QUALITY OF SURFACE AND GROUND WATERS,

YAKIMA INDIAN RESERVATION, WASHINGTON, 1973-74

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U.S. Geological Survey

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CONTENTS

Page

ILLUSTRATIONS

TABLES

METRIC CONVERSION FACTORS

The following factors are provided for conversion of English values used in this report to metric values:

Multiply	By	To obtain
Inches	25.4	millimeters (mm)
Feet (ft)	0.3048	meters (m)
Miles	1.609	kilometers (km)
Square miles (mi^2)	2.590	square kilometers (km^2)
Acres	4047.	square meters (m^2)
Acres	.004047	square kilometers (km^2)

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ABSTRACT

This report describes the quality of the surface and ground waters of the Yakima Indian Reservation in south-central Washington, during the period November 1973-October 1974.

The average dissolved-solids concentrations ranged from 48 to 116 mg/L (milligrams per liter) in the mountain streams, and from 88 to 372 mg/L in the lowland streams, drains, and a canal. All the mountain streams contain soft water (classified as 0-60 mg/L hardness as $CaCO_3$) and the lowland streams, drains, and canal contain soft to very hard water (more than 180 mg/L hardness as $CaCO_3$). The water is generally of suitable quality for irrigation, and neither salinity nor sodium hazards are a problem in waters from any of the streams studied.

Most of the surface waters maintain adequate concentrations of dissolved oxygen for healthy fish life, but Wanity Slough, Mud Lake Drain, and Outlet Creek exhibit a potential for inade-

quate dissolved-oxygen concentrations during the warm summer months.

At 13 of the 18 mountain stream sites and at all 11 of the lowland surface-water sites the total phosphorus concentrations were 0.05 mg/L or greater, indicating that phosphorus is not a limiting nutrient but is available in sufficient quantity to support abundant growth of aquatic vegetation, provided other nutrients and other physical factors are favorable. Water from all the mountain streams had average concentrations of less than the 0.3 mg/L nitrate (as N) generally considered necessary ~~for~~ to potentially cause excessive growth of aquatic vegetation. Eight of the lowland streams and drains had concentrations averaging more than 0.3 mg/L; irrigation return-flow waters are a significant portion of all these waters.

All the mountain streams studied, except Logy Creek and South Fork Simcoe Creek, were bacteriologically suitable for irrigation, recreational use and for raw source water for treated drinking-water supplies. Analyses of water in lowland streams, drains, and one canal ~~all~~ indicated their potential for exceeding the bacteriological criteria recommended by the Federal Water Pollution Control Administration for either primary or secondary recreation use, and in some ~~instances~~ places even for irrigation use.

The specific conductance of water from the major aquifers ranged from 20 to nearly 1,500 micromhos. Ground water was most dilute in mineral content in the Klickitat River basin and most concentrated in part of the Satus Creek basin. The ground water in the Satus Creek basin with the most concentrated mineral content also contained the highest percentage composition of sulfate, chloride, and nitrate. For drinking water, the nitrate-nitrogen concentrations exceeded the U.S. Public Health Service's recommended limit of 10 mg/L over an area of several square miles, with a maximum observed concentration of 170 mg/L.

Hardness concentrations of the ground waters from the major aquifers ranged from 8 to 480 mg/L (as $CaCO_3$). The ground water in the Klickitat River basin was mostly soft, and in the other three basins it ranged from soft to very hard. Most of the ground water is suitable for irrigation; it is low in sodium hazard and low to medium in salinity hazard.

All the major aquifers yield water whose average iron concentration is less than the recommended limit for drinking water, but at some locations the concentrations equal or exceed recommended limits. Average manganese concentrations are less than recommended limits for drinking water in all the major aquifers in the Klickitat River basin, but they exceed recommended limits in all the major aquifers in the Toppenish Creek basin and in the waters of one or more major aquifer in each of the other basins.

Most wells and springs were free from bacterial contamination, but eight springs and three wells had one or more fecal-coliform colonies per 100 milliliters of water. The presence of bacteria is considered to be highly localized.

INTRODUCTION

Purpose and Scope of the Study

This report describes the results of a study of the quality of surface and ground waters of the Yakima Indian Reservation. The study was made in cooperation with the Yakima Tribal Council to provide general water-quality information and to aid the council in water-resources management. The specific objectives of the study are to (1) evaluate the surface- and ground-water quality throughout the reservation, (2) determine the nature of existing or potential water-quality problems, and (3) define the water quality in terms of suitability for various uses. To the extent possible the data collected on surface-water quality for the other objectives ~~was~~ were related also to the suitability of the water for fish habitat.

Sequence of Discussion

To facilitate the Yakima Tribe's use of this report in future planning and management, it is divided into three parts. Part I summarizes the quality of surface and ground waters reservationwide. Parts II and III, by design, repeat much of the information in Part I, but on a basin-by-basin basis for more specific discussion of each basin; this allows greater usefulness of the report for future planning and management. Part II discusses surface-water quality by individual streams, including one canal and four drains, and Part III discusses ground-water quality for each water-yielding unit.

The report contains ~~a number of~~ tabulations of data collected during the study, along with a~~n~~ section ~~appendix~~ that discusses the general significance of various water-~~quality~~ ~~parameters and~~ criteria.

Data Collection

Surface-Water Sampling

This study was of 1-year duration during the period November 1973-October 1974. Of the 29 sampling sites in the surface-water quality network (pl. 1, in pocket), 18 were on mountain streams (3 intermittent), 6 were on lowland streams, 4 on drains, and 1 on a canal. The sites were selected as representative of anticipated water-quality extremes, summations of subbasins, and major points of use. The mountain streams are in forest or rangeland where the influence of man's activities is low, and restricted mostly to cattle grazing, logging and a few dwellings or small farms. The lowland streams, drains, and one canal (hereafter all referred to as lowland streams) are located in farmland and all receive part of their flow from irrigation return waters.

Table 1 Table 1 lists the sampling frequencies and the physical, chemical, and biological parameters analyzed for each surface-water sampling site.

Ground-Water Sampling

Ground-water quality was analyzed relative to the water's occurrence areally--within the four major drainage basins--and its occurrence within the principal aquifers. Samples were collected from about 480 wells and springs throughout the reservation. Each sample was analyzed for specific conductance, nitrite-plus-nitrate concentrations, and fecal-coliform bacteria. On the basis of these preliminary analyses, about one-sixth of the samples received a more complete additional analysis for the following constituents and characteristics:

Calcium	Chloride
Magnesium	Fluoride
Sodium	Iron
Potassium	Manganese
Bicarbonate-plus-carbonate	Color
Sulfate	

Plate 1 shows the locations of about 100 wells for which the more complete analyses are available, and indicates the aquifers tapped by the wells.

Previous Investigations

Other investigators have studied the geology and water resources of the reservation, but little emphasis has been placed on the study of water quality. Early investigations of the geologic features include a reconnaissance of central Washington by Russell (1893, 1897) and more detailed studies of a part of Yakima County (Smith, 1901), the Ellensburg quadrangle (Smith, 1903), most of the Columbia River Basalt Group (Newcomb, 1970), and the Simcoe Mountain area (Sheppard, 1960). A geologic and water-resources reconnaissance by Waring (1913) included much of the Ahtanum, Toppenish, and Satus Creek basins, and Foxworthy (1962) described the geology and ground-water resources of the Ahtanum Valley and included information on the ground-water quality. More recent studies of the geology and water resources of parts of the reservation include those of the Toppenish Creek basin by the U.S. Geological Survey (1975) and Gregg and Laird (1975), the upper Klickitat River basin by Cline (1976), and the Satus Creek basin by Mundorff, Mac Nish, and Cline (1977) and Molenaar (1977).

Several water-quality studies have been made in the Yakima River basin. Sylvester and others (1951) studied water pollution in the basin, Sylvester and Seabloom (1967) studied water-quality changes attributable to irrigation return flows. Boucher (1975) studied sediment yields in the reservation. Nelson and Weaver

(1971) reported on the salt balance within the Wapato Irrigation District in the reservation during 1970-71, and compared it with the salt balance during 1941-42, which was reported by Scofield (1941, 1942).

The U.S. Bureau of Reclamation has water-quality records on file in Boise, Idaho, for the Yakima River and for several of the canals and drains in the Wapato Irrigation District. The U.S. Geological Survey has water-quality records on file in Tacoma, Wash., for miscellaneous surface-water-quality sampling sites in the reservation, and also has published data (U.S. Geological Survey, 1965-75) from a few sites on the Yakima River.

Acknowledgments

The ground-water data for this study were obtained through the help of the many well owners who permitted collection of water samples from their wells. Chemical, temperature, and biological data from 6 of the 29 surface-water sites were obtained under the cooperative program between ~~supported by~~ the State of Washington Department of Ecology and the U.S. Geological Survey.

Well-Numbering System

Wells discussed in this report have been assigned numbers identifying them by location, within a section, township, and range.

For example, in the symbol 9/13-2C1, the part preceding the hyphen indicates successively the township and range (T. 9 N., R. 13 E.) north and east of the Willamette base line and meridian. Because the study area lies entirely north and east of the base line and meridian, the letters indicating the directions north and east are omitted. The first number following the hyphen indicates the section (sec. 2), and the letter "C" gives the 40-acre subdivision of the section, as shown in the figure below. The numeral "1" indicates that this well is the first one inventoried within the subdivision.

For brevity on the maps, only the latter part, 2C1, is used to identify the well, the township and range being obvious from the location on the map. The computer-generated tabular data for this well is listed as 09/13-02C01.

Description of the Area

Location and Extent

The Yakima Indian Reservation covers about 2,100 mi^2 in south-central Washington (pl. 1). The reservation is bounded on the west by the crest of the Cascade Range, on the east by the Yakima River, on the south by the crest of Simcoe Mountains and Horse Heaven Hills, and on the north by Klickton Divide, Darling Mountain, and the South Fork and main stem of Ahtanum Creek.

