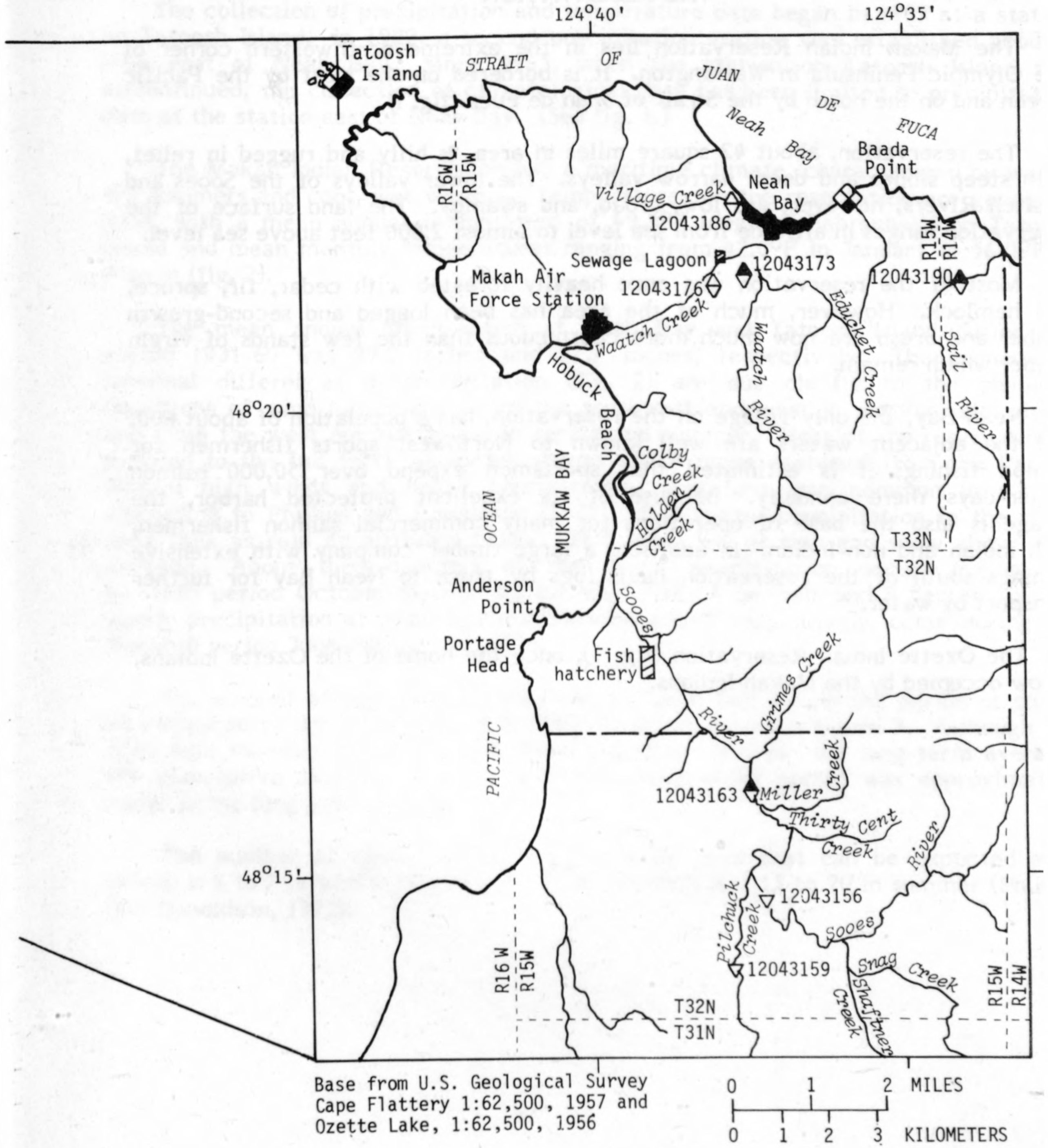


FIGURE 1.--Location of study area and data-collection sites.

LOCATION AND DESCRIPTION OF THE RESERVATION

The Makah Indian Reservation lies in the extreme northwestern corner of the Olympic Peninsula in Washington. It is bordered on the west by the Pacific Ocean and on the north by the Strait of Juan de Fuca (fig. 1).

The reservation, about 42 square miles in area, is hilly and rugged in relief, with steep slopes and deep, narrow valleys. The lower valleys of the Sooes and Waatch Rivers, however, are low, broad, and swampy. The land surface of the reservation ranges in altitude from sea level to almost 2,000 feet above sea level.

Most of the reservation was once heavily forested with cedar, fir, spruce, and hemlock. However, much of the area has been logged and second-growth timber and brush are now much more conspicuous than the few stands of virgin timber which remain.

Neah Bay, the only village on the reservation, has a population of about 600, and the adjacent waters are well known to Northwest sports fishermen for salmon fishing; it is estimated that sportsmen expend over 50,000 salmon angler-days there annually. Because of its excellent protected harbor, the village is also the base of operations for many commercial salmon fishermen, both Indian and non-Indian. In addition, a large timber company with extensive holdings south of the reservation hauls logs by truck to Neah Bay for further transport by water.

The Ozette Indian Reservation (fig. 1), once the home of the Ozette Indians, is now occupied by the Makah Indians.

CLIMATE

The collection of precipitation and temperature data began in 1902 at a station on Tatoosh Island. In 1922, a second precipitation station was established about 1 mile east of Neah Bay. Since 1965, when the station on Tatoosh Island was discontinued, the collection of climatological data has been limited to precipitation data at the station east of Neah Bay. (See fig. 1.)

The Makah Indian Reservation has a maritime climate, characterized by warm, dry summers and cool, wet winters. Temperatures on the reservation are generally mild, with a mean annual temperature of 49.3°F (degrees Fahrenheit) on Tatoosh Island and mean monthly temperatures ranging from 42.0°F in January to 56.0°F in August (fig. 2).

The mean annual precipitation at Neah Bay and Tatoosh Island during the period 1931-60 was 99.2 inches and 77.7 inches, respectively. The pronounced seasonal differences in precipitation (fig. 2) are due chiefly to the changing directions of wind movement--from the southwest and west in autumn and winter and from the west and northwest in spring and summer. Most of the reservation is exposed to the full force of winter storms which move eastward from the Pacific Ocean; high winds and heavy precipitation, therefore, are common in winter. According to Phillips and Donaldson (1972), most winter precipitation in the study area falls as rain at altitudes below 1,000 feet, and as rain and snow above that altitude. About three-quarters of the yearly precipitation occurs during the 6-month period October-March. By contrast, only 8 percent and 9 percent of the yearly precipitation at Neah Bay and Tatoosh Island, respectively, occur during the 3-month period June-August.

The amount of precipitation received at Neah Bay during the period of study, as compared to the long-term (1931-60) average, is shown in figure 3. Although the individual monthly totals often differed significantly from the long-term average, the cumulative amount received over the entire study period was approximately equal to the long-term average.

The number of clear or only partly cloudy days that can be expected each month is 4 to 7 in winter, 8 to 15 in spring and fall, and 15 to 20 in summer (Phillips and Donaldson, 1972).

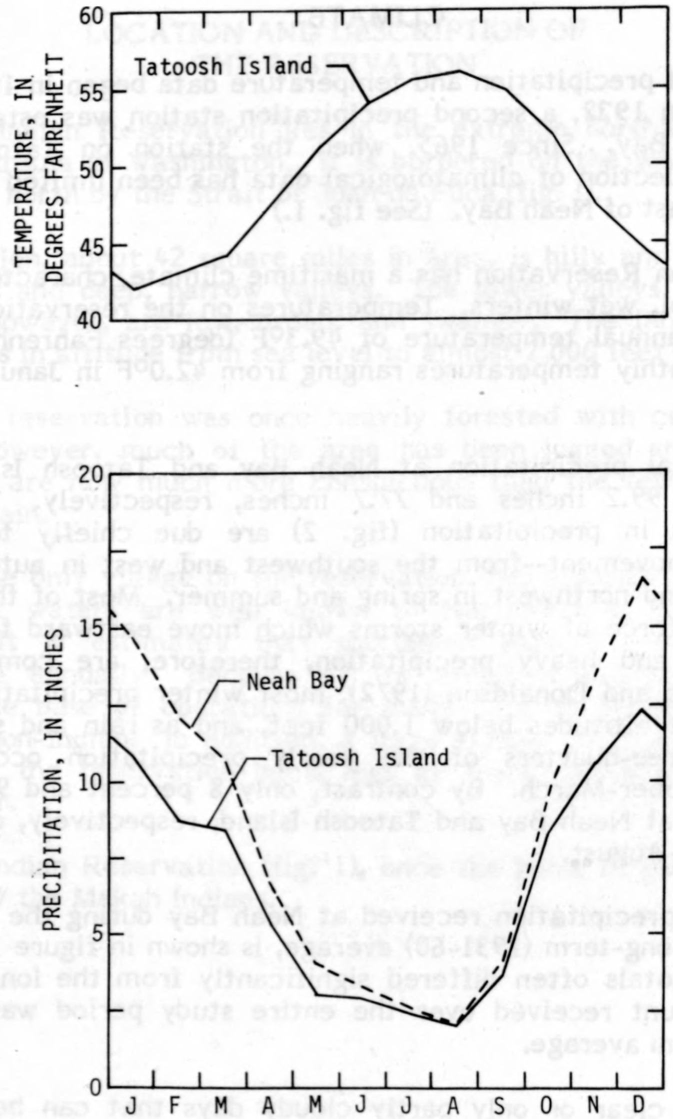


FIGURE 2.--Mean monthly temperature at Tatoosh Island, and mean monthly precipitation at Tatoosh Island and Neah Bay.

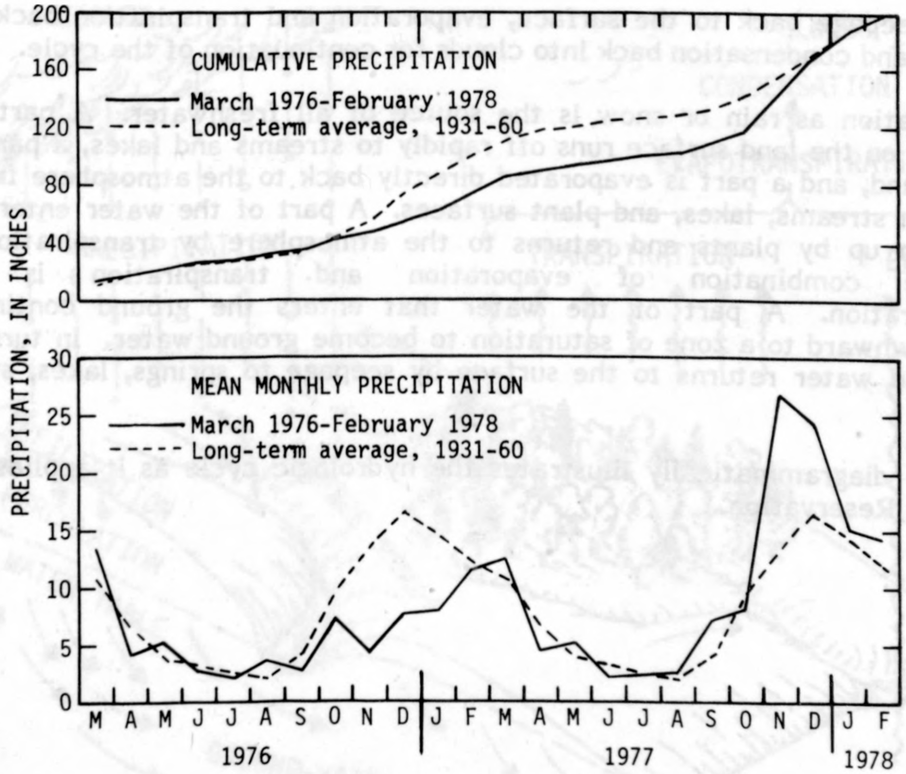


FIGURE 3.--Cumulative and mean monthly precipitation at Neah Bay during March 1976-February 1978, compared to long-term average, 1931-60.

THE HYDROLOGIC CYCLE

The hydrologic cycle is the pattern of water movement as it circulates through the natural system. It includes precipitation from the atmosphere to the earth, surface runoff and streamflow to the sea or lakes, percolation to ground-water bodies and seepage back to the surface, evaporation and transpiration back to the atmosphere, and condensation back into clouds for continuation of the cycle.

Precipitation as rain or snow is the source of all freshwater. A part of the precipitation on the land surface runs off rapidly to streams and lakes, a part soaks into the ground, and a part is evaporated directly back to the atmosphere from the soil and from streams, lakes, and plant surfaces. A part of the water entering the soil is drawn up by plants and returns to the atmosphere by transpiration from leaves; the combination of evaporation and transpiration is called evapotranspiration. A part of the water that enters the ground continues to percolate downward to a zone of saturation to become ground water. In turn, most of the ground water returns to the surface by seepage to springs, lakes, streams, and the sea.