Principal Drainage Basins

The reservation is drained by four major streams. The eastern two-thirds of the reservation is drained to the Yakima River by the generally east-flowing Ahtanum, Toppenish, and Satus Creeks. The western one-third of the reservation is drained to the Columbia River by the south-flowing upper Klickitat River.

Ahtanum Creek basin.--About 45 mi^2 of the Ahtanum Creek basin lies within the reservation, and all this area is on the south sides of the main stem and South Fork of Ahtanum Creek (pl. 1). The South Fork lies in a steep-walled canyon between Sedge Ridge on the north and Ahtanum Ridge on the south. The creek descends from an altitude of nearly 6,000 feet to about 2,100 feet in the 13 miles of its length. The South Fork basin is predominantly forest land in the upper 11 miles and rangeland below. The North Fork (outside the reservation) merges with the South Fork near the town of Tampico, to form Ahtanum Creek. Ahtanum Creek then flows along the northern base of Ahtanum Ridge throughout most of its 24 miles, descending another 1,150 feet to its mouth at the Yakima River, near the town of Union Gap. The main stem of Ahtanum Creek lies predominantly in farmland, with rangeland in the higher elevations. However, only about 12 mi^2 of the farmland lies within the reservation.

Toppenish Creek basin.--The Toppenish Creek basin extends to ~~rises at~~

an altitude of about 5,000 feet in the high western plateaus, which also form the eastern divide of the Klickitat River basin. Toppenish Ridge forms the southern divide and Ahtanum Ridge forms the northern divide. From the high plateaus, the basin descends eastward. The upper slopes are predominantly forested with conifers with semiarid rangeland immediately below. Below an altitude of about 1,000 feet, the irrigated farmland begins, sloping gently eastward to the Yakima River.

The Toppenish Creek basin is by far the most populated, industrially developed, and agriculturally productive basin in the reservation. The basin covers about 627 mi^2 (401,000 acres) of which irrigated agricultural lands comprise about 130,000 acres, and forest land another 101,000 acres. Most of the remainder is rangeland.

Six towns located within the basin include Toppenish (pop. 5,850), Wapato (pop. 3,015), Harrah (pop. 336), White Swan (pop. 397), Parker (pop. 150), and Brownstown (pop. 112). The population figures are based on 1974 U.S. Post Office estimates.

<u>Satus Creek basin</u>.--The 618 mi^2 Satus Creek basin is bounded on the west by the upper Klickitat River basin, on the north by Toppenish Ridge, on the south by the Simcoe Mountains and Horse Heaven Hills, and on the east by the Yakima River, to which it drains. Included in the study of the Satus Creek basin is an area of 92 mi^2 to the east, which

is drained to the Yakima River lowland by several unnamed intermittent streams.

Forest land in the Satus Creek basin extends down to an altitude of 2,500-3,000 feet, below which is semiarid rangeland. Farmland begins at an altitude of about 900 feet and continues eastward to the Yakima River. Satus is the only town in the basin, with a population of about 50 in 1974. Other habitation is sparse.

Upper Klickitat River basin.--The upper, northern part of the Klickitat River basin is in the reservation and covers 749 mi^2. For this report, any reference to the basin implies only that part within the reservation. The Klickitat River rises on the southwestern flank of Gilbert Peak in the Goat Rocks and flows generally southward on the eastern flank of the Cascade Range. The river drops about 3,500 feet in about 55 miles within the reservation. The basin is predominantly forest land characterized by plateaus and steep to precipitous canyons. Although 12,276-foot Mount Adams, a glacier-mantled volcano, visually dominates the landscape, about 85 percent of the basin lies below the 5,000-foot altitude. Virtually all the farmland in the upper Klickitat River basin (about 5,600 irrigated acres) is in the Camas Prairie-Glenwood area in the southwestern part of the basin. This relatively flat land between 2,000 and 1,800 feet altitude covers about 50 mi^2. The population of Glenwood and the immediate area was approximately 550 in 1972. Habitation elsewhere is sparse.

Geology of the Reservation

Structure and rock types

All drainage basins in the Yakima Indian Reservation are underlain by bedrock composed of the Yakima Basalt of the Columbia River Basalt Group of Miocene age; the Yakima Basalt is herein referred to as the old basalt (relative to Quaternary age andesite and basaltic lavas in some of the higher western parts of the reservation). The Yakima Basalt layers have been folded to form the anticlinal ridges--Ahtanum and Toppenish Ridges and Horse Heaven Hills--and the intervening synclinal ~~basis~~ basins of Ahtanum, Toppenish, and Satus Creeks and the upper Klickitat River that delineate the three major areas studied. Successively overlying the basalt in the lowlands of the Toppenish and Satus Creek basins, and in places interbedded with the upper basalt flows, are the consolidated deposits of the Ellensburg Formation and unconsolidated deposits of gravel, sand, silt, and clay. The lake-deposited silt and clay were named the Touchet Beds by Flint (1938). Overlying the basalt in the Klickitat River basin and western upland of the Satus Creek basin are the younger andesitic and basaltic lavas of Quaternary age referred to herein as the young basalt; these are related in age to the volcanic extrusions that formed 12,276-foot Mount Adams, a glacier-mantled strato-volcano rising along the Cascade Range crest on the western margin of the reservation. The oldest rocks in the reservation are andesitic lavas of Eocene-Oligocene age found only in the headwater parts of the Klickitat River basin.

Ahtanum Creek basin.--The old basalt underlying the main-stem part of the Ahtanum Creek basin is overlain successively by the Ellensburg Formation, cemented gravel and unconsolidated alluvium of gravel, sand, and clay. Near the mouth of the basin the Ellensburg Formation is more than 1,000 feet thick and is overlain by cemented gravel between 300 and 400 feet thick which is mantled by as much as 30 feet of alluvium.

Toppenish Creek basin.--High plateaus of the young basalt, overlying the old basalt (Yakima Basalt) form the western upland of the Toppenish Creek basin. Alluvial sand and gravel with interbeds of lake-deposited silt and clay fill the flat-lying lowland of the oval-shaped basin to depths of more than 1,000 feet. These unconsolidated valley-fill materials consist of gravels derived from the old and young basalts and the Ellensburg Formation, and of younger materials deposited by the glacial melt waters of the ancestral Yakima River during a time of alpine glaciation in the Cascade Range.

Satus Creek basin.--The young basalt occurs extensively in the western, higher parts of the Satus Creek basin. The lower slopes are formed of the old basalt which in the lowland is overlain by old alluvium consisting of local basaltic materials and Ellensburg Formation. Along the southeastern edge of the valley flat, and abutting the base of the mountains, lake deposits of silt and clay, the Touchet Beds, overlie this alluvium to depths of more than 70 feet. Young alluvium deposited by the glacial melt waters of the Yakima River are prevalent nearer the Yakima River.

Upper Klickitat River basin.--The old basalt underlying the Klickitat River basin is overlain mostly by the young basalt extruded from the Simcoe Mountains, King Mountain, and Mount Adams. Some areas of old basalt are still exposed, particularly near Camas Prairie and from the headwaters of Diamond Fork Creek down the east side of the Klickitat River to a few miles below the mouth of Big Muddy Creek. The young basalt includes predominantly basalt, andesite and pumice. In the headwaters of the basin lava flows (mostly andesitic) even older than the old basalt extend down almost to the junction of the Klickitat River and Diamond Fork Creek.

In the Camas Prairie area of the basin alluvium and lake-deposited sand~~s~~ and silt~~s~~ overlie the young basalt.

Major water-yielding materials

The divides of the major stream basins are also the ground-water divides. Within the basins ~~the~~ ground water occurs in significant quantities in three major geologic units--the basalt (including both the old and young basalt), the old valley fill, and the young valley fill. The basalt is capable of yielding large quantities of water in many areas. In the lowlands of the Ahtanum, Toppenish, and Satus Creek basins unconsolidated valley fill deposits overlying the basalt include what are referred to in this report as the old valley fill and the young valley fill; both yield water to wells. The young valley fill was deposited primarily by melt-water streams from alpine glaciers of Quaternary age, but locally includes some interbedded lake deposits. Although the basalt contains the only significant aquifers in the Klickitat River basin, some water is obtained from alluvium underlying the Camas Prairie-Glenwood area, the only populated and agriculturally developed area in the basin.

Climate

The Yakima Indian Reservation has a continental climate, ranging from subhumid in the forested uplands to arid in the lowlands of the Toppenish and Satus Creek basins. Climate progressively becomes cooler and wetter with increasing altitude. The upper slopes and summit of Mount Adams are covered by

Precipitation exceeds 100 inches annually along much of the summit of the Cascade Range and rapidly decreases eastward with the decreasing altitude and increasing distance from the range crest (U.S. Weather Bureau, 1965). At the Klickitat River-Toppenish Creek divide, precipitation is about 35 to 50 inches annually, and at the Klickitat River-Satus Creek divide, it is about 25 to 35 inches annually. Precipitation continues to decrease easterly across the reservation to about 7 to 8 inches annually near the Yakima River.

Mean annual precipitation (U.S. Weather Bureau, 1950-72) at various localities on or near the reservation is approximately as follows:

Location	Mean annual precipitation (inches)
Mount Adams Ranger Station--- (at Trout Lake)	47
Glenwood---------------------	34
Signal Peak------------------	32
Bickleton--------------------	14
White Swan-------------------	8
Wapato-----------------------	7
Yakima-----------------------	8
Prosser----------------------	8

PART I. SUMMARY OF WATER QUALITY

Surface-Water Quality

Percentage of Ion Composition

fig. 1

In streams of such extreme differences--from mountain streams to lowland drains--there is a remarkable similarity in the percentage composition of common ions. Figure 1 illustrates that most of the waters studied differ from the overall average by less than 10-percent milliequivalence. The two exceptions are Big Muddy Creek and South Drain, which have sulfate percentages three to five times the average. The lowland streams generally have lower percentages of bicarbonate and higher percentages of sodium and sulfate than do the mountain streams.

Dissolved Solids

Although the percentage composition of constituents in the water on the reservation is similar, there is a large difference in dissolved-solids concentrations, as shown in plate 2 (in pocket). The average dissolved-solids concentrations ranged from 48 to 116 mg/L (milligrams per liter) in the mountain streams and from 88 to 372 mg/L in lowland streams, drains, and canal. Incoming irrigation waters in the Ahtanum, Toppenish, and Satus Creek basins averaged between 76 and 112 mg/L in dissolved solids, but irrigation return flows averaged between 136 and 372 mg/L. The dissolved-solids concentrations in the Yakima River increased from an average of about 100 mg/L at Parker to about 160 mg/L at Mabton. A large part of this increase is attributable to inflow from the reservation, but the Sulphur Creek Wasteway on the east side of the river is also a large contributor.

fig 2 Figure 2 illustrates that for 23 sites there is a relatively constant relationship between specific conductance and dissolved solids. Therefore, from a specific-conductance measurement at any of these sites, a fairly accurate estimate of dissolved solids can be made. For example, Ahtanum Creek (site 3) had a specific conductance of 218 micromhos per centimeter at 25°C on February 4, 1974. The estimated dissolved-solids concentration from the graph (fig.2) is about 150 mg/L, which compares favorably with the actual measured value of 140 mg/L. On August 6, 1974, the specific conductance was 388 micromhos, and the estimated and measured values for dissolved solids were both 255 mg/L.

Silica

In the mountain streams, silica averaged 42 percent of the dissolved solids, but in the lowland streams silica averaged only 18 percent of the dissolved solids. The mountain streams are in intimate contact with the decomposed surface of the basalt rock; these surficial materials may contain significant amounts of volcanic ash, which is capable of producing high silica concentrations in water. As the water is diverted and used to irrigate fields it comes into contact with soils having more soluble calcium, magnesium, and sodium than silica. The net effect is a reduction in the percentage of silica in the water. Figure 3 shows the relationship between specific conductance and silica at the 23 sites studied. The dashed line indicates streams that are predominantly in mountainous areas underlain by basalt, and the remaining points indicate lowland streams in areas underlain predominantly by alluvial deposits and soils.

Common Ions

The specific conductance may be used for a good estimate of common-ion concentrations. Figures 4 through 9 illustrate the relationships between specific conductance and various common ions.

The relationships of the common ions to specific conductance were sufficiently good to develop a general equation which expresses the concentration of any of the common ions, except nitrate, as a function of specific conductance. The equation is

mg/L of an ion = specific conductance x equivalent weight of the ion x average ion percentage for the particular stream type x 10^{-4}.

The equivalent weights necessary for the calculations are as follows:

Calcium (Ca)---	20	Bicarbonate (HCO_3)---	61
Magnesium (Mg)-	12	Sulfate (SO_4)--------	48
Sodium (Na)----	23	Chloride (Cl)--------	35.5
Potassium (K)--	39		

The average common-ion percentage for the streams studied are listed below:

~~Percent milliequivalence~~ constituent	[a]16 mountain streams	11 lowland streams
	average cation percentage	
Calcium (Ca)---------	42	41
Magnesium (Mg)-------	34	30
Sodium (Na)----------	20	26
Potassium (K)--------	4	3
Bicarbonate (HCO_3)---	[b]93	83
Sulfate (SO_4)--------	4	[c]8
Chloride (Cl)--------	3	6

[a]Common-ion analyses were not made on ~~performed for~~ samples from sites 5 and 6.

[b]Average for 14 streams--site 22 and 23 not included.

[c]Average for 9 streams--sites 13 and 20 not included.

To calculate the calcium concentration in water of a lowland stream having a specific conductance of 200 micromhos, per centimeter at 25°C the equation becomes:

$$200 \times 20 \times 41 \times 10^{-4} = 16 \text{ mg/L calcium.}$$

Following is a list of calculated and measured values for a sample collected from Marion Drain on March 6, 1974. The specific conductance was 390 micromhos per centimeter at 25°C.

	Ion concentration, in milligrams per liter	
	Calculated	Measured
Calcium (Ca)--------	32	35
Magnesium (Mg)------	14	14
Sodium (Na)---------	23	22
Potassium (K)-------	4.6	4.0
Bicarbonate (HCO_3)--	197	187
Sulfate (SO_4)-------	15	17
Chloride (Cl)-------	8.2	7.4

A few individual constituents are erratic in certain streams, such as sulfate in the upper Klickitat River and in Big Muddy Creek, and potassium in Ahtanum Creek. In addition, several calculations are unreliable for Mud Lake Drain, which has erratic concentrations of sodium, potassium, and sulfate, and for South Drain which has erratic concentrations of sodium, sulfate, and chloride. Nitrate concentrations show little relationship to specific conductance.

The table below summarizes the ranges of average common-ion concentrations for two groups of streams. As can be seen, the maximum common-ion concentrations for lowland streams are from two to more than eight times as much as those for mountain streams.

Constituent	Mountain streams	Lowland streams
	Range in concentration (mg/L)	
Calcium (Ca)-----------	4.1-12	11-44
Magnesium (Mg)---------	1.8-6.4	4.5-19
Sodium (Na)------------	2.6-6.4	5.9-52
Potassium (K)----------	0.7-3.1	1.5-6.2
Bicarbonate------------	22-79	72-275
Sulfate (SO_4)----------	1.0-7.2	4.7-58
Chloride (Cl)----------	0.6-2.0	2.9-17

Hardness ~~of Water~~

All the mountain streams had soft water, and the lowland streams, drains, and canal had water that ranged from soft to very hard. (For hardness classification see p. 202.) Average hardness concentrations ranged from 18 to 56 mg/L (as $CaCO_3$) in the mountain streams and between 47 and 190 mg/L in the lowland streams, drains, and canal.

A close relationship exists between specific conductance and hardness, as illustrated in figure 10.

fig. 10

Suitability of Water for Irrigation

~~(Appendix 1~~ (diagram, p. 210)

The mountain streams all had C1-S1 waters, and the SAR (sodium adsorption ratio) did not exceed 0.6 for any sample, indicating negligible sodium hazard. The lowland streams had C1-S1 to C2-S1 waters, and the SAR did not exceed 2.3, indicating that sodium hazard is not a problem in waters of any of the streams studied on the reservation.

Temperature

Because of the many factors influencing temperature, more data are necessary than allowed by the scope and duration of this study to ~~better~~ delineate stream-temperature characteristics clearly. However, it is possible to make some generalization from the data available. Observed minimum and maximum stream temperatures ranged from 0° to 25.9°C in the lowland streams, drains, and canal, and from 0.3° to 20.8°C in the mountain streams. Average annual temperatures also are lower in the mountain streams than in the lowland streams, but the seasonal amplitude of variation is greater in lowland streams. Observed summertime diel temperature variations (temperature variations within 24-hr period) ranged from a minimum of 1.0°C to a maximum of 8.9°C. Diel temperature variations averaged about the same for mountain and lowland streams in June, and slightly higher for the mountain streams in August. The greater diel variations in temperatures of mountain streams is probably due to the wider range of diel air temperatures in the mountains then in the lowlands.

A few of the streams in the reservation have received a more thorough temperature analysis by Collings and Higgins (1973).

Turbidity

Average turbidities ranged from 2 to 38 JTU (Jackson Turbidity Units), with a mean of 6 JTU for the mountain streams and 15 JTU for the lowland streams, drains, and canal. The maximum observed turbidity was 100 JTU in Mud Lake Drain on June 12, 1974. ~~This~~ Turbidity is well below a harmful level for fish life, but in the higher range may decrease biological productivity by reducing the light necessary for photosynthesis.

Color

Average color values ranged from 4 to 43 units. Mountain streams averaged 14 units and lowland streams, drains, and canal averaged 23 units. The maximum color value observed was 130 units in Toppenish Creek, on November 11, 1973. Color in the higher range may decrease biological productivity by reducing the light necessary for photosynthesis.

Dissolved Oxygen

During the June diel (24-hour) study, minimum DO (dissolved oxygen) concentrations in eight mountain streams (excluding Outlet Creek) ranged from 9.2 to 10.6 mg/L. During the August diel study at the same sites minimum concentrations ranged from 6.8 to 10.0 mg/L. Percentage DO saturation averaged between 95 and 100 percent for both studies. In general, these data indicate that mountain streams (excluding Outlet Creek) are of excellent quality with respect to the DO necessary for the support of aquatic life.

During the June diel study, the lowland streams, drains, and canal had minimum DO concentrations ranging from 5.9 to 10.4 mg/L. During the August diel study of the same waters, minimum DO concentrations ranged from 5.6 to 8.2 mg/L. The range in average DO saturation was from about 73 percent to 95 percent.

All the streams averaged more than 85-percent DO saturation, except at the sites on Wanity Slough, Mud Lake Drain, and Outlet Creek, which had the lowest minimum DO concentrations--5.6, 6.0, and 5.9 mg/L, respectively. At these three sites a distinct potential exists for DO concentration decreasing to 5 mg/L or less, the recommended minimum for a well-rounded warm-water fish population (Aquatic Life Advisory Committee of Ohio River Valley Sanitation Commission, 1955) such as is found in many of the lowland streams. This could occur in various ways, such as additional decaying organic matter, which would reduce the average percentage DO saturation, or else increased nutrient concentations could stimulate biologic productivity and increase the amplitude of the diel variation, causing nighttime concentrations to decrease to less than 5 mg/L. Other factors, such as extended periods of high temperatures, or lower flows, also could produce DO minimums less than 5 mg/L under the same chemical-quality conditions as present during the August study.

As shown by the June diel curves for Wanity Slough, Mud Lake Drain, and Outlet Creeks (figs. 16,17,20) percentage DO saturation began to rise before sunrise. This rise cannot be due to photosynthetic activity. This same peculiarity has been observed before by others in different studies. Gunnerson (1964) discusse~~s~~d it in some detail, and conclude~~s~~d that the most probable explanation is that the water temperature drops to some critical level where respiration slows down very markedly and the gradual rise in percentage DO saturation thereafter is due to natural stream reaeration.