Figure 4 diagrammatically illustrates the hydrologic cycle as it applies to the Makah Indian Reservation.

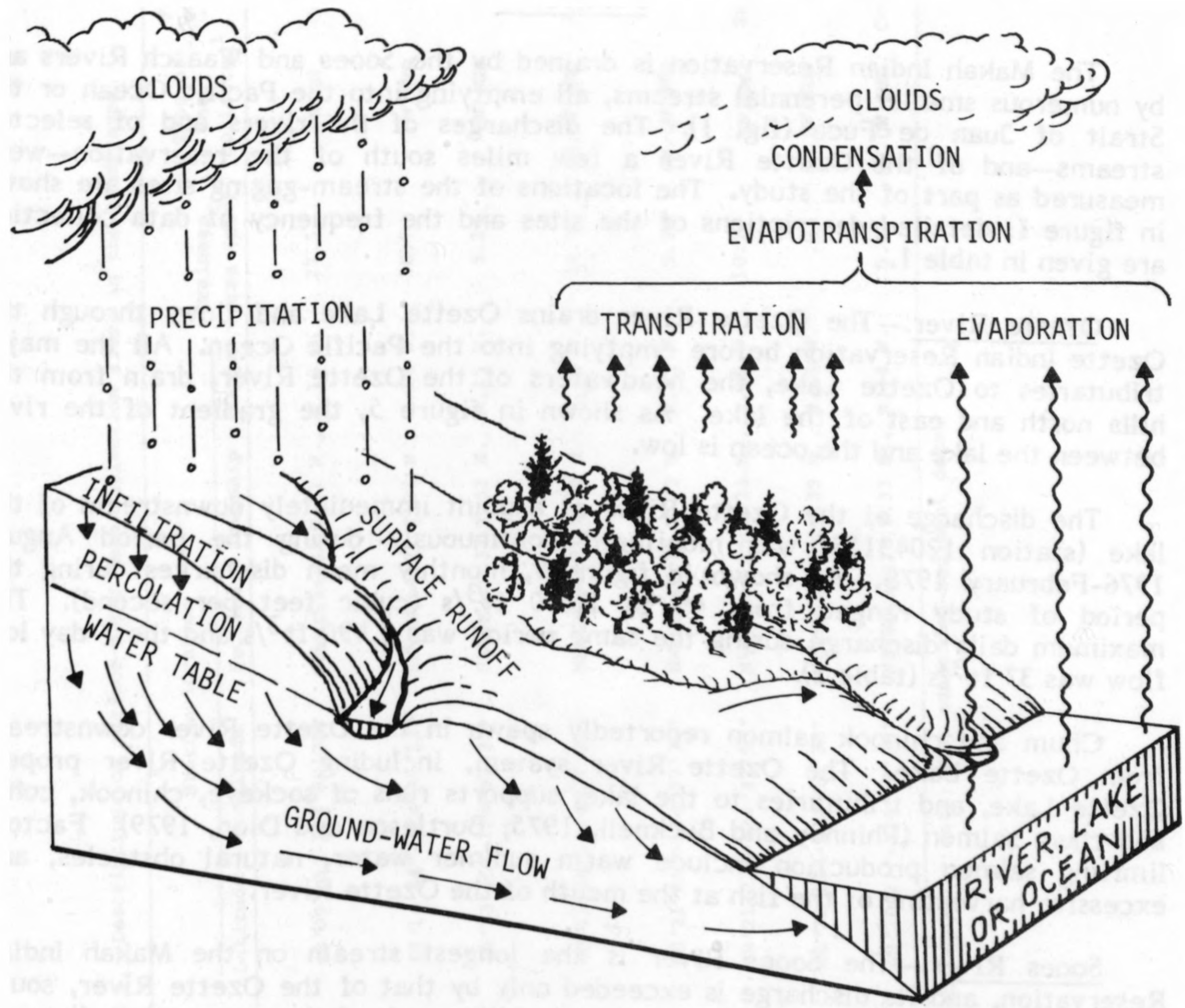


FIGURE 4.--Diagrammatic sketch of the hydrologic cycle.

SURFACE-WATER RESOURCES

Occurrence

The Makah Indian Reservation is drained by the Sooes and Waatch Rivers and by numerous smaller perennial streams, all emptying into the Pacific Ocean or the Strait of Juan de Fuca (fig. 1). The discharges of the rivers and of selected streams--and of the Ozette River a few miles south of the reservation--were measured as part of the study. The locations of the stream-gaging sites are shown in figure 1; detailed descriptions of the sites and the frequency of data collection are given in table 1.

Ozette River.--The Ozette River drains Ozette Lake and flows through the Ozette Indian Reservation before emptying into the Pacific Ocean. All the major tributaries to Ozette Lake, the headwaters of the Ozette River, drain from the hills north and east of the lake. As shown in figure 5, the gradient of the river between the lake and the ocean is low.

The discharge of the Ozette River at a point immediately downstream of the lake (station 12043150) was monitored continuously during the period August 1976-February 1978. As shown in figure 6, monthly mean discharges during the period of study ranged from 49 to 1,150 ft^3/s (cubic feet per second). The maximum daily discharge during the same period was 1,490 ft^3/s and the 7-day low flow was 37 ft^3/s (table 2).

Chum and chinook salmon reportedly spawn in the Ozette River downstream from Ozette Lake. The Ozette River system, including Ozette River proper, Ozette Lake, and tributaries to the lake, supports runs of sockeye, chinook, coho, and chum salmon (Phinney and Bucknell, 1975; Bortleson and Dion, 1979). Factors limiting salmon production include warm summer water, natural obstacles, and excessive harvesting of the fish at the mouth of the Ozette River.

Sooes River.--The Sooes River is the longest stream on the Makah Indian Reservation, and its discharge is exceeded only by that of the Ozette River, south of the reservation. The Sooes River rises in hills south of the reservation, flows in a northwesterly direction, and empties into Mukkaw Bay. Along its course it is joined by numerous tributaries, the larger being Snag, Pilchuck, and Miller Creeks. As shown in figure 5, the gradient of the main stem is low to moderate throughout its entire length, whereas gradients of the tributaries are moderate to steep. The lowermost reach of the river is in a marsh and is under tidal influence.

The monthly mean discharge of the Sooes River (station 12043163) during the period March 1976-February 1978 ranged from 30 to 613 ft^3/s (fig. 6). The maximum daily discharge for the same period was 2,070 ft^3/s and the 7-day low flow was 14 ft^3/s (table 2).

The Sooes River and its tributaries support runs of chinook, coho, and chum salmon. Production is limited, however, by low summer streamflow, log and debris jams, and siltation of the spawning gravels (Phinney and Bucknell, 1975).

TABLE 1.--Descriptions of surface-water data-collection sites in the study area

Station name	Station no.	Station location		Drainage area (mi^2)	Type of data collected[1]	Frequency of data collection (1976-78)	
		Latitude - Longitude	Section - Township - Range			Discharge	Frequency
Ozette River at outlet point of Ozette Lake	12043150	48°09'15"-124°40'06"	NE¼NE¼sec31,T.31 N., R.15 W.	77.5	SW,QW	Continuous	Intermittent
Sooes River above Pilchuck Creek near Ozette	12043156	48°14'44"-124°37'13"	SW¼NW¼sec27,T.32 N., R.15 W.	20.7	QW,SED	--	Do.
Pilchuck Creek near Ozette	12043159	48°13'55"-124°37'35"	SE¼NE¼sec33,T.32 N., R.15 W.	5.24	QW,SED	--	Do.
Sooes River below Miller Creek near Ozette	12043163	48°15'56"-124°37'28"	NE¼NE¼sec21,T.32 N., R.15 W.	32.0	SW,QW,SED	Continuous	Do.
Waatch River below Educket Creek at Neah Bay	12043173	48°21'26"-124°37'30"	NW¼SE¼sec15,T.33 N., R.15 W.	9.96	SW,QW,SED	do.	Do.
Waatch River at Neah Bay	12043176	48°21'23"-124°37'57"	N½SW¼sec 15,T.33 N., R.15 W.	10.7	SW,QW	Intermittent	Do.
Village Creek at Neah Bay	12043186	48°22'11"-124°37'38"	NE¼SW¼sec10,T.33 N., R.15 W.	.63	SW,QW,SED	do.	Do.
Sail River near Neah Bay	12043190	48°21'27"-124°33'38"	NE¼SW¼sec18,T.33 N., R.14 W.	5.42	SW,QW,SED	Continuous	Do.

[1] SW, streamflow data; QW, water-quality data; SED, suspended-sediment data.

TABLE 2.--Maximum daily and 7-day low flows of selected streams, June 1976-February 1978

Station number	Station name	Discharge (ft^3/s) Maximum daily	Date	7-day low	Dates
12043150	Ozette River at Ozette[1]	1,490	12/3/77	37	8/18/77-8/24/77
12043163	Sooes River below Miller Creek, near Ozette	2,070	12/2/77	14	8/14/77-8/20/77
12043173	Waatch River below Educket Creek, at Neah Bay	573	12/2/77	1.0	8/15/77-8/21/77
12043190	Sail River near Neah Bay	371	12/2/77	1.3	8/13/77-8/19/77

[1]For period August 1976-February 1978.

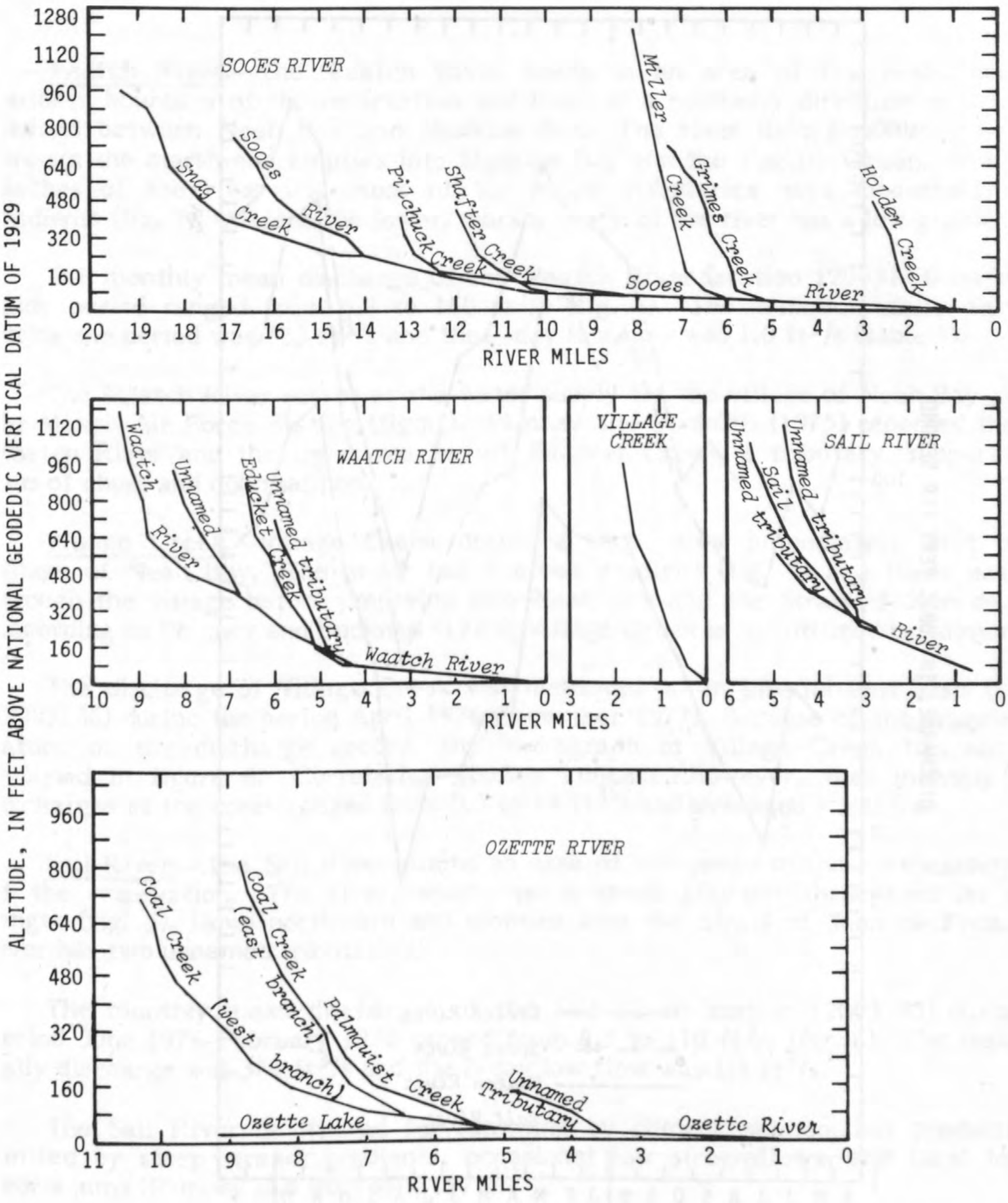


FIGURE 5.--Gradients and lengths of streams; vertical exaggeration is 26 times. (National Geodetic Vertical Datum of 1929, previously known as mean sea level.)