Chlorophyll *a*

Chlorophyll *a* concentrations in the suspended material in the stream were determined at the same frequency as the other constituents. However, from the data collected it is evident that this approach is not entirely suitable for streams. In lakes, chlorophyll *a* concentrations in the suspended material has historically proven to be a usable index of lake productivity. However, streams are subject to scouring which results in increased chlorophyll *a* in suspension, both from non-aquatic plants and from dislodged aquatic plants. The increase in chlorophyll *a* concentrations from these sources makes interpretation of the data extremely difficult. Fortunately, the most important part of the data is salvagable. Low flows generally occur in late summer and correspond with maximum water temperatures and maximum sunlight which produce maximum photosynthesis. During low-flow periods, scouring is at a minimum, and chlorophyll *a* concentrations should be a valid index of productivity. Single samples collected at each site in late August or early September are the basis of the following discussion.

Chlorophyll *a* concentrations, and by implication, stream biologic productivities, are related to nitrate concentrations. The mountain streams had nitrate (as N) concentrations ranging from 0.01 to 0.04 mg/L at the time of late-summer chlorophyll *a* sampling. Only two of these streams (upper Satus Creek and Outlet Creek) contained chlorophyll a concentrations greater than 1.0 mg/L. These two exceptions are probably caused by higher effective nitrate concentrations than measured at the time of the chlorophyll a sampling. The concentration of nitrate (as N) in upper Satus Creek was 0.01 mg/L when the chlorophyll a sample was taken, but the mean for the year was 0.25 mg/L, and the maximum observed value was 0.93 mg/L. These are the highest mean and maximum values observed for any of the mountain streams, and probably reflect a higher effective nitrate concentration than indicated by the 0.01 mg/L of nitrate at the time of the chlorophyll a sampling. Outlet Creek had a low late-summer nitrate (as N) concentration of 0.04 mg/L, which probably is the result of nitrate depletion caused by the production of algae and other submerged plantlife in Conboy Lake and the millpond. Enough free-floating algae ~~is~~ are carried out of the lake and millpond to cause the stream to exhibit a higher chlorophyll a concentration than the nitrate concentration in the stream would seem to warrant, when compared with other similar streams in the reservation.

Chlorophyll a concentrations in the lowland streams and canal were 1.8 mg/L or greater; this corresponds with higher nitrate concentrations in the lowland waters than in the mountain streams.

Total Phosphorus

The mean total-phosphorus (as P) concentration of the mountain streams was 0.06 mg/L; the individual stream averages ranged from 0.02 to 0.09 mg/L. For the lowland streams, drains, and canal, the mean was 0.16 mg/L and the individual stream averages ranged from 0.09 to 0.30 mg/L. A total-phosphorus concentration of 0.05 mg/L is generally considered to be sufficient to support abundant growth of algae and other aquatic vegetation, provided other nutrients and other physical factors are favorable.

Nitrogen

Of all the chemical constituents, nitrate exhibited the largest difference between mountain streams and lowland streams. Mean nitrate (as N) concentrations in mountain streams ranged from 0.01 to 0.25 mg/L and averaged 0.06 mg/L, and in lowland streams ranged from 0.20 to 1.8 mg/L and averaged 0.77 mg/L.

Only one mountain-stream sample exceeded the 0.3 mg/L-nitrate (as N) concentration generally considered necessary for excessive algal growth. This sample from site 16 on upper Satus Creek, had a concentration of 0.93 mg/L on February 5, 1974. The source of the excess nitrate is not known.

Most total-nitrogen (as N) concentrations in the mountain streams were less than 0.6 mg/L, the concentration at which excessive algal growth may occur, even if nitrate concentrations are less than 0.3 mg/L. The exceptions were South Fork Simcoe Creek, 0.68 mg/L on May 8, 1974; upper Klickitat River, 2.0 mg/L on May 7, 1974; and lower Klickitat River, 1.0 mg/L on May 8, 1974. May is a month of higher streamflow due to spring snowmelt, generally resulting in the highest suspended-sediment concentrations. Undoubtedly, the high total-nitrogen concentrations in May were due mostly to the nitrogen-containing organic particles in suspension. Sediment samples from selected streams on the reservation collected by Boucher (1975) indicated that concentrations were higher at this time. On May 8, 1974, suspended-sediment concentrations in the South Fork Simcoe Creek were nearly three times that in the North Fork, and on May 7 the upper Klickitat River had the highest suspended-sediment concentration of any of the streams sampled in the Klickitat River basin.

Even with low nitrate (less than 0.3 mg/L) and low total-nitrogen (less than 0.6 mg/L) concentrations, excessive algal growth could still occur in many of the mountain and lowland streams which have total-phosphorus concentrations greater than 0.05 mg/L. However, chlorophyll a data indicate that excessive algal growth was not occurring at the time of sampling in August and September.

Organic Carbon

Organic-carbon concentrations in the mountain streams ranged from 1.0 to 12 mg/L, and averaged 5.1 mg/L. Nelson and Lysuj (1968) examined streams in uninhabited forested watersheds of California and Oregon, and found similar values, which ranged from 3.7 to 7.7 mg/L. Ott, Barker, and Growtiz (1973) examined streams in the sparsely populated Conewago Lake drainage basin in Pennsylvania and found organic-carbon concentrations ranging from 4 to 12 mg/L.

Organic-carbon concentrations in lowland streams ranged from 2.9 to 17 mg/L and averaged 7.2 mg/L, a slightly higher average than in the mountain streams, probably due to agricultural influences.

Pesticides

Whole water samples--a mixture of water and suspended sediment~~s~~--were collected monthly during May through September at site 4 on the Main Canal to determine the presence of 14 varieties of pesticides (table 1). The only one noted was the herbicide 2,4-D found in a concentration of 0.07 µg/L (micrograms per liter) in the sample of May 9, 1974. In Washington this herbicide is used most heavily during the months of March and April, with most application being for grain crops.

Trace Metals

Because of the toxicity of the trace metals, a minimal assessment was considered advisable to determine their presence in the surface waters of the reservation. A single sampling at 21 surface-water sites was accomplished during a period of low streamflow when trace-metals concentrations from natural sources are generally highest. Table 2 lists the concentrations of copper, lead, mercury, and zinc found in the sample from each site. All but one of the concentrations found are quite normal for central Washington, according to sampling of other streams in central Washington by the U.S. Geological Survey (1965-75). The total mercury concentration found at site 4 on the Main Canal was 3.3 μg/L, considerably above normal concentrations for central Washington streams. The cause of the high concentration is not known, but trace-metals data collected from the Yakima River at Parker (site 5) during the 1973 water year (U.S. Geological Survey, 1974) indicate that the high concentration in the Main Canal is an anomaly and not representative of normal mercury concentrations in the canal. None of the waters sampled exceeded the approximate threshold concentrations for maintenance of healthy aquatic life or for irrigation suitability. (See ~~Appendix I,~~ p. 212-213.)

Coliform Bacteria

On the basis of the samples collected, all mountain streams studied except Logy Creek and South Fork Simcoe Creek were bacteriologically suitable for irrigation and recreational use and for raw-source water for treated drinking-water supplies. The lowland streams, drains, and canal all indicated the potential for exceeding the criteria for either primary or secondary recreation use, and in some instances even for irrigation. Table 3 lists the number of times a stream exceeded, or potentially could exceed, the various criteria.

Temporal Variation in Surface-Water Quality

In basins such as those in the Yakima Indian Reservation, where both ground and surface waters pass through or over the same soil and rock materials, the ground water will generally have a higher dissolved-solids concentration. This is in part because the ground water has been in more intimate contact with the rocks and soils, affording more opportunity for dissolution of the minerals.

For natural streams whose flow is not controlled by man, there is generally a relationship between streamflow and variations in precipitation. Streamflow varies from predominantly overland runoff during periods of intense rainfall or snowmelt to almost 100 percent ground water during extended periods of little or no precipitation. During periods of very high streamflow, a stream is rather uniformly dilute in chemical constituents throughout its length, whereas during extended periods of no precipitation or snowmelt, a stream reaches a low or base flow composed virtually of only the ground-water contribution. This ground-water base flow increases the stream's dissolved-solids concentrations.

For streams influenced by man, the high and low flows may no longer be controlled by precipitation or snowmelt, but may be controlled according to water use. The dissolved-solids concentrations may be expected to vary according to the combined influences of water use and precipitation.

The general relationship of higher dissolved-solids concentrations during low flows and lower dissolved-solids concentrations at high flows is most apparent as a seasonal fluctuation. Attempts to refine the relationship to a relation of the dissolved-solids concentrations to daily or instantaneous streamflow values generally work with widely varying degrees of success, but in any case, such an attempt is beyond the scope of this study. All but six of the streams had the highest observed dissolved-solids concentrations during late summer and fall, which coincides with seasonal low streamflows. The same streams had the lowest observed dissolved-solids concentrations in the late spring or early summer, owing ~~due~~ to the rapid snowmelt at the higher elevations producing seasonal high flows.

Although no samples were collected during the major floods of January 1974, the mountain streams probably were very dilute at that time, possibly more so than in the spring.

The six streams whose variations in dissolved-solids concentrations are apparently not due to differences in seasonal precipitation are Wanity Slough, Marion Drain, Mud Lake Drain, lower Satus Creek, South Drain, and Outlet Creek. The variations resulted ~~were due~~ mainly from ~~to~~ water-use patterns, except for Outlet

Creek, which probably is more affected by Conboy Lake through which it flows.

Ground-Water Quality

Dissolved Solids

As can be seen from the specific-conductance values, which in general are measures of dissolved-solids concentrations, the two major aquifers underlying the Klickitat River basin contain the most dilute ground water in the reservation. The basalt underlying the Ahtanum Creek basin contains the second most dilute ground water in the reservation. The greatest concentrations of dissolved solids are found in the water in the old valley fill in the Satus Creek basin. The specific conductance of waters from the major aquifers ranged from 20 to nearly 1,500 microhmos per centimeter at 25°C. However, water from three springs in the Klickitat River basin, and believed to originate in the deeper lava flows, had ~~have~~ specific conductances of at least 1,500, ~~microhmos,~~ with a maximum of 1,800 microhmos per centimeter at 25°C.

Silica

The silica concentrations in 13 ground-water samples ranged from 32 to 68 mg/L and averaged 49 mg/L. However, insufficient data are available to differentiate silica concentrations in ground water in the different basins, and the silica concentrations showed little correlation ~~to~~ with specific-conductance values.

Common ions

Variability in percentage composition of most of the ground waters indicated there was poor relationship between specific conductance and the common-ion concentrations except in water from the old valley fill in the Ahtanum and Satus Creek basins. In these materials the waters were sufficiently similar in cation composition to establish a fair relationship between specific conductance and the cations. This relationship is expressed by the equation,

$$\text{Mg/l of a cation} = \text{specific conductance} \times \text{equivalent weight of the cation} \times \text{average cation percentage} \times 10^{-4}.$$

Average cation percentages are as follows:

Constituent	Ahtanum Creek	Satus Creek
	Average cation percentage	
Calcium (Ca)------	47	54
Magnesium (Mg)----	38	32
Sodium (Na)-------	12.5	12.5
Potassium (K)-----	2.5	1.5

Of all the basins studied, ground water in the Klickitat River basin contained the lowest average concentrations of each of the common ions, whereas water from the old valley fill in the Satus Creek basin had the highest average concentrations of each of the common ions, with the exception of bicarbonate and fluoride. Average bicarbonate concentrations are the highest in water from the young valley fill in the Toppenish Creek and Satus Creek basins. Average fluoride concentrations are highest in water from the basalt and old valley fill of these latter two basins.

Sulfate, chloride and nitrate concentrations are considerably higher in the water from the old valley fill in the Satus Creek basin than in water found in the other basins. The basalt and young valley fill in the basin also show a localized increase above normal for the same ions. These local high concentrations are all near an area underlain by the silt and clay of the Touchet Beds. These fine-grained deposits may have delayed irrigation-water seepage in this area, and flushing of the much older and more chemically concentrated ground water from the old valley fill may not have been as rapid as in areas of higher permeability.

In water from the old valley fill in the Satus Creek basin, concentrations of nitrate (as N) exceeded the maximum recommended limit of 10 mg/l for drinking water, as established by the USPHS (U.S. Public Health Service; 1962). (Hereinafter throughout the report, any reference to drinking-water standards refers to the USPHS classification.) Figure 11 shows generally the part of the Satus Creek basin where nitrate (as N) concentrations exceed 10 mg/L.

Concentrations of nitrate also exceeded the maximum recommended limit for drinking water in a few other areas. Well 12/18-8K1, tapping the old valley fill in the Ahtanum Creek basin, had a concentration of 11 mg/L. Wells 11/16-22G1 and 11/18-17D1, in the old valley fill in the Toppenish Creek basin, had water with concentrations of 20 and 15 mg/L, respectively. Basalt in the Satus Creek basin yielded water (well 8/22-3K1) containing 11 mg/L nitrate (as N); this is unusual for the basalt, and probably reflects ~~is due to a~~ localized entry of water from the old valley fill.

Hardness ~~of Water~~

Hardness concentrations ranged from 8 to 480 mg/L (as $CaCO_3$) in water from the major aquifers. The maximum concentration~~s~~ observed was 670 mg/L in water from a spring in the Klickitat River basin thought to originate in the deeper lava flows, which are not at present considered to be a major aquifer. However, most ground water in the Klickitat River basin is soft. The basalt in the other three basins, the old valley fill in the Toppenish Creek basin, and the young valley fill in the Ahtanum Creek basin yield water that is mostly moderately hard. The old valley fill in the Ahtanum Creek basin and the young valley fill in the Toppenish Creek basin both yield water that is mostly hard, and both the young and old valley fill in the Satus Creek basin yield water that is mostly very hard.

Suitability for Irrigation

Of the 104 samples with sufficient data to allow computation of the SAR, all but one contained waters of low sodium hazard and are classified as S1 waters (see ~~Appendix~~ I, p. 12), the one exception was water from a spring (11/13-4K1s) which contained S3 water (high sodium hazard). This spring is thought to originate in the deeper lava flows in the Klickitat River basin.

The major aquifers in the Klickitat River basin yield water of C1-S1 classification. However, three springs (6/13-4H1s, 9/13-18P1s, and 11/12-24L1s) thought to originate in deeper lava flows have C3-S1 waters.

Samples from ~~The~~ the remaining major aquifers sampled throughout the reservation yield C1-S1 or C2-S1 waters, except for two wells in the Toppenish Creek basin and four in the Satus Creek basin that yield C3-S1 waters.

From the foregoing, it can be stated that for irrigation the ground water in the reservation is of low sodium hazard and of low to medium salinity hazard.

Iron and Manganese

The average iron concentration in water from the major aquifers throughout the reservation does not exceed the recommended limit for drinking water. However, two very high iron concentrations were observed in water from two springs believed to orginate in deeper lava flows in the Klickitat River basin--9/13-18P1s and 11/12-24L1s contained 19,000 and 23,000 ug/L, respectively. All aquifers yield water locally that has iron or manganese concentrations that equal or exceed the recommended limits. Average manganese concentrations in water exceed~~s~~ the recommended limit for drinking water in the (1) valley fill in all the basins, (2) young valley fill in the Toppenish Creek and Ahtanum Creek basins, and (3) basalt in the Toppenish Creek basin.

Temperature

Ground-water temperature generally tends to increase with increasing well depth ~~due~~ owing to the temperature gradient within the earth. Average air temperatures affect ground-water temperature, particularly at shallower depths. At higher altitudes, where the average air temperature is lower, water from springs tends to be colder than at lower altitudes, other variables being the same. The lowest temperature observed (2.4°C) was at spring 12/13-27F1s, high on Darland Mountain. The highest water temperature observed (29.6°C) was at well 12/18-27H1, whose bottom (in the old basalt) is at an altitude of 100 feet, 1,020 feet below land surface.

Fecal-Coliform Bacteria

Most of the well~~s~~ and spring~~s~~ water sampled for chemical quality also were analyzed for fecal-coliform bacteria. Water from only eight springs and three wells had one or more fecal colonies per 100 millilitres; and samples from adjacent wells did not indicate widespread contamination. The most likely source of bacteria in the wells is direct local contamination from coliform-bearing surface water running down along the inside or outside of the well casing. The areas near the springs with fecal-coliform bacteria are all frequented by cattle, which often walk directly through the spring water and are probably the direct source of contamination.

Data Summary

A summary of the ground-water quality data collected from the major aquifers and over the entire reservation is presented below:

Item	Micrograms per litre		Milligrams per litre															
	Dissolved Iron (Fe)	Dissolved Manganese (Mn)	Dissolved Silica (SiO_2)	Dissolved Calcium (Ca)	Dissolved Magnesium (Mg)	Dissolved Sodium (Na)	Dissolved Potassium (K)	Bicarbonate (HCO_3)	Dissolved Sulfate (SO_4)	Dissolved Chloride (Cl)	Dissolved Fluoride (F)	Total Nitrite plus Nitrate (N)	Total Hardness (Ca, Mg)	Noncarbonate hardness	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C
Maximum[1]	2100	1500	68	120	44	160	9.0	650	240	70	1.4	120	480	380	5.5	1540	29.
Mean[1]	180	70	49	26	11	18	3.3	143	16	7.2	0.3	3.0	110	15	0.7	339	13.
Minimum	10	0	32	2.1	0.6	0.8	0.6	10	0.1	0.2	0.0	0.00	8	0	0.1	20	2.4
Number of samples	96	91	16	99	99	99	99	99	99	99	99	466	99	99	99	479	47

[1] Does not include waters from four springs in Klickitat River basin as they are not considered to originate in the major aquifers. The springs are 6/13-4H1s, 9/13-18P1s, 11/12-24L1s, and 11/13-4K1s.

PART II. SURFACE-WATER QUALITY, BY BASIN

Ahtanum Creek Basin

Stream System

The principal streams in the Ahtanum Creek basin include the two mountain streams, the North and South Forks Ahtanum Creek and the main stem Ahtanum Creek. The North and South Forks join near the town of Tampico and become Ahtanum Creek, which flows to the Yakima River. Ahtanum Creek water is used and reused for irrigation, and irrigation ditches interlace the valley. Much of the drainage water is returned to Ahtanum Creek.

North and South Forks Ahtanum Creek

The North and South Forks Ahtanum Creek contain very similar waters. The dissolved-solids concentrations are low, averaging 76 and 82 mg/L, respectively. These low concentrations are due largely to the low solubility of the basalt across which they flow, and the slow weathering processes in the forest lands.

Not only are the dissolved-solids concentrations very similar, but their percentage compositions, in terms of the common constituents, also are very similar, as illustrated in plate 2. The three predominant constituents in decreasing order of percentage composition are bicarbonate, silica, and calcium. These constituents are characteristic of all the mountain streams on the reservation and reflect the similarity of the basalt across which they flow.

The two major concerns related to the common constituents are the hardness of water and the suitability of its use for irrigation. The water from both mountain streams is soft, and is of the C1-S1 irrigation-water classification, indicating it is excellent for irrigation.

Concentrations of fecal-coliform bacteria were quite different in the two mountain streams. The North Fork Ahtanum

Creek averaged 18 col/100 mL (colonies per 100 milliliters), which is slightly high for a mountain stream, but still indicates only slight contamination. The South Fork Ahtanum Creek, however, averaged 120 col/100 mL, which is abnormally high for a mountain stream. The higher concentrations are probably due to a greater number of range cattle, and to the few small farms along the South Fork Ahtanum Creek. The water from both streams, on the basis of the samples collected, appears to be bacteriologically suitable for primary recreation use. (See ~~Appendix I~~ Page 191.)