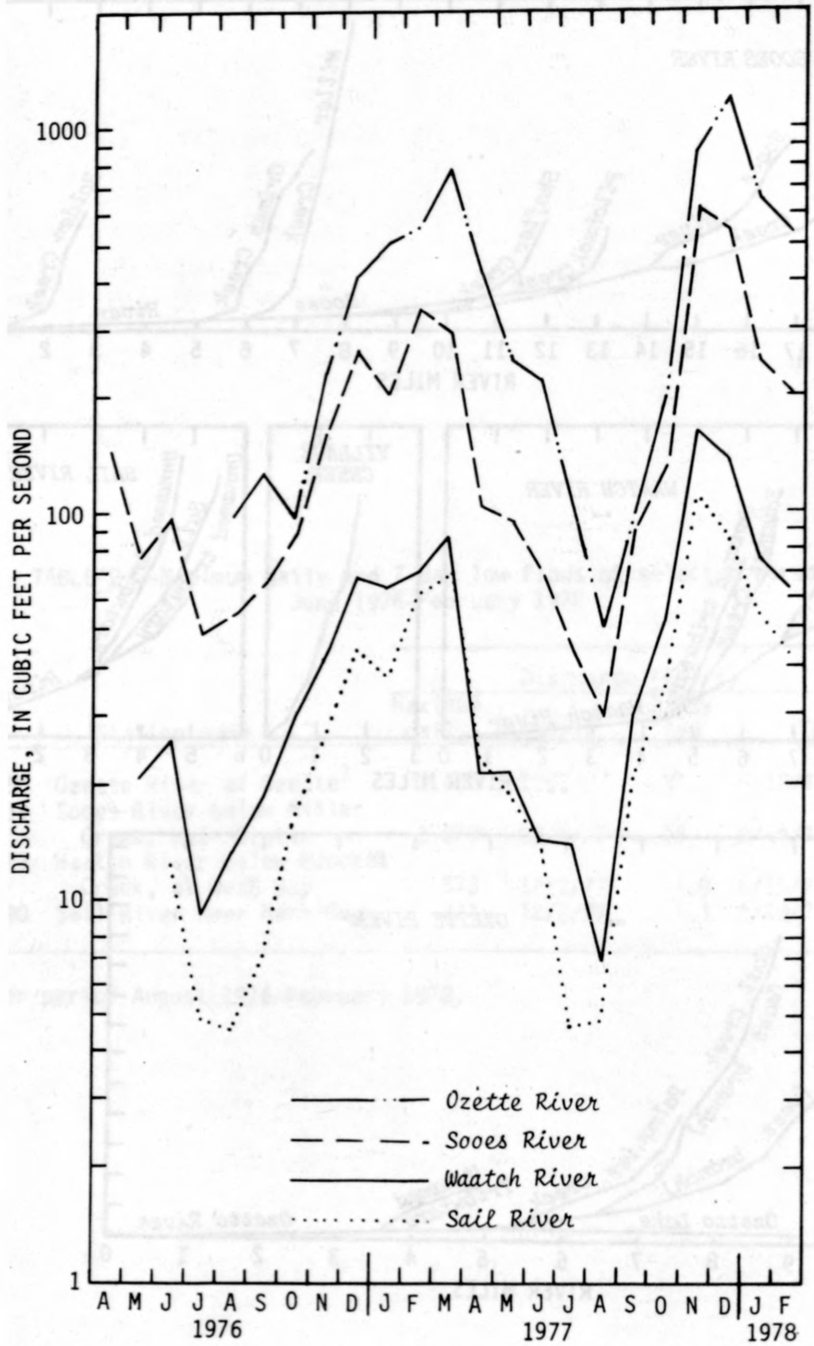


FIGURE 6.--Monthly mean discharges of selected streams, April 1976-February 1978.

Waatch River.--The Waatch River heads in an area of low peaks near the southern boundary of the reservation and flows in a northerly direction to a marshy lowland between Neah Bay and Mukkaw Bay. The river then flows southwesterly through the marsh and empties into Mukkaw Bay and the Pacific Ocean. The upper reaches of the river and most of the major tributaries have moderately steep gradients (fig. 5), whereas the lower, marshy reach of the river has a low gradient.

The monthly mean discharge of the Waatch River (station 12043173) during the study period ranged from 6.8 to 160 ft^3/s (fig. 6). The maximum daily discharge during the period was 573 ft^3/s and the 7-day low flow was 1.0 ft^3/s (table 2).

The Waatch River serves as the water supply for the village of Neah Bay and for the Makah Air Force Station (fig. 1). Phinney and Bucknell (1975) reported that the Waatch River and the lower reaches of Educket Creek, a tributary, support small runs of chum and coho salmon.

Village Creek.--Village Creek drains a small area immediately west of the village of Neah Bay. The creek has a steep gradient (fig. 5) and flows eastward through the village before emptying into Neah Bay and the Strait of Juan de Fuca. According to Phinney and Bucknell (1975), Village Creek is not utilized by salmon.

The discharge of Village Creek was measured on an intermittent basis (station 12043186) during the period April 1976-December 1977. Because of the fragmentary nature of the discharge record, the hydrograph of Village Creek has not been included in figure 6. Correlation studies indicate, however, that monthly mean discharges of the creek ranged from 0.5 to 19 ft^3/s and averaged 4.5 ft^3/s.

Sail River.--The Sail River drains an area of low peaks in the northeastern part of the reservation. The river, which has a steep gradient throughout its entire length (fig. 5), flows northward and empties into the Strait of Juan de Fuca. The river has two unnamed tributaries.

The monthly mean discharges of the Sail River (station 12043190) during the period June 1976-February 1978 ranged from 4.5 to 110 ft^3/s (fig. 6). The maximum daily discharge was 371 ft^3/s and the 7-day low flow was 1.3 ft^3/s.

The Sail River is utilized for spawning by chinook salmon, but production is limited by steep stream gradients, occasional low streamflows, and local log and debris jams (Phinney and Bucknell, 1975).

In general, maximum daily discharges of streams in and near the study area occurred in early December 1977, a period of above-average precipitation (fig. 3). Seven-day low flows occurred in late August 1977, a time of seasonally low rainfall.

As might be expected in an area of abundant precipitation and mild winter temperatures, the magnitudes of stream discharges in the study area are determined in large part by the amount of precipitation. This relationship is readily seen by comparing graphs of precipitation (fig. 3) with those of streamflow (fig. 6). In order to depict and quantify this relationship, correlations were made of total monthly precipitation (recorded near Neah Bay) and monthly mean discharge at the gaging stations equipped with continuous recorders (fig. 1 and table 1). The graphs of the correlations (fig. 7) allow the estimation of monthly mean discharge at each of the sites for specified amounts of total monthly precipitation. Although the number of data sets available for correlation was limited by the number of months in the study period, the precipitation during the study period was about average. (See p. 7.) Correlation coefficients determined for stations on the Sooes, Waatch, and Sail Rivers were 0.94, 0.96 and 0.95, respectively, and standard errors of estimate were 52, 11, and 9.2 ft^3/s, respectively. Because the correlation coefficient for the Ozette River station was relatively low, probably as a result of the influence of Ozette Lake in the headwaters of the river, interpretation of data for that station is not included in figure 7.

Using the graphs in figure 7, estimates of monthly mean discharges were made for the Sooes, Waatch, and Sail Rivers under conditions of average (mean monthly) precipitation and using the standard errors of estimate as confidence intervals. The resulting estimated discharges are given in table 3 for both ± 1 standard error of estimate (68 percent of cases) and ± 2 standard errors of estimate (95 percent of cases). For example, assuming the total monthly precipitation near Neah Bay to be 14.55 inches (the mean monthly value for January), the estimated monthly mean discharge of the Sooes River at station 12043163 will be between 260 and 360 ft^3/s 68 percent of the time (± 1 standard error), and between 210 and 420 ft^3/s 95 percent of the time (± 2 standard errors). Discharge estimates corresponding to precipitation values not shown in table 3 can be obtained by referring to the appropriate graph in figure 7. However, the method should not be used for time periods shorter than 1 month, nor for monthly precipitation values outside the range observed during the study and on which the relationships are based.

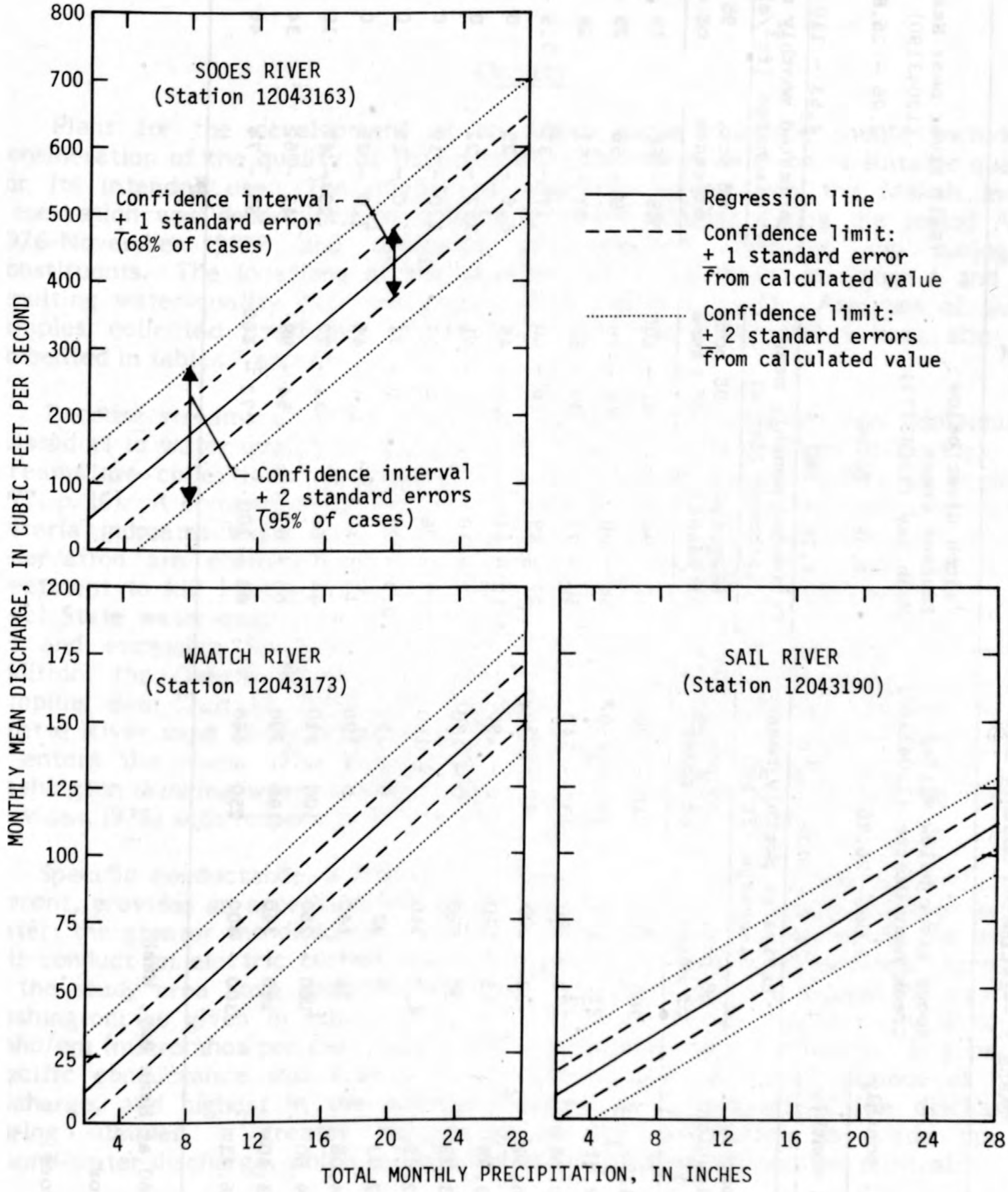


FIGURE 7.--Correlation of monthly mean discharges of Sooes, Waatch, and Sail Rivers with total monthly precipitation at Neah Bay.