DO concentrations and stream temperatures were monitored for diel variations in early June and again in late August. The results are listed below:

Site Number	Station Name	June Diel Profile: Sampling Interval Start	Stop		Dissolved oxygen, mg/l	Temperature, °C	August Diel Profile: Sampling Interval Start	Stop		Dissolved oxygen, mg/l	Temperature, °C
1	North Fork Ahtanum	June 4	June 5	max	11.2	7.1	Aug 27	Aug 28	max	9.8	12.7
	Creek at Tampico	at	at	min	10.8	5.7	at	at	min	8.6	12.4
		0920hrs	0655hrs	range	.4	1.4	0910hrs	0630hrs	range	1.2	5.3
2	South Fork Ahtanum	June 4	June 5	max	11.0	7.0	Aug 27	Aug 28	max	9.7	16.3
	Creek at Tampico	at	at	min	10.7	5.7	at	at	min	8.8	12.1
		0935hrs	0705hrs	range	.3	1.3	0920hrs	0640hrs	range	.9	4.2

The diel profiles, in percentage saturation, are illustrated in figure 12. Both in early June and in late August photosynthetic activity was minimal, and saturation remained near 95 percent. The DO concentrations appear to remain adequate for healthy fish populations.

Nitrate (as N) concentrations were low in the mountain streams averaging only 0.04 and 0.06 mg/L, respectively, in the North and South Forks Ahtanum Creek. Such low concentrations imply that the streams may not be very productive of aquatic vegetation or fish life--that is, growth rates are slow. The fishery ~~fishing~~ is predominantly for hatchery-reared fish.

The following table summarizes the data collected at the North and South Forks Ahtanum Creek:

Site number on map (figure)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
1	12500600	NF Ahtanum Creek at Tampico	maximum	38	8.8	4.2	4.5	2.3	61	2.3
			mean	35	6.8	3.2	3.6	1.9	47	1.8
			minimum	31	5.2	2.2	2.9	1.4	36	1.3
			n	4	4	4	4	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (Col/100 ml)
maximum	1.2	.40	.07	.09	89	39	10	.3	95	30	20	2.0	40
mean	.9	.24	.04	.06	76	30	6.6	.3	79	17	8	1.1	18
minimum	.7	.09	.01	.04	63	22	4.6	.3	63	7	1	.4	7
n	4	4	4	4	4	4	3	4	4	4	4	4	4

Site number on map (figure)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
2	12501600	SF Ahtanum Creek at Tampico	maximum	41	9.6	4.4	3.7	2.5	63	2.3
			mean	38	7.4	3.4	3.3	2.1	51	1.8
			minimum	35	5.5	2.4	3.0	1.7	40	1.4
			n	4	4	4	4	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (Col/100 ml)
maximum	1.2	.23	.18	.06	92	42	10	.3	99	20	5	1.4	190
mean	.7	.18	.06	.06	82	33	6.4	.2	86	14	3	1.1	120
minimum	.3	.11	.01	.05	70	24	4.4	.2	66	5	1	.6	20
n	4	4	4	4	4	4	4	4	4	4	4	3	4

Ahtanum Creek

Ahtanum Creek near its mouth had an average dissolved-solids concentration of 194 mg/L, nearly 2½ times the averages of the North and South Forks Ahtanum Creek. This results from the water of Ahtanum Creek being used and reused for irrigation a number of times as it moves down the valley. In addition to irrigation return waters, ground water also enters the stream. The difference between the amount of natural increase in dissolved solids and that from irrigation has not been determined.

The predominant constituents remain the same in Ahtanum Creek (pl. 2) as in the two mountain streams, but there is a marked increase in the percentages of sodium and sulfate. This increase is probably mostly because of irrigation use, although ground water entering the stream also may contribute to the increase. Silica also represents a smaller fraction of the predominant constituents in Ahtanum Creek than in the two mountain streams for the reasons explained on page 28.

Ahtanum Creek waters average moderately hard. The irrigation classification averages C2-S1, still a good-quality irrigation water.

Concentrations of fecal-coliform bacteria in Ahtanum Creek averaged 450 col/100 mL. This increase is predominantly due to agricultural use, the feces of cattle, horses, and other farm animals being the probable major source. On the basis of available data, it appears that Ahtanum Creek may be bacteriologically unsuitable for primary recreation a large part of the time, and for secondary recreation and irrigation some of the time. (See table 2 and p. 199-200.)

DO concentrations were monitored for diel variations in early June and in late August. The variations in DO concentrations and stream temperatures are listed below:

In early June photosynthesis and respiration activity was minimal, and saturation remained near 90 percent. In late August the water fluctuated widely in percentage DO saturation, indicating pronounced photosynthesis and respiration activity, probably due to an increase in the quantity of attached algae and submerged aquatic plants during the summer months. The diel variations are [illegible] Ahtanum Creek also appears to maintain adequate DO for [illegible] tions.

SITE NUMBER	Station Name	JUNE DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temperature °C	AUGUST DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temper °C
3	Ahtanum Creek at	June 4	June 5	max	10.3	10.0	Aug. 27	Aug. 28	max	10.6	22.[illegible]
	Goodman Road at	at	at	min	9.9	8.7	at	at	min	7.2	16.[illegible]
	Union Gap	0840hrs	0620hrs	range	0.4	1.3	0830hrs	0550hrs	range	3.4	6.[illegible]

The nitrate (as N) concentrations in Ahtanum Creek averaged 0.60 mg/L, about a 10- to 15-fold increase over the average concentrations in the two mountain streams. Agricultural fertilizers and animal wastes are probably the major cause of the increase. Nitrate concentrations are more than sufficient for large growths of aquatic plants and algae.

The following table summarizes the data collected at Ahtanum Creek:

In early June photosynthesis and respiration activity was minimal, and saturation remained near 90 percent. In late August the water fluctuated widely in percentage DO saturation, indicating pronounced photosynthesis and respiration activity, probably due to an increase in the quantity of attached algae and submerged aquatic plants during the summer months. The diel variations are illustrated in figure 13. Ahtanum Creek also appears to maintain adequate DO for healthy fish populations.

The nitrate (as N) concentrations in Ahtanum Creek averaged 0.60 mg/L, about a 10- to 15-fold increase over the average concentrations in the two mountain streams. Agricultural fertilizers and animal wastes are probably the major cause of the increase. Nitrate concentrations are more than sufficient for large growths of aquatic plants and algae.

The following table summarizes the data collected at Ahtanum Creek:

[illegible]	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
3	12502490	Ahtanum Creek	maximum	52	35	19	29	7.1	239	21
		at Goodman Road	mean	43	21	11	16	5.2	156	12
		at Union Gap	minimum	34	7.0	3.3	4.1	2.8	63	4.3
			n	4	12	12	12	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (col/100ml)
	8.8	.75	1.4	.26	289	170	8.4	1.0	430	40	50	14	2600
	5.3	.42	.60	.16	194	98	5.3	.7	263	16	13	4.0	450
	1.5	.20	.08	.10	92	31	3.1	.3	91	5	1	1.0	64
	4	12	12	12	4	12	3	12	12	12	12	11	12

water from the Yakima River just south of the town of Union Gap. The water is distributed to arterial canals throughout much of the valley. In addition, waters from all of the perennial streams, North and South Forks Simcoe Creek, and upper Toppenish Creek, are used to irrigate upper valley lands and to supplement flow in the main arterial canals.

Wanity Slough and Marion Drain receive ground water and irrigation return flows from farmland underlain predominantly by the young valley fill. Wanity Slough flows into Marion Drain, which returns to the Yakima River, except for a part of the water which is diverted into the Satus Creek basin for irrigation.

Mud Lake Drain and lower Toppenish Creek receive ground water and irrigation return flow from farmland underlain predominantly by the old valley fill. Mud Lake Drain flows into Toppenish Creek, which flows to the Yakima River.

Toppenish Creek Basin

Stream System

The stream system within the Toppenish Creek basin is rather complex. In addition to the several natural streams, an extensive system of irrigation canals and drainage ditches interlaces the valley, and utilizes predominantly imported water from the Yakima River. The irrigation water enters the Toppenish Creek basin through the Main Canal, which diverts water from the Yakima River just south of the town of Union Gap. The water is distributed by arterial canals throughout much of the valley. In addition, waters from all of the perennial streams, North and South Forks Simcoe Creek, and upper Toppenish Creek, are used to irrigate upper valley lands and to supplement flow in the main arterial canals.

Wanity Slough and Marion Drain receive ground water and irrigation return flows from farmland underlain predominantly by the young valley fill. Wanity Slough flows into Marion Drain, which returns to the Yakima River, except for a part of the water which is diverted into the Satus Creek basin for irrigation.

Mud Lake Drain and lower Toppenish Creek receive ground water and irrigation return flow from farmland underlain predominantly by the old valley fill. Mud Lake Drain flows into Toppenish Creek, which flows to the Yakima River.

Mountain Streams and Main Canal

The mountain streams and the Main Canal are discussed together because of their similarities in concentrations of dissolved solids and other constituents and their classification for irrigation water. Upper Toppenish Creek and the North and South Forks Simcoe Creek are the only perennial mountain streams in the Toppenish Creek basin. Dissolved-solids concentrations averaged 88, 112, and 102 mg/L, respectively. Single samples from Agency and Mill Creeks, two intermittent mountain streams, had dissolved-solids concentrations of 90 and 116 mg/L, respectively. Dissolved-solids concentrations averaged 88 mg/L in the waters entering Toppenish Creek basin through the Main Canal, which is similar to the concentrations in the mountain streams.

As with the mountain streams of the Ahtanum Creek basin, the mountain streams and the Main Canal in the Toppenish Creek basin are very similar in percentage compositions (pl. 2). The three predominant constituents in decreasing order are bicarbonate, silica, and calcium; this is characteristic of all the mountain streams in the reservation.

The mountain streams and the Main Canal contain soft waters on the average, and the waters are of the C1-S1 irrigation classification, indicating excellent quality for the purpose.