TABLE 3.--Estimated monthly mean discharges of selected streams

		Sooes River below Miller Creek near Ozette (12043163)		Waatch River below Educket Creek at Neah Bay (12043173)		Sail River near Neah Bay (12043190)	
Range of observed total monthly precipitation (in.)-----------		2.06 - 26.86		2.06 - 26.86		2.06 - 26.86	
Range of observed mean monthly discharge (ft³/s)-------------		29.7 - 613		6.78 - 160		4.53 - 110	
		Estimated monthly mean discharge (ft³/s)		Estimated monthly mean discharge (ft³/s)		Estimated monthly mean discharge (ft³/s)	
	Mean monthly precipitation (in.)[1]	68 pct. of cases[2]	95 pct. of cases[3]	68 pct. of cases	95 pct. of cases	68 pct. of cases	95 pct. of cases
January	14.55	260 - 360	210 - 420	72 - 94	61 - 100	48 - 66	39 - 76
February	12.01	210 - 310	160 - 360	58 - 80	46 - 90	38 - 56	29 - 66
March	10.74	180 - 280	130 - 340	50 - 72	39 - 83	33 - 51	24 - 61
April	6.64	92 - 200	40 - 250	27 - 49	16 - 60	17 - 35	7.8 - 45
May	3.96	35 - 140	0 - 190	12 - 34	0.9 - 45	6.6 - 25	0 - 34
June	3.22	20 - 120	0 - 180	7.7 - 30	0 - 41	3.7 - 22	0 - 31
July	2.52	4.7 - 110	0 - 160	3.7 - 26	0 - 37	1.0 - 19	0 - 29
August	2.03	0 - 98	0 - 150	0.9 - 23	0 - 34	0 - 17	0 - 27
September	4.06	38 - 140	0 - 190	12 - 34	1.4 - 45	7.0 - 25	0 - 35
October	9.60	160 - 260	100 - 310	44 - 66	33 - 77	29 - 47	19 - 56
November	13.40	240 - 340	180 - 390	65 - 87	54 - 98	43 - 62	34 - 71
December	16.43	300 - 400	250 - 460	83 - 100	72 - 100	55 - 74	46 - 83

[1] For period 1931-60 at Neah Bay, Wash.

[2] ±1 standard error.

[3] ±2 standard errors.

Quality

Plans for the development of an area's water resource should include a consideration of the quality of that resource; the water must be of suitable quality for its intended use. The quality of water in streams on the Makah Indian Reservation was determined by collecting water samples during the period April 1976-November 1977 and analyzing for selected chemical and biological constituents. The locations of the sampling sites are shown in figure 1 and the resulting water-quality data are presented in tables 4 to 11. Analyses of water samples collected previously (1971) from the Sooes and Sail Rivers also are presented in tables 7 and 11.

Because streams on the Makah Indian Reservation have not been individually classed as to water quality by the State of Washington Department of Ecology, the streams are collectively designated class A (Washington Department of Ecology, 1977, p. 16). A comparison of the water-quality data in tables 4-11 with the class-A criteria indicates that, with but a few exceptions, the surface waters of the reservation are chemically of good quality and suitable for most uses after treatment to kill bacteria and filter out suspended solids. Occasional failures to meet State water-quality standards were observed in most streams because of low pH and excessive fecal-coliform-bacteria populations and turbidity levels. In addition, the Ozette River failed to meet the temperature standard on one sampling date (July 12, 1977). The generally higher temperatures observed in the Ozette River most likely result from the warming of water in Ozette Lake before it enters the river. The streams of the reservation also failed to meet the Washington drinking-water standards (Washington Department of Social and Health Services, 1978) with respect to fecal-coliform bacteria and turbidity.

Specific conductance, a measure of the water's ability to conduct an electric current, provides an approximation of the total amount of minerals dissolved in the water; the greater the dissolved-minerals concentration, the more easily the water will conduct an electric current and the higher the specific conductance. Streams in the study area have specific-conductance values that are typical of western Washington; as given in tables 4-11, specific conductance ranged from 36 to 81 umho/cm (micromhos per centimeter) and averaged about 51 umho/cm. In general, specific conductance was lowest in the winter months, during periods of high discharge, and highest in the summer months, during periods of low discharge. During summer, a greater percentage of the streamflow is made up of ground-water discharge, which is characteristically higher in dissolved minerals.

Determinations of the concentrations of several aquatic-plant nutrients, chiefly inorganic nitrogen (nitrate, nitrite, and ammonia) and inorganic (orthophosphate) phosphorus, were made to determine the likelihood of nuisance-plant growths, such as algal blooms, in the reservation's streams. Springtime concentrations of inorganic nitrogen and phosphorus of 0.30 and 0.015 mg/L (milligram per liter), respectively, have long been considered the critical concentrations above which summer algal blooms are likely to develop in lakes. Very little information is available, however, concerning the nutrient concentrations likely to cause blooms in streams. Even though the stream concentrations may be different from those in lakes, the lake concentrations were used for assessing the potential of streams in the study area for producing nuisance aquatic plants. It should be emphasized that other factors, such as water temperature and amount of light, also help to determine the extent of plant growth in water. The nutrient concentrations measured in most streams during the period of study were generally below the critical concentrations given above. In November 1977, however, inorganic-nitrogen concentrations were high at both Waatch River stations (0.76 and 0.66 mg/L) and in the Sail River (0.68 mg/L). In addition, the inorganic-phosphorus concentration in the Waatch River at Neah Bay was moderately high (0.02 mg/L) in August 1976.

Although algae in stream waters are not necessarily undesirable, an extensive algal bloom at any time of the year usually results in esthetically unpleasant conditions. If a bloom were to occur during the warm summer months, as is more likely, the DO necessary to support fish life could become depleted following the bloom as the algae decompose and are oxidized. It is unlikely, however, that an algal bloom severe enough to affect fish life would occur in the streams studied.

A comparison of the coliform-bacteria population and nutrient concentrations at sampling stations on the Waatch River above and below the Neah Bay sewage lagoon indicates that no significant difference existed. This suggests that the sewage lagoon had no continuous detectable effect on the quality of the Waatch River. However, under certain runoff conditions the sewage lagoon could have considerable effect on the quality of water in the river.

Water samples from the Sooes River (August 25, 1976) at the fish hatchery site and from a small ditch (November 3, 1977) that drains a large log-sorting yard and discharges into the Sooes River near the center of sec. 22, T.32 N., R.15 W., were analyzed for oil and grease. None was present in either sample. Both samples were collected after several days of moderately heavy rainfall following prolonged dry periods, when any accumulation of oil and grease in the drainage basin would be flushed into the streams.

In August 1976 trace-metal determinations were made for chromium, copper, lead, mercury, and zinc in water from Pilchuck Creek and from both stations on the Sooes River. According to criteria of the U.S. Environmental Protection Agency (1976), none of the water analyzed had concentrations that would make it unfit for domestic water supplies, freshwater aquatic life, or livestock.

In order to monitor the quality of water in streams on the reservation and to protect the valuable fishery resource, a water-quality-monitoring program is hereby proposed that would entail bimonthly sampling and analysis of water in selected streams for the characteristics that affect, either directly or indirectly, the well-being of fish. Initially, the sampling program would include monitoring of water temperature, DO, specific conductance, total- and fecal-coliform bacteria, trace metals, and nutrients. If conditions within the drainage basin were to change, it might be necessary to also analyze for pesticides and for oil and grease.

The times of sampling should include periods of high flow (mid-winter) and low flow (late summer). The stream sites tentatively selected for sampling (fig. 1) are as follows:

Station number	Station name
12043163	Sooes River below Miller Creek near Ozette.
12043173	Waatch River below Educket Creek at Neah Bay.
12043186	Village Creek at Neah Bay.
12043190	Sail River near Neah Bay.

TABLE 4.--Water-quality data, Ozette River at outlet of Ozette Lake (station 12043150)

[Milligrams per liter unless otherwise indicated]

Date of collection	4/27/76[a]	5/27/76	6/21/76	7/21/76	11/11/76	2/8/77	3/9/77	5/17/77	7/12/77	9/20/77
Mean daily discharge (ft^3/s)	--	--	--	--	173	420	1,010	230	101	110
Specific conductance (µmho/cm at 25°C)	37	37	36	--	--	39	43	42	40	42
pH (units)	--	7.0	6.3	--	--	--	--	--	--	--
Temperature (°C)	10.0	13.0	14.0	17.8	12.5	8.2	6.9	13.3	18.3	16.0
Turbidity (Jtu)	--	--	1	--	0	0	1	0	0	0
Dissolved oxygen (DO)	11.0	9.8	--	9.3	9.4	11.7	11.6	10.0	9.2	9.2
Immediate coliform (col/100 mL)	--	7	4	12	90	--	14	24	73	160
Fecal coliform (col/100 mL)	--	4	< 1	8	94	--	3	1	1	17

[a]	
Total nitrate (as N)	0.05
Total nitrite (as N)	.00
Total ammonia nitrogen (as N)	.05
Total Kjeldahl nitrogen (as N)	.17
Total phosphorus (as P)	.01
Dissolved orthophosphate phosphorus (as P)	.00

TABLE 5.--Water-quality data, Sooes River above Pilchuck Creek near Ozette (station 12043156)

[Milligrams per liter unless otherless indicated]

Date of collection	4/21/76	6/2/76	8/25/76	11/17/76	1/18/77	3/23/77
Mean daily discharge (ft^3/s)	--	--	--	--	--	--
Specific conductance (μmho/cm at 25°C)	46	52	68	40	39	53
pH (units)	6.7	7.1	7.6	6.9	7.2	6.9
Temperature (°C)	6.5	8.5	14.6	10.2	7.8	6.2
Turbidity (Jtu)	2	1	--	90	55	10
Dissolved oxygen (DO)	11.8	11.5	10.2	10.6	11.3	10.9
Immediate coliform (col/100 mL)	30	--	>800	2700	910	--
Fecal coliform (col/100 mL)	8	--	140	<1	<1	--
Hardness as $CaCO_3$ (Ca, Mg)	18	--	25	--	--	--
Noncarbonate hardness	3	--	2	--	--	--
Dissolved calcium (Ca)	4.7	--	6.6	--	--	--
Dissolved magnesium (Mg)	1.6	--	2.0	--	--	--
Dissolved sodium (Na)	4.0	--	4.7	--	--	--
Dissolved potassium (K)	.3	--	.4	--	--	--
Bicarbonate (HCO_3)	19	--	28	--	--	--
Total alkalinity (as $CaCO_3$)	16	--	23	--	--	--
Dissolved sulfate (SO_4)	2.7	--	5.6	--	--	--
Dissolved chloride (Cl)	4.6	--	4.9	--	--	--
Total nitrate (as N)	.02	--	.01	--	--	--
Total nitrite (as N)	.00	--	.00	--	--	--
Total nitrite plus nitrate (as N)	--	--	--	--	--	--
Total ammonia nitrogen (as N)	.07	--	.03	--	--	--
Total Kjeldahl nitrogen (as N)	.14	--	.10	--	--	--
Total phosphorus (as P)	.01	--	.01	--	--	--
Dissolved orthophosphate phosphorus (as P)	.00	--	.01	--	--	--
Dissolved chromium (as Cr) (μg/L)	--	--	0	--	--	--
Dissolved copper (as Cu) (μg/L)	--	--	1	--	--	--
Dissolved lead (as Pb) (μg/L)	--	--	--	--	--	--
Total mercury (as Hg) (μg/L)	--	--	.0	--	--	--
Dissolved zinc (as Zn) (μg/L)	--	--	0	--	--	--

TABLE 6.--Water-quality data, Pilchuck Creek near Ozette (station 12043159)

[Milligrams per liter unless otherwise indicated]

Date of collection	4/20/76	6/2/76	8/25/76	11/17/76	1/18/77	3/23/77	11/3/77
Mean daily discharge (ft^3/s)	--	--	--	--	--	--	--
Specific conductance (µmho/cm at 25°C)	40	48	65	46	38	68	55
pH (units)	6.5	6.7	7.2	6.5	6.9	6.8	6.5
Temperature (°C)	8.5	9.0	14.5	10.2	7.8	6.4	7.0
Turbidity (Jtu)	4	2	--	35	10	10	2
Dissolved oxygen (DO)	11.5	10.4	9.0	9.5	10.8	10.5	10.5
Immediate coliform (col/100 mL)	35	--	870	3700	1500	--	230
Fecal coliform (col/100 mL)	12	--	36	130	6	--	44
Hardness as $CaCO_3$ (Ca, Mg)	18	--	21	--	--	--	--
Noncarbonate hardness	7	--	2	--	--	--	--
Dissolved calcium (Ca)	4.7	--	5.5	--	--	--	--
Dissolved magnesium (Mg)	1.5	--	1.8	--	--	--	--
Dissolved sodium (Na)	3.9	--	4.9	--	--	--	--
Dissolved potassium (K)	.6	--	.6	--	--	--	--
Bicarbonate (HCO_3)	13	--	23	--	--	--	--
Total alkalinity (as $CaCO_3$)	11	--	19	--	--	--	--
Dissolved sulfate (SO_4)	4.6	--	5.7	--	--	--	--
Dissolved chloride (Cl)	5.4	--	5.7	--	--	--	--
Total nitrate (as N)	.00	--	.01	--	--	--	--
Total nitrite (as N)	.01	--	.00	--	--	--	--
Total nitrite plus nitrate (as N)	--	--	--	--	--	--	.24
Total ammonia nitrogen (as N)	.12	--	.06	--	--	--	.06
Total Kjeldahl nitrogen (as N)	.22	--	.21	--	--	--	.27
Total phosphorus (as P)	.02	--	.04	--	--	--	
Dissolved orthophosphate phosphorus (as P)	.01	--	.01	--	--	--	--
Dissolved chromium (as Cr) (µg/L)	--	--	0	--	--	--	--
Dissolved copper (as Cu) (µg/L)	--	--	1	--	--	--	--
Dissolved lead (as Pb) (µg/L)	--	--	2	--	--	--	--
Total mercury (as Hg) (µg/L)	--	--	.0	--	--	--	--
Dissolved zinc (as Zn) (µg/L)	--	--	0	--	--	--	--

TABLE 7.--Water-quality data, Sooes River below Miller Creek near Ozette (station 12043163)
[Milligrams per liter unless otherwise indicated]

Date of collection	6/30/71	4/20/76	6/2/76	8/25/76	11/17/76	1/18/77	3/23/77
Mean daily discharge (ft^3/s)	--	230	144	49	870	1,430	230
Specific conductance (µmho/cm at 25°C)	72	41	53	75	45	39	55
pH (units)	7.2	6.5	7.2	7.3	7.1	6.9	7.1
Temperature (°C)	--	7.0	9.2	15.3	10.6	8.0	6.8
Turbidity (Jtu)	--	7	2	--	22	45	15
Dissolved oxygen (DO)	--	12.0	11.2	9.7	10.3	10.1	11.1
Immediate coliform (col/100 mL)	--	43	--	670	5400	1400	--
Fecal coliform (col/100 mL)	--	7	--	92	200	9	--
Hardness as $CaCO_3$ (Ca, Mg)	22	15	--	25	--	--	--
Noncarbonate hardness	0	3	--	1	--	--	--
Dissolved calcium (Ca)	6.2	4.0	--	6.7	--	--	--
Dissolved magnesium (Mg)	1.7	1.3	--	2.0	--	--	--
Dissolved sodium (Na)	--	3.8	--	4.9	--	--	--
Dissolved potassium (K)	--	.5	--	.5	--	--	--
Bicarbonate (HCO_3)	33	15	--	29	--	--	--
Total alkalinity (as $CaCO_3$)	--	12	--	24	--	--	--
Dissolved sulfate (SO_4)	4.0	3.1	--	5.8	--	--	--
Dissolved chloride (Cl)	--	5.1	--	5.3	--	--	--
Total nitrate (as N)	.04	.01	--	.01	--	--	--
Total nitrite (as N)	--	.01	--	.00	--	--	--
Total nitrite plus nitrate (as N)	--	--	--	--	--	--	--
Total ammonia nitrogen (as N)	--	.12	--	.04	--	--	--
Total Kjeldahl nitrogen (as N)	--	.26	--	.19	--	--	--
Total phosphorus (as P)	--	.03	--	.01	--	--	--
Dissolved orthophosphate phosphorus (as P)	--	.01	--	.00	--	--	--
Dissolved chromium (as Cr) (µg/L)	--	--	--	0	--	--	--
Dissolved copper (as Cu) (µg/L)	6	--	--	1	--	--	--
Dissolved lead (as Pb) (µg/L)	--	--	--	6	--	--	--
Total mercury (as Hg) (µg/L)	--	--	--	.0	--	--	--
Dissolved zinc (as Zn) (µg/L)	20	--	--	0	--	--	--

TABLE 8.--Water-quality data, Waatch River below Educket Creek at Neah Bay (station 12043173)

[Milligrams per liter unless otherwise indicated]

Date of collection	4/20/76	6/2/76	8/25/76	11/16/76	1/18/77	3/22/77	11/2/77
Mean daily discharge (ft^3/s)	--	37	13	146	450	70	165
Specific conductance (µmho/cm at 25°C)	37	47	60	51	44	38	50
pH (units)	6.6	6.9	7.1	7.0	7.3	6.9	6.3
Temperature (°C)	5.5	7.2	11.1	9.9	7.8	7.0	8.0
Turbidity (Jtu)	4	1	--	2	8	1	1
Dissolved oxygen (DO)	11.9	11.8	10.0	10.7	11.5	10.3	11.3
Immediate coliform (col/100 mL)	4	280	560	1000	400	--	100
Fecal coliform (col/100 mL)	1	24	25	31	18	--	6
Hardness as $CaCO_3$ (Ca, Mg)	19	--	--	--	--	--	--
Noncarbonate hardness	9	--	--	--	--	--	--
Dissolved calcium (Ca)	5.7	--	--	--	--	--	--
Dissolved magnesium (Mg)	1.1	--	--	--	--	--	--
Dissolved sodium (Na)	3.8	--	5.1	--	--	--	--
Dissolved potassium (K)	.4	--	.4	--	--	--	--
Bicarbonate (HCO_3)	12	--	20	--	--	--	--
Total alkalinity (as $CaCO_3$)	10	--	16	--	--	--	--
Dissolved sulfate (SO_4)	4.3	--	6.3	--	--	--	--
Dissolved chloride (Cl)	6.6	--	5.9	--	--	--	--
Total nitrate (as N)	.15	--	.15	--	--	--	--
Total nitrite (as N)	.01	--	.00	--	--	--	--
Total nitrite plus nitrate (as N)	--	--	--	--	--	--	.69
Total ammonia nitrogen (as N)	.07	--	.03	--	--	--	.07
Total Kjeldahl nitrogen (as N)	.17	--	.11	--	--	--	.20
Total phosphorus (as P)	.02	--	.01	--	--	--	--
Dissolved orthophosphate phosphorus (as P)	.00	--	.01	--	--	--	--
Dissolved chromium (as Cr) (µg/L)	--	--	--	--	--	--	--
Dissolved copper (as Cu) (µg/L)	--	--	--	--	--	--	--
Dissolved lead (as Pb) (µg/L)	--	--	--	--	--	--	--
Total mercury (as Hg) (µg/L)	--	--	--	--	--	--	--
Dissolved zinc (as Zn) (µg/L)	--	--	--	--	--	--	--

TABLE 9.--Water-quality data, Waatch River at Neah Bay (station 12043176)

[Milligrams per liter unless otherwise indicated]

Date of collection	4/20/76	6/2/76	8/25/76[a]	11/17/76	1/18/77	3/22/77	11/2/77
Mean daily discharge (ft^3/s)	--	--	--	--	--	--	--
Specific conductance (µmho/cm at 25°C)	41	81	--	61	51	72	65
pH (units)	6.2	7.1	7.3	6.6	6.7	6.8	6.1
Temperature (°C)	5.5	8.8	12.0	9.4	8.2	7.0	8.3
Turbidity (Jtu)	3	1	--	4	3	1	2
Dissolved oxygen (DO)	11.6	11.8	9.0	10.6	11.2	10.9	10.5
Immediate coliform (col/100 mL)	50	1400	660	900	580	--	160
Fecal coliform (col/100 mL)	5	62	64	72	19	--	3
Hardness as $CaCO_3$ (Ca, Mg)	15	--	49	--	--	--	--
Noncarbonate hardness	6	--	30	--	--	--	--
Dissolved calcium (Ca)	3.2	--	7.4	--	--	--	--
Dissolved magnesium (Mg)	1.8	--	7.3	--	--	--	--
Dissolved sodium (Na)	4.4	--	56	--	--	--	--
Dissolved potassium (K)	.4	--	2.6	--	--	--	--
Bicarbonate (HCO_3)	11	--	23	--	--	--	--
Total alkalinity (as $CaCO_3$)	9	--	19	--	--	--	--
Dissolved sulfate (SO_4)	4.2	--	18	--	--	--	--
Dissolved chloride (Cl)	6.5	--	97	--	--	--	--
Total nitrate (as N)	.14	--	.15	--	--	--	--
Total nitrite (as N)	.01	--	.00	--	--	--	--
Total nitrite plus nitrate (as N)	--	--	--	--	--	--	.54
Total ammonia nitrogen (as N)	.08	--	.05	--	--	--	.12
Total Kjeldahl nitrogen (as N)	.22	--	.16	--	--	--	.26
Total phosphorus (as P)	.02	--	.02	--	--	--	--
Dissolved orthophosphate phosphorus (as P)	.01	--	.02	--	--	--	--
Dissolved chromium (as Cr) (µg/L)	--	--	--	--	--	--	--
Dissolved copper (as Cu) (µg/L)	--	--	--	--	--	--	--
Dissolved lead (as Pb) (µg/L)	--	--	--	--	--	--	--
Total mercury (as Hg) (µg/L)	--	--	--	--	--	--	--
Dissolved zinc (as Zn) (µg/L)	--	--	--	--	--	--	--

[a] Sample is a mixture of freshwater and saltwater. The saltwater migrated upstream at high tide.

TABLE 10.--Water-quality data, Village Creek at Neah Bay (station 12043186)
[Milligrams per liter unless otherwise indicated]

Date of collection	4/21/76	6/2/76	8/25/76	11/16/76	1/17/77	3/22/77	11/2/77
Mean daily discharge (ft^3/s)	--	--	--	--	--	--	--
Specific conductance (µmho/cm at 25°C)	40	51	65	46	43	50	53
pH (units)	6.7	6.8	7.3	6.4	7.7	6.7	6.9
Temperature (°C)	6.5	7.5	10.8	10.0	8.0	7.0	8.2
Turbidity (Jtu)	1	1	--	5	7	1	1
Dissolved oxygen (DO)	--	11.4	9.1	11.4	11.5	11.4	11.1
Immediate coliform (col/100 mL)	40	370	340	180	82	--	92
Fecal coliform (col/100 mL)	2	4	16	11	<1	--	6
Hardness as $CaCO_3$ (Ca, Mg)	18	--	--	--	--	--	--
Noncarbonate hardness	9	--	--	--	--	--	--
Dissolved calcium (Ca)	4.6	--	--	--	--	--	--
Dissolved magnesium (Mg)	1.5	--	--	--	--	--	--
Dissolved sodium (Na)	4.2	--	5.1	--	--	--	--
Dissolved potassium (K)	.3	--	.4	--	--	--	--
Bicarbonate (HCO_3)	11	--	15	--	--	--	--
Total alkalinity (as $CaCO_3$)	9	--	12	--	--	--	--
Dissolved sulfate (SO_4)	3.8	--	6.7	--	--	--	--
Dissolved chloride (Cl)	6.6	--	6.5	--	--	--	--
Total nitrate (as N)	.02	--	.03	--	--	--	--
Total nitrite (as N)	.00	--	.00	--	--	--	--
Total nitrite plus nitrate (as N)	--	--	--	--	--	--	.22
Total ammonia nitrogen (as N)	.05	--	.03	--	--	--	.03
Total Kjeldahl nitrogen (as N)	.18	--	.17	--	--	--	.10
Total phosphorus (as P)	.01	--	.01	--	--	--	--
Dissolved orthophosphate phosphorus (as P)	.00	--	.01	--	--	--	--
Dissolved chromium (as Cr) (µg/L)	--	--	--	--	--	--	--
Dissolved copper (as Cu) (µg/L)	--	--	--	--	--	--	--
Dissolved lead (as Pb) (µg/L)	--	--	--	--	--	--	--
Total mercury (as Hg) (µg/L)	--	--	--	--	--	--	--
Dissolved zinc (as Zn) (µg/L)	--	--	--	--	--	--	--

TABLE 11.--Water-quality data, Sail River near Neah Bay (station 12043190)

[Milligrams per liter unless otherwise indicated]

Date of collection	6/30/71	4/19/76	6/2/76	8/25/76	11/16/76	1/17/77	3/22/77	11/2/77
Mean daily discharge (ft^3/s)	--	--	17	5.2	70	186	39	153
Specific conductance (µmho/cm at 25°C)	74	42	45	72	56	48	47	50
pH (units)	8.4	6.6	6.6	7.6	6.8	7.7	7.0	7.5
Temperature (°C)	--	7.4	8.9	10.8	12.2	8.0	7.2	8.0
Turbidity (Jtu)	--	6	5	--	2	6	1	1
Dissolved oxygen (DO)	--	12.0	11.6	--	10.8	11.9	11.5	10.3
Immediate coliform (col/100 mL)	--	8	220	800	--	150	--	120
Fecal coliform (col/100 mL)	--	<1	79	8	--	<1	--	<3
Hardness as $CaCO_3$ (Ca, Mg)	18	16	--	--	--	--	--	--
Noncarbonate hardness	0	4	--	--	--	--	--	--
Dissolved calcium (Ca)	4.9	5.1	--	--	--	--	--	--
Dissolved magnesium (Mg)	1.5	.9	--	--	--	--	--	--
Dissolved sodium (Na)	--	4.2	--	6.1	--	--	--	--
Dissolved potassium (K)	--	.4	--	.4	--	--	--	--
Bicarbonate (HCO_3)	24	15	--	21	--	--	--	--
Total alkalinity (as $CaCO_3$)	12	12	--	17	--	--	--	--
Dissolved sulfate (SO_4)	7.0	4.0	--	8.7	--	--	--	--
Dissolved chloride (Cl)	--	4.0	--	4.5	--	--	--	--
Total nitrate (as N)	.26	.07	--	.26	--	--	--	--
Total nitrite (as N)	--	.01	--	.00	--	--	--	--
Total nitrite plus nitrate (as N)	--	--	--	--	--	--	--	.63
Total ammonia nitrogen (as N)	--	.06	--	.03	--	--	--	.05
Total Kjeldahl nitrogen (as N)	--	.12	--	.20	--	--	--	.20
Total phosphorus (as P)	--	.02	--	.01	--	--	--	--
Dissolved orthophosphate phosphorus (as P)	--	.00	--	.01	--	--	--	--
Dissolved chromium (as Cr) (µg/L)	--	--	--	--	--	--	--	--
Dissolved copper (as Cu) (µg/L)	11	--	--	--	--	--	--	--
Dissolved lead (as Pb) (µg/L)	--	--	--	--	--	--	--	--
Total mercury (as Hg) (µg/L)	--	--	--	--	--	--	--	--
Dissolved zinc (as Zn) (µg/L)	40	--	--	--	--	--	--	--

Sediment Transport

Suspended-sediment data were collected at three sites on the Makah Indian Reservation and at three sites in the Sooes River basin south of the reservation (fig. 1, table 1) to estimate the sediment transport on the reservation. No sediment samples were collected on the Ozette River because of the effect of Ozette Lake on the sediment discharge and yield of that river. The reconnaissance nature of the sediment study necessitated the extrapolation and interpolation of the data collected. The methods used in this study for the collection and the analysis of suspended-sediment samples are described by Guy and Norman (1970) and Guy (1969), respectively.