Concentrations of fecal-coliform bacteria were lowest in the intermittent mountain streams. Single samples from Agency and Mill Creeks contained 3 and 4 col/100 mL, respectively. Upper Toppenish Creek and North Fork Simcoe Creek also were quite low in fecal coliform, averaging 20 and 11 col/100 mL, respectively. South Fork Simcoe Creek contained considerably more fecal coliforms, averaging 94 col/100 mL. This higher concentration probably is due to range cattle, observed in the vicinity of the sampling site. The Main Canal contained higher fecal-coliform concentrations, averaging 230 col/100 mL. There are several contributors to these higher concentrations. These include the numerous municipal, agricultural, and industrial sources of bacteria in the vicinity of Yakima, such as sewage treatment plants, slaughter houses, meat-packing plants, and feedlots. Many of these wastes find their way to the Yakima River, and thence to the Main Canal.

The water from the mountain streams appears to be bacteriologically suitable as primary recreation water, on the basis of the samples collected. South Fork Simcoe Creek, however, did exhibit the potential of exceeding primary recreation criteria, as indicated by one sample containing 340 col/100 mL. Water in the Main Canal had the potential of exceeding primary and secondary recreation, and even irrigation criteria a small part of the time.

DO concentrations appear to remain adequate for healthy fish life in the mountain streams and Main Canal. The diel variations in DO concentrations and stream temperatures in June and August are listed below:

SITE NUMBER	Station Name	JUNE DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temperature, °C	AUGUST DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temp. °C
4	New Reservation	June 4	June 5	max	10.8	9.4	Aug. 27	Aug. 28	max	9.8	20.
	Canal near	at	at	min	10.4	8.2	at	at	min	8.2	16.
	Parker	0810 hrs	0600 hrs	range	0.4	1.2	0815 hrs	0535 hrs	range	1.6	3.
9	Toppenish Creek	June 6	June 7	max	10.8	10.8	Aug. 29	Aug. 30	max	9.2	20.
	near Fort Simcoe	at	at	min	10.2	7.6	at	at	min	8.2	16.
		1000 hrs	0605 hrs	range	0.6	3.2	0945 hrs	0650 hrs	range	1.0	4.
10	North Fork Simcoe	June 6	June 7	max	11.2	11.6	Aug. 29	Aug. 30	max	9.4	20.
	Creek near Fort	at	at	min	9.8	6.6	at	at	min	8.2	15.
	Simcoe	0900 hrs	0510 hrs	range	1.4	5.0	0850 hrs	0615 hrs	range	1.2	4.
11	South Fork Simcoe	June 6	June 7	max	11.2	10.8	Aug. 29	Aug. 30	max	9.0	18.
	Creek near Fort	at	at	min	10.0	6.0	at	at	min	8.2	15.
	Simcoe	0920 hrs	0530 hrs	range	1.2	4.8	0910 hrs	0620 hrs	range	0.8	3.

In early June photosynthetic activity was minimal, and DO saturation remained near 95 percent. In late August all the streams in this group except South Fork Simcoe Creek had noticeable, although not pronounced, photosynthetic and respiration activity, with the Main Canal exhibiting the most variation. Average saturation remained near 95 percent. The variations are illustrated in figures 14 and 15.

figs. 14 & 15

Nitrate (as N) concentrations in both the perennial and intermittent mountain streams were low, averaging 0.06 mg/L or less. Such low concentrations indicate that the streams probably are not very productive of aquatic vegetation or fish life. The Main Canal had average nitrate (as N) concentrations somewhat higher, averaging 0.20 mg/L. Productivity would be expected to be somewhat higher, other factors being equal. The slightly more pronounced diel variation in percentage DO saturation indicated that the Main Canal was, in fact, slightly more productive.

The following table summarizes the data collected at sites on each of the mountain streams and on the Main Canal:

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
4	12503500	~~New Reservation~~ Wapato Canal near Parker	maximum	25	20	8.3	13	2.5	118	7.6
			mean	19	11	4.5	5.9	1.5	72	4.7
			minimum	14	6.0	2.2	2.6	1.0	46	2.9
			n	3	9	9	9	3	3	3

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (Col/100 ml)
maximum	5.2	2.2	.40	.15	140	84	9.6	.6	210	20	30	6.6	100[illegible]
mean	2.9	.48	.20	.09	88	47	6.0	.4	126	9	9	2.8	23[illegible]
minimum	1.7	.11	.09	.05	62	24	3.7	.2	78	2	1	1.2	11[illegible]
n	3	9	9	9	3	9	3	9	9	9	9	8	9

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
9	12506000	Toppenish Creek nr Fort Simcoe	maximum	38	12	6.1	6.3	2.4	86	2.[illegible]
			mean	34	9.2	4.4	4.6	1.8	64	2.2
			minimum	27	5.4	2.4	3.0	1.3	38	1.9
			n	4	4	4	4	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (Col/100 ml)
maximum	1.3	.40	.04	.17	109	55	9.3	.4	139	30	30	2.2	3[illegible]
mean	.9	.20	.03	.08	88	41	5.2	.3	112	15	9	1.2	2[illegible]
minimum	.6	.11	.01	.04	60	23	2.0	.3	64	10	1	.7	6
n	4	4	4	4	4	4	4	4	4	4	4	4	4

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
10	12506300	North Fork Simcoe	maximum	48	13	6.7	8.6	3.8	97	3.
		Creek near Fort	mean	44	11	5.3	6.4	3.1	78	2.
		Simcoe	minimum	38	7.3	3.1	3.7	2.4	49	2.
			n	4	4	4	4	4	4	[illegible]

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (col/
maximum	1.3	.31	.05	.09	129	60	10	.5	150	20	10	3.2	2
mean	.8	.23	.04	.08	112	49	7.3	.4	127	14	4	2.0	1
minimum	.4	.16	.01	.07	82	31	4.7	.3	84	7	2	.6	2
n	4	4	4	4	4	4	4	4	4	4	4	4	5

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate
11	12506330	South Fork Simcoe	maximum	47	14	6.3	5.3	3.2	90	2
		Creek near Fort	mean	41	11	4.9	4.3	2.6	71	2
		Simcoe	minimum	30	6.1	2.5	2.8	1.8	41	2
			n	4	4	4	4	4	4	

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform
maximum	1.6	.57	.11	.14	122	61	11	.3	144	30	30	3.3	3
mean	1.1	.28	.06	.08	102	48	6.3	.3	120	22	10	1.4	[illegible]
minimum	.8	.14	.01	.05	67	26	3.4	.2	70	20	2	.4	
n	4	4	4	4	4	4	4	4	4	4	4	4	

Site number on map (figure)	Station Number	Station Name	Date of Single Sample	Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
12	12506600	Agency Creek near Fort Simcoe	4/9/74	42	9.0	4.2	3.4	1.8	54	1.4
14	12507100	Mill Creek at Canyon Road near White Swan	4/9/74	47	12	6.4	5.1	2.4	79	2.1

Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (col/100 ml)
1.3	.27	.02	.05	90	40	4.8	.2	103	5	2	1.0	3
2.0	.26	.01	.09	116	56	4.6	.3	140	7	3	1.4	4

Wanity Slough and Marion Drain

Ground or surface waters finding their way into Marion Drain are predominantly Main Canal water modified by use for irrigation. Wanity Slough water also represents irrigation return flows, but it is further modified by industrial and municipal wastes, the degree of which was not determined in this study.

Dissolved-solids concentrations in Wanity Slough averaged 136 mg/L. Not all of the common constituents were analyzed for Marion Drain; however, an estimated average of about 200 mg/L dissolved solids may be assumed from specific conductance. This concentration is representative of the water returning to the Yakima River or being diverted into the Satus Creek basin; however, it is not representative of much of the water in Marion Drain, as the drain was sampled at site 8 below the confluence of Wanity Slough. The samples therefore represent the combined waters, and are considerably more dilute than much of the water in Marion Drain above Wanity Slough. The amount of the difference was not determined.

The difference in dissolved-solids concentrations between Wanity Slough and Marion Drain is in part attributable to the amount and type of water use, but of more importance is the soil type from which Wanity Slough and Marion Drain recover water. Wanity Slough drains an area of non-saline, medium- to moderately coarse-textured alluvial soils underlain by very gravelly material in the upper part of its course and an area of medium- to moderately fine-textured, saline, and in places alkaline, alluvial soils in its lower part. Almost the entire length of Marion Drain is in the same saline and alkaline soil as the lower part of the area drained by Wanity Slough. The finer texture and the saline characteristics tend to cause an increase in dissolved solids, which is more strongly reflected in Marion Drain, as more of its water comes from this type of soil.

The predominant constituents remained the same in Wanity Slough and in Marion Drain as in the Main Canal (pl. 2) but there is a slight increase in percentage of nitrate with a corresponding decrease in percentage of bicarbonate. Silica also represents a smaller fraction of the dissolved solids in Wanity Slough than in the Main Canal, for the same reason as given for Ahtanum Creek.

Wanity Slough and Marion Drain waters average moderately hard. The average irrigation classification of Wanity Slough is C1-S1; of Marion Drain below Wanity Slough it is C2-S1. Both remain good-quality water for further irrigation use.