Sooes and Waatch Rivers.--The relations of suspended-sediment concentrations to water discharge (streamflow), depicted in figures 8 and 9, were determined largely from data collected from December 1978 to March 1979 at stations 12043163 and 12043173 (fig. 1). Using these relations and the streamflow records for the period April 1976-March 1979, the suspended-sediment transport at the two stations was estimated to be as follows:

	Suspended sediment			
	Sooes River (12043163)		Waatch River (12043173)	
Period	Discharge (tons)	Yield (tons/mi^2)	Discharge (tons)	Yield (tons/mi^2)
April-September 1976	200	6.2	40	4.0
October 1976-March 1977	3,800	120	480	48
April-September 1977	100	3.1	30	3.0
October 1977-March 1978	10,600	330	1,120	110
April-September 1978	600	19	100	10
October 1978-March 1979	3,700	120	640	64

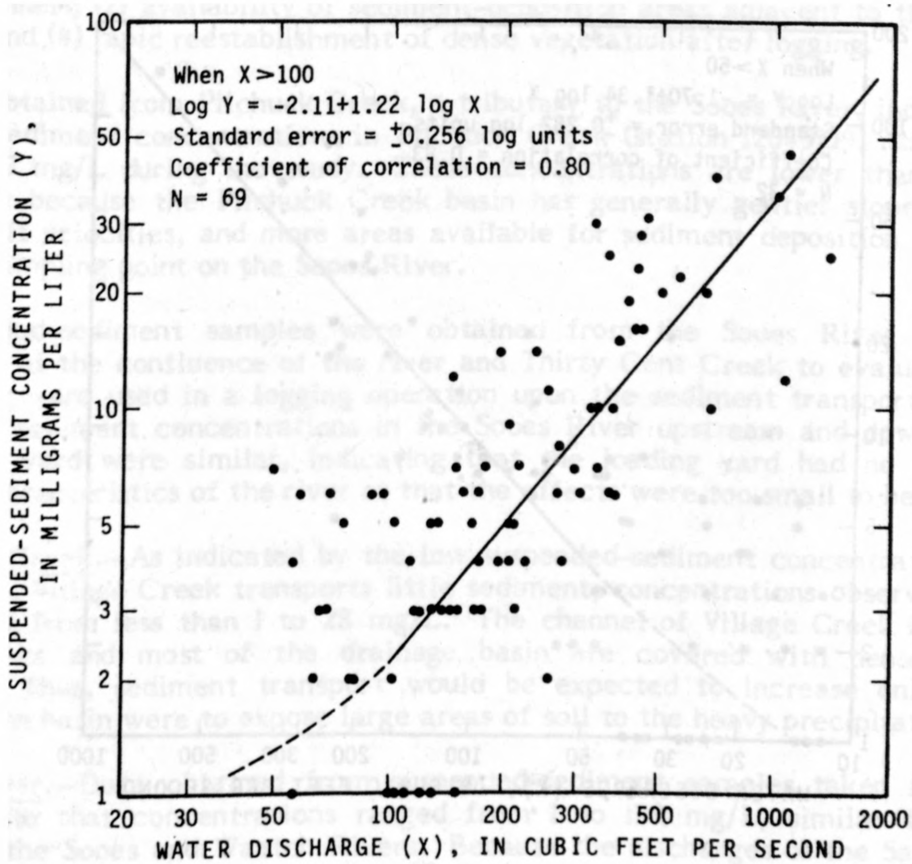


FIGURE 8.--Relation of suspended-sediment concentration to water discharge, Sooes River below Miller Creek, near Ozette.

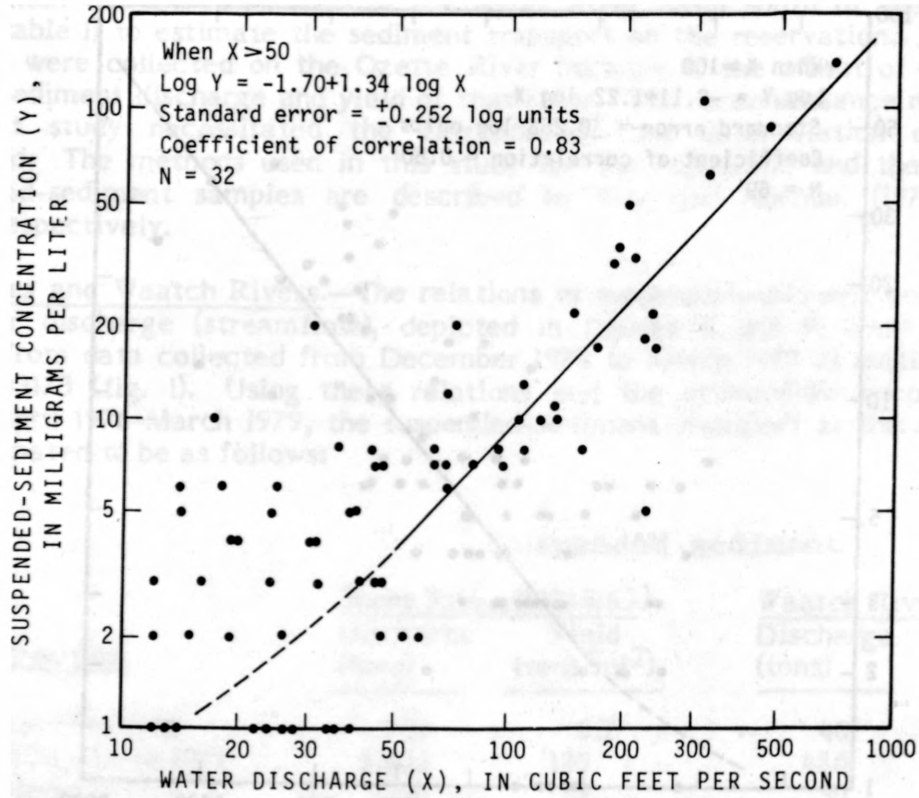


FIGURE 9.--Relation of suspended-sediment concentration to water discharge, Waatch River below Educket Creek at Neah Bay.

The suspended-sediment concentrations during the study ranged from less than 1 to 200 mg/L in both the Sooes and Waatch Rivers. These low concentrations suggest that the quantities of sediment available for transport in the basins of the two rivers are small. Even though logging has occurred in the drainage basins of both rivers upstream of the sampling points, the sedment transport has remained low because of: (1) stable stream channels; (2) availability of sediment-deposition areas adjacent to the streams; (3) thin soils; and (4) rapid reestablishment of dense vegetation after logging.

Data obtained from Pilchuck Creek, a tributary to the Sooes River, indicate that the suspended-sediment concentrations in Pilchuck Creek (station 12043159) ranged from less than 1 to 79 mg/L during the study. These concentrations are lower than those in the Sooes River because the Pilchuck Creek basin has generally gentler slopes, less runoff, slower runoff velocities, and more areas available for sediment deposition than the basin above the sampling point on the Sooes River.

Suspended-sediment samples were obtained from the Sooes River upstream and downstream of the confluence of the river and Thirty Cent Creek to evaluate the effect of a loading yard used in a logging operation upon the sediment transport of the Sooes River. The sediment concentrations in the Sooes River upstream and downstream from the loading yard were similar, indicating that the loading yard had no effect on the sediment characteristics of the river or that the effects were too small to be detected.

Village Creek.—As indicated by the low suspended-sediment concentrations observed in this study, Village Creek transports little sediment; concentrations observed during the study ranged from less than 1 to 28 mg/L. The channel of Village Creek is very stable, and the banks and most of the drainage basin are covered with dense growths of vegetation. Thus, sediment transport would be expected to increase only if land-use changes in the basin were to expose large areas of soil to the heavy precipitation.

Sail River.—Data obtained from suspended-sediment samples taken from the Sail River indicate that concentrations ranged from 1 to 179 mg/L, similar to the ranges observed in the Sooes and Waatch Rivers. Because the discharges of the Sail and Waatch are similar, the sediment transport of the Sail River is probably similar to that of the Waatch River (p. 32). The discharge of the Sooes River, however, is generally about five times greater than that of the Sail River; the sediment transport of the Sail River would therefore be expected to be much less than that of the Sooes River.

Logging activity in the drainage basin of the Sail River, if it occurred, would probably cause large increases in the sediment load of that stream because of the presence of easily eroded soils. These increases would most likely be temporary because of the rapid recovery of vegetation after logging ceased.

GROUND-WATER RESOURCES

Occurrence

The Makah Indian Reservation is underlain in most places by massive sandstone, shale, and conglomerate. These rocks are well cemented and not characterized by cracks and joints, hence they are essentially devoid of water.

A narrow ridge of basalt forms the western margin of the low hills that extend from near the mouth of the Waatch River to beyond the southeast corner of the reservation (fig. 1). Similar rocks in other areas of western Washington yield moderate quantities of water to wells, but the water-yielding capabilities of the rocks beneath the reservation have not been determined because of inaccessibility.

Known occurrences of ground water in significant quantities on the reservation are limited to sand-and-gravel layers incorporated in thicker clay and silt deposits that underlie the lowland areas. Although such unconsolidated deposits also occur at altitudes as much as 650 feet above sea level at some places on the reservation, these types of deposits, where the land surface is more than about 100 feet above sea level, are generally too thin or too limited in areal extent to contain significant aquifers (water-yielding materials). Lowland areas of the reservation where significant aquifers occur are outlined in figure 10.

Numerous wells and test holes have been drilled in the lowland of the Waatch River and Educket Creek drainages, but none has been capable of producing water of good quality in large amounts. The most productive known aquifers in the area are generally at depths of 25 to 65 feet and occur within about 1,000 feet of the southern shoreline of Neah Bay, between Baada Point and the mouth of Village Creek. These aquifers are composed of sand with some gravel (table 12), contain numerous shell fragments, and probably are in ancient beach deposits. Yields of wells tapping these aquifers range generally from 5 to 90 gal/min. Several wells that tap this aquifer system initially produced brackish water--or water with some other objectionable taste and odor--and were never put into service; others were used but abandoned after water of better quality became available.

The area between the Makah Air Force Station and the Neah Bay townsite is underlain by clay, silt, fine sand, and decomposed gravel that were deposited by the Waatch River and Educket Creek. There, stream-deposited materials are considerably less permeable than the beach deposits near Neah Bay or materials in the Sooes River lowland (fig. 10). In fact, few wells in the Waatch River-Educket Creek lowland have produced significant quantities of potable water. There is a flowing well (33/15W-16R1) in the area, but little information is available concerning it. It reportedly is "deep" and is capable of yielding a significant quantity of water. However, the water from this well contains more than 500 mg/L of chloride and is too salty for most uses.

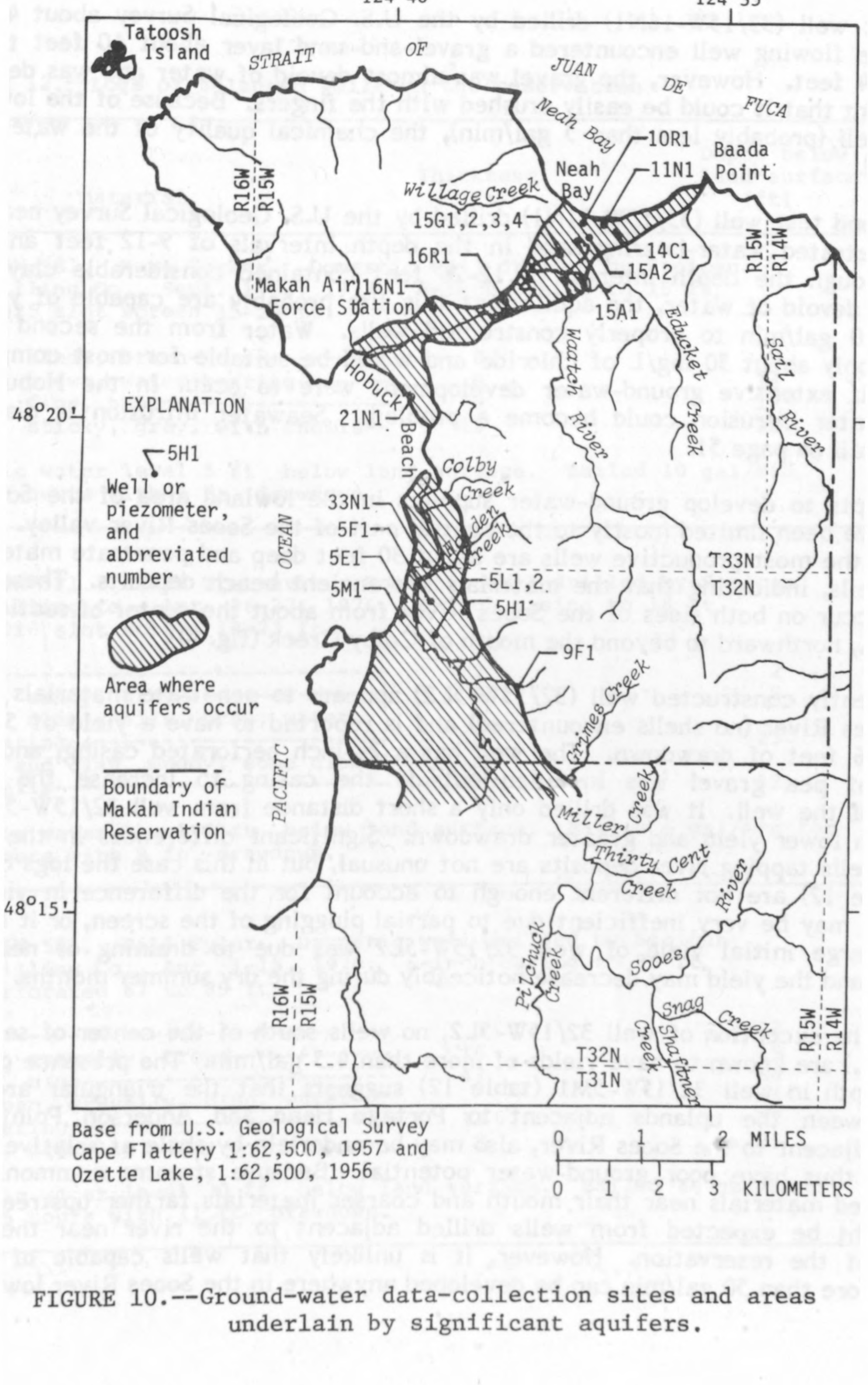


FIGURE 10.--Ground-water data-collection sites and areas underlain by significant aquifers.

A test well (33/15W-16N1) drilled by the U.S. Geological Survey about 4,500 feet west of the flowing well encountered a gravel-and-sand layer about 10 feet thick at a depth of 84 feet. However, the gravel was almost devoid of water and was decomposed to the extent that it could be easily crushed with the fingers. Because of the low yield of the test well (probably less than 5 gal/min), the chemical quality of the water was not determined.

A second test well (33/15W-21N1) drilled by the U.S. Geological Survey near Hobuck Beach penetrated water-bearing sand in the depth intervals of 9-12 feet and 26-27.5 feet. Although the depth interval of 12-26 feet contained considerable clay and was essentially devoid of water, the aquifers at this site probably are capable of yielding as much as 10 gal/min to properly constructed wells. Water from the second test well contained only about 50 mg/L of chloride and would be suitable for most common uses. However, if extensive ground-water development were to occur in the Hobuck Beach area, seawater intrusion could become a problem. Seawater intrusion is discussed in greater detail on page 51.

Attempts to develop ground-water supplies in the lowland area of the Sooes River (fig. 10) have been limited mostly to the central part of the Sooes River valley. With one exception, the most productive wells are about 30 feet deep and penetrate materials that contain shells, indicating that the materials are ancient beach deposits. These deposits probably occur on both sides of the Sooes River from about the center of section 5, T.32 N., R.15 W., northward to beyond the mouth of Colby Creek (fig. 10).

A recently constructed well (32/15W-5L2) appears to penetrate materials deposited by the Sooes River (no shells encountered) and is reported to have a yield of 50 gal/min with only 6 feet of drawdown. The well has a 24-inch perforated casing, and a 6-inch envelope of pea gravel was installed outside the casing to increase the effective diameter of the well. It was drilled only a short distance from well 32/15W-5L1, which has a much lower yield and greater drawdown. Significant differences in the yields of adjacent wells tapping river deposits are not unusual, but in this case the logs of the two wells (table 12) are not different enough to account for the difference in yield. Well 32/15W-5L1 may be very inefficient due to partial plugging of the screen, or it is possible that the large initial yield of well 32/15W-5L2 was due to draining of near-surface materials, and the yield may decrease noticeably during the dry summer months.

With the exception of well 32/15W-5L2, no wells south of the center of sec. 5 (T.32 N., R.15 W.) are known to have yields of more than 4.5 gal/min. The presence of shale at shallow depth in well 32/15W-5M1 (table 12) suggests that the triangular area to the south, between the uplands adjacent to Portage Head and Anderson Point and the lowlands adjacent to the Sooes River, also may be underlain by shale at relatively shallow depth and thus have poor ground-water potential. Because streams commonly deposit finer grained materials near their mouth and coarser materials farther upstream, higher yields might be expected from wells drilled adjacent to the river near the southern boundary of the reservation. However, it is unlikely that wells capable of sustained yields of more than 50 gal/min can be developed anywhere in the Sooes River lowland.

TABLE 12.--Logs of selected wells on the reservation

Material	Thickness (ft)	Depth below land surface (ft)
32/15W-5E1. Nora Barker. Domestic well drilled by Stoican Drilling Co., Sept. 1-22, 1977. 6-inch casing to 15 ft, 0.025 slot screen 15-20 ft.		
Clay, sandy, brown----------------	8	8
Silt, brown, water-bearing-------	6	14
Sand, fine, brown----------------	3	17
Clay, sticky, gray, with shells--	13	30
Static water level 5 ft below land surface. Bailed 10 gal/min for 2 hours with 9 ft drawdown.		
32/15W-5F1. Lewis Trettevik. Domestic well drilled by Stoican Drilling Co., Apr. 26-27, 1976. 6-inch casing to 18 ft, 0.016 slot screen 18-23 ft.		
Soil----------------------------	2	2
Clay, sandy, gray----------------	6	8
Sand, clam shells, gray, water-bearing------------------------	15	23
Sand and clay, muddy, some clam shells------------------------	9	32
Static water level 5 ft below land surface. Bailed 6 gal/min for 1½ hours with 9 ft drawdown.		
32/15W-5H1. Bill Tyler. Domestic well drilled by Stoican Drilling Co., Aug. 1-15, 1976. 6-inch casing to 85 ft, perforated 67 to 85 ft.		
Fill----------------------------	3	3
Clay, gravelly, brown------------	16	19
Clay, blue-----------------------	47	66
Hardpan, gravelly, blue, water-bearing------------------------	11	77
Clay, gravelly, gray-------------	8	85
Static water level 30 ft below land surface. Bailed 4½ gal/min for 6 hours with 11 ft drawdown.		

TABLE 12.--Logs of selected wells on the reservation--continued

Material	Thickness (ft)	Depth below land surface (ft)
32/15W-5L1. Gene Ray. Domestic well drilled by Stoican Drilling Co., Aug. 11-14, 1976. 6-inch casing to 46 ft, 0.018 slot screen 46-51 ft.		
Surface soil	1	1
Clay, brown	7	8
Clay, silty, blue	42	50
Clay, gravelly, gray	3	53
Clay, blue	13	66
Well flows. Bailed 4½ gal/min for about 1¼ hours with 51 ft, drawdown (well bailed dry).		
32/15W-5L2. Gene Ray. Domestic well bored by Slead Const. Co., Oct. 27, 1977. 24-inch casing to 56 ft, perforated 46 to 56 ft. Gravel-packed with pea gravel 20-56 ft.		
Clay, silty, brown	5	5
Clay, blue, and sand	20	25
Clay, blue	11	36
Clay, blue, and sand	4	40
Clay, blue	14	54
Clay, blue, and gravel	2	56
Well flows. Pumped about 50 gal/min for 2 hours with 6 ft drawdown.		
32/15W-5M1. Matilda Flinn. Domestic well drilled by Stoican Drilling Co., Sept. 28-30, 1977. 6-inch casing.		
Soil, brown	4	4
Clay, gravelly, brown	8	12
Shale, gray	73	85
No water, casing removed and well destroyed.		

TABLE 12.--Logs of selected wells on the reservation--continued

Material	Thickness (ft)	Depth below land surface (ft)
32/15W-9F1. Ben Cheeka. Domestic well drilled by Stoican Drilling Co., Sept. 22-27, 1977. 6-inch casing.		
Clay, gravelly, brown----------	6	6
Clay, brown--------------------	5	11
Gravel, cemented, brown---------	12	23
Clay, gravelly, gray-----------	21	44
Shale, gray--------------------	56	100
No water, casing removed and well destroyed.		
33/15W-10R1. Bay Fish Co. Industrial well drilled by H.F. Mykol, 1952. 6-inch casing.		
Soil---------------------------	1½	1½
Sand, fine, black---------------	10	11½
Gravel, clean, pea size---------	20	31½
Gravel and shells---------------	5½	37
Static water level about 9 ft below land surface. Pumped 19 gal/min with 12 ft drawdown. Water "brackish" well destroyed.		
33/15W-11N1. Fishermans Coop Association. Industrial well drilled by H. F. Mykol, Feb. 1952. 6-inch casing.		
Silt---------------------------	5	5
Clay, sandy--------------------	1	6
Sand---------------------------	32	38
Static water level about 2½ ft below land surface.		

TABLE 12.--Logs of selected wells on the reservation--continued

Material	Thickness (ft)	Depth below land surface (ft)
33/15W-14C1. Test well. Drilled by A.L. Nicholsen, Feb. 1953. 6-inch casing to 52 ft.		
Sand, medium, brown; with some rounded pebbles----------	23	23
Sand, medium to coarse, contains shell fragments------	10	33
Shale, dark blue-gray-----------	19	52
Static water level 2½ ft below land surface. Pumped about 5 gal/min. Water had objectionable taste and odor, well destroyed.		
33/15W-15A1. U.S. Department of Health. Public Supply well drilled by Stoican Drilling Co., July 1961. 6-inch casing to 35 ft, 0.030 slot screen 35-45 ft.		
Sand and silt, dark brown-------	4	4
Sand, medium, brown, with clay--	12	16
Sand, medium, brown, some shells, water-bearing-----------------	8	24
Sand, medium, gravel and sea shells bailed 30 gal/min-------	5	29
Clay and gravel, gray-----------	6	35
Sand, muddy, gray---------------	2	37
Sand, medium; and gravel, some shells, bailed 30 gal/min-----	13	50
Sand, medium, gray, shells------	12	62
Sand, fine, muddy, gray, and shells------------------------	7	69
Clay, gray----------------------	31	100
Casing pulled back and hole backfilled to 45 ft. Static water level about 8 ft below land surface. Pumped 50 gal/min for 2 hours with 19 ft drawdown. Well is now abandoned because of inferior water quality, and insufficient yield.		

TABLE 12.--Logs of selected wells on the reservation--continued

Material	Thickness (ft)	Depth below land surface (ft)
33/15W-15A2. U.S. Department of Health. Public Supply well drilled by Stoican Drilling Co., Aug. 1961. 8-inch casing to 40 ft, 0.030 slot screen 40-65 ft.		
Sand and silt, dark brown--------	4	4
Sand, medium, brown; some clay---	12	16
Sand, medium, brown, some shells water-bearing------------------	8	24
Sand, medium, brown, and gravel, some shells-------------------	5	29
Clay, and gravel-----------------	8	37
Sand, gray, muddy----------------	3	40
Sand, medium; and gravel, water-bearing------------------	14	54
Sand, medium, gray, with shells--	9	63
Sand, fine, gray, muddy, with shells-------------------------	2	65

Static water level 7½ ft below land surface. Pumped 92 gal/min for 12 hours with 22 ft drawdown. Well is now abandoned because of inferior water quality, and insufficient yield.

TABLE 12.--Logs of selected wells on the reservation--continued

Material	Thickness (ft)	Depth below land surface (ft)
33/15W-16N1. U.S. Geological Survey. Test well drilled by Stoican Drilling Co., Sept. 22-24, 1976. 6-inch casing to 102 ft.		
Fill material-------------------	4	4
Sand, fine, muddy, gray----------	14	18
Sand, fine, muddy, shell fragments---------------------	9	27
Clay, blue gray; and very fine sand, shell fragments---------	43	70
Clay, blue, sticky, some wood, shell fragments, and pebbles--	5	75
Clay, blue, sticky, much wood, roots, peat, and shell fragments---------------------	9	84
Gravel, mostly rounded, rotten, easily crushed with fingers, contained a 1-foot zone that appeared to produce a little water-------------------------	3	87
Gravel and sand, rotten; and clay. Clay increased with depth. No evidence of water-------------------------	5	92
Gravel and sand; contained less clay than above, no evidence of water----------------------	2½	94½
Clay, some large gravel---------	4½	99
Rock, hard, black, no water-----	13	112

Static water level 3.5 ft below land surface.

TABLE 12.--Logs of selected wells on the reservation--continued

Material	Thickness (ft)	Depth below land surface (ft)
33/15W-21N1. U.S. Geological Survey. Test well drilled by Stoican Drilling Co., Sept. 20-21, 1976. 6-inch casing removed and well destroyed.		
Sand, silty, fine, dark brown-----	5	5
Sand, angular, fine, dark gray---	3	8
Sand, angular, fine, trace of clay, water at 9 ft -----------	4	12
Sand, fine, considerable clay and many shell fragments-------	14	26
Sand, fine to medium, blue gray, some gravel, shells, and wood--	1½	27½
Rock, broken, black; trace of clay------------------------	1	28½
Shale, clayey, very hard, black, non water-bearing--------------	6½	35
Static water level 9 ft below land surface.		
33/15W-33N1. Bruce Wilkie. Domestic well drilled by Stoican Drilling Co., May 1964. 6-inch casing to 31 ft perforated 24-29 ft.		
Soil-------------------------------	1	1
Sand, silty---------------------	22	23
Sand and gravel, shells----------	6	29
Sand, and fine gravel------------	2	31
Static water level 20 ft below land surface. Bailed 50 gal/min with 3 ft drawdown.		

Quality

Ground water underlying the Makah Indian Reservation is, in general, much more highly mineralized than the surface water. The specific conductance of surface-water samples ranged from 36 to 81 umho/cm and averaged 51 umho/cm (tables 4-11). By contrast, the specific conductance of ground-water samples ranged from 376 to 516 umho/cm and averaged 428 umho/cm (table 13).

The hardness of water is determined chiefly by the amount of calcium and magnesium present, and it noticeably affects the amount of soap required to form a lather. Hardness of water is commonly classified (Hem, 1970) as follows:

Hardness range (mg/L)	Classification
0-60	soft
61-120	moderately hard
121-180	hard
181 and greater	very hard

The three wells in the Waatch River-Educket Creek lowland for which hardness data are available yield water that is in or near the very-hard range. The two wells in the Sooes River lowland for which hardness data are available both yield soft water. The higher-than-average sodium content of water from the two wells in the Sooes River lowland suggests that perhaps some sort of natural water-softening process may take place there.

Wells now in use on the reservation produce water that meets the recommended drinking-water standards of the U.S. Environmental Protection Agency (1977a, 1977b). However, some wells that are not presently in use, or which have been destroyed, produced water in which the recommended limits for chloride, iron, and manganese concentrations were exceeded. Locally, ground water is colored by decomposing vegetation to the extent that it is undesirable for drinking.

Four shallow wells (piezometers) were installed by the U.S. Geological Survey in the vicinity of the Neah Bay sewage lagoon to provide data on the effect the lagoon might have on the local ground water and on the quality of water in the lower Waatch River. The piezometers range in depth from 8 to 16 feet, extend below the water table, and are located about 150 feet north, 50 feet south, 60 feet east, and 75 feet west of the lagoon. Figure 11 shows water-level fluctuations in the piezometers during a 9-month period in 1976 and 1977. During that period the water table sloped to the southeast and the movement of ground water was in that direction. Surface drainage in the area surrounding the lagoon is to the south, and water that was observed being discharged from the lagoon in January 1976 flowed through a swampy area and into a tributary of the Waatch River.

TABLE 13.--Quality of ground water on the reservation

				Milligrams per liter								Milligrams per liter			Micrograms per liter		
Well no.	Date sampled	Specific conductance (umho/cm)	Temperature (°F)	Total hardness	Non-carbonate hardness	Dissolved calcium	Dissolved magnesium	Dissolved sodium	Dissolved potassium	Bicarbonate	Carbonate	Dissolved sulfate	Dissolved chloride	Dissolved fluoride	Total nitrite plus nitrate	Iron	Manganese
32/15W-5H1	11-30-77	--	--	40	--	--	--	49	--	--	--	--	27	0.3	1.1	<50	14
-5L2	11-30-77	--	--	26	--	--	--	56	--	--	--	--	16	.5	.9	120	22
33/15W-10R1	5-16-52	516	--	244	24	--	--	--	--	268	0	--	26	.4	2.2	--	--
	2-27-53	466	50	--	--	--	--	--	--	--	--	--	--	--	--	110	--
-14C1	2-27-53	377	47	175	4	59	6.7	14	1.0	208	0	20	7	--	3.9	--	--
-16R1	9-23-76	--	--	--	--	--	--	--	--	--	--	--	550	--	--	--	--

(continued)

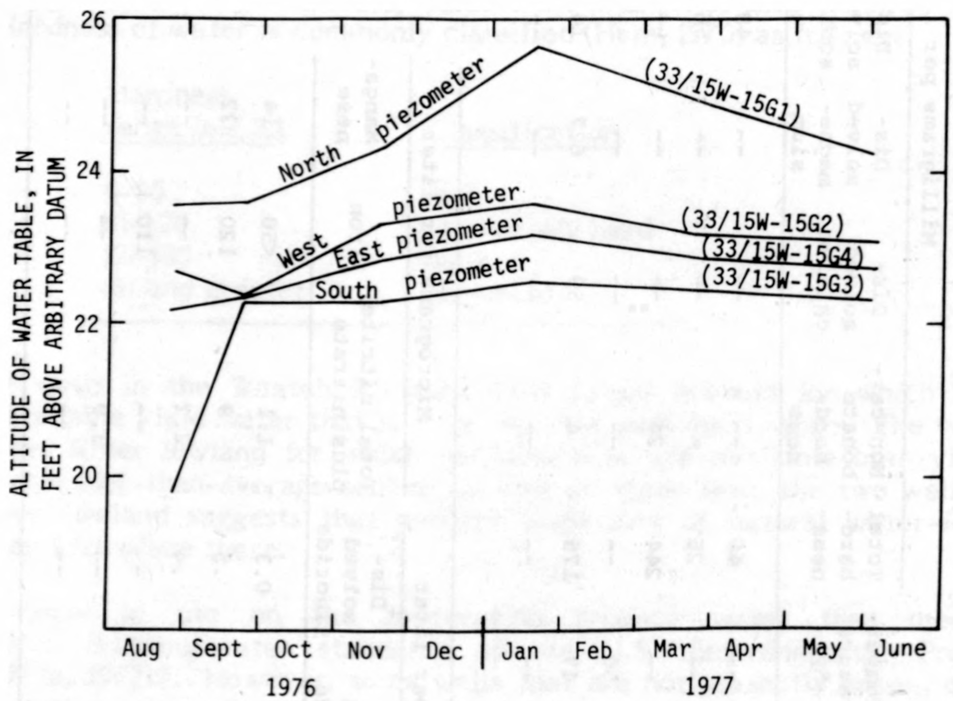


FIGURE 11.--Water levels in piezometers near the Neah Bay sewage lagoon, August 25, 1976-June 1, 1977.

Water contaminated by sewage commonly contains high concentrations of nutrients. Table 14 shows that the greatest concentrations of nutrients occurred in the piezometer that is north--upgradient--from the lagoon. This could be due to local variations in the permeability of surficial materials that cause water from the lagoon to move northward before it finally reaches the water table and moves southeastward. Or, it could be that (1) water from the piezometer west of the lagoon represents that of natural conditions, (2) water from the piezometers south and east of the lagoon is contaminated from the lagoon, and (3) contamination not directly related to the operation of the lagoon is indicated by water from the piezometer on the north.

The bacterial quality of water samples from the piezometers was evaluated by counting the number of colonies of coliform bacteria per 100 milliliters of water. The somewhat higher coliform count in water from the piezometer south of the lagoon (table 14) suggests contamination by sewage in that area.
Continued sampling and analysis of water from the piezometers over a period of several years would be necessary to adequately determine the probable long-term effects of the lagoon on ground- and surface-water supplies.

TABLE 14.--Water-quality data from piezometers near Neah Bay sewage lagoon

[Values in milligrams per liter unless otherwise indicated]

	Piezometer number and location from sewage lagoon			
	33/15W-15G1 North	33/15W-15G2 West	33/15W-15G3 South	33/15W-15G4 East
Date of collection	11/3/77	11/3/77	11/3/77	11/3/77
Time of collection	0650	0710	0730	0745
Temperature (°C)	10.0	10.0	10.0	10.0
Turbidity (Jtu)	3	2	20	15
Immediate coliform (col/100 mL)	<3	<3	36	<3
Total nitrite plus nitrate (as N)	.01	.01	.01	.01
Total ammonia nitrogen (as N)	.79	.02	.25	.27
Total organic nitrogen (as N)	.51	.08	.37	.23
Total Kjeldahl nitrogen (as N)	1.3	.10	.62	.50
Total nitrogen (as N)	1.3	.11	.63	.51
Total nitrogen (as NO_3)	5.8	.50	2.8	2.3

Seawater Intrusion

Brackish ground water has been a continuing problem on the reservation. Most of the wells that produced brackish water when first drilled were tapping seawater that was trapped in the aquifer materials when they were deposited under marine conditions. However, seawater intrusion due to excessive pumping is indicated when a well originally producing freshwater starts to produce saltwater. The collection of sufficient data to permit an accurate calculation of the potential for seawater intrusion under various conditions of ground-water development was beyond the scope of this investigation. However, the following information should be considered before closely spaced wells are installed in coastal areas of the reservation.

Seawater intrusion of coastal aquifers is most likely to occur during the dry summer months when ground-water withdrawal is greatest, recharge from precipitation is least, and ground-water levels are low. The latter two factors result, in part, from the average monthly evapotranspiration exceeding the precipitation. As estimated by a modified Blaney-Criddle analysis (U.S. Department of Agriculture, 1967), the following factors are considered:

(1) The period when evapotranspiration exceeds precipitation extends from about mid-May until mid-September. An additional month is required to replace the soil moisture that is depleted during the summer. Thus, recharge to the ground-water body is limited to the 7-month period mid-October to mid-May.

(2) In test well 33/15W-21N1 the water level was about 9 feet below land surface on September 21, 1976. Additional pumping of ground water in that area would lower the water table and remove water from storage in the fine sand between depths of 8 and 12 feet below land surface (table 12). According to Johnson (1967) this fine sand may have a specific yield of about 20 percent; that is, each cubic foot of material that is dewatered would yield 0.2 ft^3 of water, or 1.5 gallons. Lowering of the water level by 1 foot beneath one acre (43,560 ft^2) would yield 8,700 ft^3 (about 65,000 gallons) of water.

(3) The average daily domestic use of water per person in Washington is 125 gallons (Dion and Lum, 1977). A family of four would use 500 gal/day, or 75,000 gallons during the 5-month period of no recharge to the ground-water reservoir.

From the foregoing, each domestic well used by a family of four might be expected to lower the water level the equivalent of 1 foot under about 1.2 acres (about 0.12 foot under an average 10-acre land allotment) during the 5-month dry period. Somewhat greater lowering of the water level would be expected in areas where materials of lower specific yield are dewatered, but except under the most unfavorable conditions, this degree of development should not materially increase the hazard of seawater intrusion.

SUMMARY

The climate of the Makah Indian Reservation is characterized by warm, dry summers and cool, wet winters. The mean annual precipitation at Neah Bay is more than 99 inches and three-quarters of that amount occurs during the 6-month period October-March.

As might be expected in an area of abundant precipitation and mild winter temperatures, the discharges of streams in the study area are determined in large part by the amount of precipitation. Coefficients of the correlation of total monthly precipitation and monthly mean discharge for the Sooes, Waatch and Sail Rivers were 0.94, 0.96, and 0.95, respectively.

The surface waters of the reservation are generally of good quality and suitable for domestic (drinking) purposes after treatment to kill bacteria and removal of suspended solids. State water-quality standards were not met by most streams at certain times of the year because of excessive fecal-coliform bacteria and turbidity levels. None of the surface water had concentrations of chromium, copper, lead, mercury, or zinc that would make the water unfit for domestic water supplies, freshwater aquatic life, or livestock. Suspended-sediment concentrations were low in all streams sampled. A proposed water-quality monitoring program would require the bimonthly sampling and analysis of water in four selected streams for the characteristics that affect the well-being of fish.

Areas of the reservation where productive aquifers are known are the Waatch River-Educket Creek lowland and the Sooes River lowland. However, the yields of almost all wells drilled in these aquifers are small and many of the wells produced brackish or salty water. In addition, water from aquifers in the lower Waatch River-Educket Creek area is very hard.

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