Concentrations of fecal-coliform bacteria in Wanity Slough averaged 1,100 col/100 mL. The presence of fecal coliforms was not determined for Marion Drain, but total coliforms were 7,200 col/100 mL on the average. The feces of cattle, horses, and other farm animals are the most probable source of the fecal coliform, although the upper reaches of Wanity Slough may receive considerable coliform from municipal and industrial sources. On the basis of available data, it appears that Wanity Slough and Marion Drain may be bacteriologically unsuitable for primary recreation most of the time, and for secondary recreation and even irrigation some of the time. (See p. 199-200.) ~~Appendix I.)~~

Diel variations in DO concentrations and stream temperatures in the two drains were studied in early June and in late August. The variations are listed below:

86

63

SITE NUMBER	Station Name	JUNE DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temperature °C	AUGUST DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temperature °C
7	Wanity Slough	June 5	June 6	max	11.4	15.5	Aug. 28	Aug. 29	max	10.8	20.6
	at Rocky Ford Road	at	at	min	7.1	11.4	at	at	min	5.6	17.9
	near Toppenish	0940 hrs	0705 hrs	range	4.3	4.1	0900 hrs	0535 hrs	range	5.2	2.7
8	Marion Drain	June 5	June 5	max	9.5	15.5	Aug. 28	Aug. 29	max	10.0	20.8
	near Granger	at	at	min	8.2	12.0	at	at	min	6.9	17.0
		0915 hrs	0630 hrs	range	1.3	3.5	0840 hrs	0515 hrs	range	3.1	3.8

Wanity Slough exhibited the most pronounced photosynthetic and respiration activity of all the streams studied, both in early June and late August. Marion Drain also exhibited pronounced variation both times, but not as great as that of Wanity Slough. The differences in DO variation between the two drains are probably attributable primarily to physical factors such as water clarity, bottom material, and ratio of surface area to volume. Wanity Slough waters are more favorable for biological activity in all three factors; the waters are clearer, the bottom material is primarily cobbles rather than mud, and the stream depth is much less, which results in a more favorable ratio of surface area to volume.

87a (88 fols)

Comparing Marion Drain and Wanity Slough to the Main Canal, the differences, in diel variations in DO concentrations probably tend to be more dependent upon differences in nutrient concentrations and stream temperatures. Both are higher in the drains, and are more favorable to biological activity. The diel variations in percentage saturation, are illustrated in figure 16.

Marion Drain probably maintains adequate DO for healthy fish populations, but Wanity Slough had a minimum observed concentration of 5.6 mg/L, only 0.6 mg/L above the 5.0 mg/L considered to be a safe lower limit for maintaining a healthy warm-water fish population. DO concentration probably drops below 5 mg/L occasionally during the warm summer months. A combination of a very hot, dry summer may cause considerably lower DO concentrations.

The nitrate (as N) concentrations in Wanity Slough and Marion Drain averaged 1.4 and 1.7 mg/L, respectively--about a seven- or eight-fold increase over that in the Main Canal. Agricultural fertilizers and animal wastes are probably the major cause of the increase. Nitrate concentrations are more than sufficient for large growths of aquatic plants and algae.

The following table summarizes the data collected at sites on Wanity Slough and Marion Drain:

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Diss. Su...
7	12505480	Wanity Slough at	maximum	32	26	10	12	3.1	125	[illegible]
		Rocky Ford Road	mean	28	19	7.3	8.9	2.4	111	[illegible]
		near Toppenish	minimum	25	16	5.4	6.2	1.7	98	[illegible]
			n	4	12	12	12	4	.4	[illegible]

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fe... Col...
maximum	6.5	.53	2.9	.16	160	110	6.8	.6	270	30	20	43	3[illegible]
mean	4.8	.40	1.4	.12	136	80	5.6	.5	205	7	8	7.8	1[illegible]
minimum	3.4	.25	.32	.09	120	52	5.1	.3	138	3	2	2.1	[illegible]
n	4	12	12	12	4	12	4	12	12	12	12	11	[illegible]

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Di... Su...
8	12505500	Marion Drain	maximum		35	14	22	5.7	192	[illegible]
		near Granger	mean		27	11	15	3.4	147	[illegible]
			minimum		21	8.4	12	2.3	113	[illegible]
			n		23	23	23	22	23	[illegible]

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	T... C...
maximum	8.4	.73	3.0	.43		150	7.9	.8	410	90	80	5.9	[illegible]
mean	5.1	.44	1.7	.17		110	6.4	.6	302	26	15	2.6	[illegible]
minimum	3.1	.30	.30	.12		85	5.0	.5	210	9	4	1.0	[illegible]
n	23	24	24	24		23	5	23	24	23	24	9	[illegible]

Mud Lake Drain and Lower Toppenish Creek

The waters of Mud Lake Drain are a composite of ground water and irrigation return-flow water originally from arterials of the Main Canal. A small amount of water comes from the natural runoff of intermittent streams on the south slope of Ahtanum Ridge. Lower Toppenish Creek waters are a composite of water from intermittent and perennial mountain streams, irrigation return flow from the same and from arterials of the Main Canal, Mud Lake Drain water, and ground water. The overall changes in water quality were studied, but differentiation of the changes due to each type of inflow was not determined.

Dissolved-solids concentrations averaged 249 mg/L in Mud Lake Drain, and an estimated average for lower Toppenish Creek, based on specific conductance, was about 220 mg/L. The difference probably is due to the dilution by spring runoff from the mountain streams, which slightly lowers the Toppenish Creek average. Both streams have very similar dissolved-solids concentrations during low streamflows.

Mud Lake Drain and Toppenish Creek, as previously mentioned, drain an area underlain by the old valley fill. Ground water from the old valley fill below the Main Canal arterials has the highest average dissolved-solids concentrations in the basin. This ground water enters lower Toppenish Creek and Mud

Lake drain and is in part responsible for these streams having the highest dissolved-solids concentrations of the streams in the basin. The amount of increased dissolved-solids concentrations attributable to surficial irrigation return flows is not known, although it is probably more for lower Toppenish Creek and Mud Lake Drain than for Marion Drain or Wanity Slough. The soil associated with lower Toppenish Creek and Mud Lake Drain is largely silt which tends to yield drainage water~~s~~ containing greater dissolved-solids concentrations than do coarser alluvial materials.

The predominant constituents in Mud Lake Drain and lower Toppenish Creek are, in decreasing order, bicarbonate, calcium, and sodium. Bicarbonate percentages are slightly less and sulfate percentages are slightly more than in the drains in areas underlain by the young alluvium.

On the average, water in lower Toppenish Creek is moderately hard, and that in Mud Lake Drain is hard. The average irrigation classification is C2-S1, indicating good-quality water for the purpose.

Concentrations of fecal-coliform bacteria in Mud Lake Drain averaged 780 col/100 mL. The presence of fecal coliform was not determined in lower Toppenish Creek waters, but total coliform averaged 11,800 col/100 mL. These are high concentrations, compared to those in the mountain streams and the

Main Canal. The feces of cattle, horses, and other farm animals are the most probable source of the fecal coliform. On the basis of available data, it appears that Mud Lake Drain and lower Toppenish Creek are bacteriologically unsuitable for primary recreation most of the time, and for secondary recreation and even irrigation some of the time. (See p. 199-200.) ~~Appendix I.)~~

Diel variations in DO concentrations and stream temperatures in the drain and stream were determined in early June and late August. The variations are listed below:

Although Mud Lake Drain has warm temperatures and sufficient nutrients, the photosynthesis and respiration are only slight. This probably is because of the restricted light penetration as indicated by the high average turbidity value of 28 JTU, which is twofold higher than that of any other [illegible] studied. In addition, the [illegible] little opportunity for the attachment of algae on the rooting of aquatic plants, which [illegible] lower Toppenish [illegible] a slight diel variation in DO in June, but [illegible] pronounced variation in August. The reasons are probably the same as for Ahtanum Creek--the growth of [illegible] attached algae and submersed aquatic plants during the warm summer months. The diel variations in percentage DO saturation are illustrated in figure 17.

SITE NUMBER	Station Name	JUNE DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temperature °C	AUGUST DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen mg/L	Temperature °C
13	Mud Lake Drain	June 6	June 7	max	9.4	18.7	Aug. 29	Aug. 30	max	7.2	22.
	near Harrah	at	at	min	7.6	9.8	at	at	min	6.0	17.
		0820 hrs	0640 hrs	range	1.8	8.9	0810 hrs	0535 hrs	range	1.2	4.
15	Toppenish Creek	June 3	June 4	max	9.2	17.5	Aug. 26	Aug. 27	max	10.6	21.
	near Satus	at	at	min	8.2	14.8	at	at	min	7.2	17.
		0800 hrs	0600 hrs	range	1.0	2.7	0835 hrs	0655 hrs	range	3.4	3.

Lower Toppenish Creek probably maintains adequate DO for healthy fish populations, but Mud Lake Drain appears to have the potential for dropping below the 5.0 mg/L recommended lower limit for healthy warm-water fish populations.

The nitrate (as N) concentrations in water in lower Toppenish Creek and Mud Lake Drain averaged 0.88 mg/L and 1.5 mg/L, respectively--about a four- to seven-fold increase over that in the Main Canal, and much more over that in the mountain streams. Agricultural fertilizers and animal wastes are probably the major cause of the increase. Nitrate concentrations are more

Although Mud Lake Drain has warm temperatures and sufficient nutrients, the photosynthesis and respiration are only slight. This probably is because of the restricted light penetration--as indicated by the high average turbidity value of 38 JTU, which is twofold higher than that of any other surface waters studied. In addition, the mud bottom affords little opportunity for the attachment of algae or the rooting of aquatic plants, which are both so important in oxygen production. Lower Toppenish Creek had only a slight diel variation in DO in June, but quite a pronounced variation in August. The reasons are probably the same as for Ahtanum Creek--the growth of additional attached algae and submerged aquatic plants during the warm summer months. The diel variations in percentage DO saturation are illustrated in figure 17.

fig 17

Lower Toppenish Creek probably maintains adequate DO for healthy fish populations, but Mud Lake Drain appears to have the potential for dropping below the 5.0 mg/L recommended lower limit for healthy warm-water fish populations.

The nitrate (as N) concentrations in water in lower Toppenish Creek and Mud Lake Drain averaged 0.88 mg/L and 1.5 mg/L, respectively--about a four- to seven-fold increase over that in the Main Canal, and much more over that in the mountain streams. Agricultural fertilizers and animal wastes are probably the major cause of the increase. Nitrate concentrations are more than sufficient for large growths of aquatic plants and algae.

The following table summarizes the data collected at sites on lower Toppenish Creek and Mud Lake Drain:

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
13	12507090	Mud Lake Drain	maximum	44	56	25	58	6.0	342	45
		near Harrah	mean	32	36	15	34	3.7	208	24
			minimum	26	22	8.5	18	2.7	141	13
			n	4	6	6	6	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (col/100 ml)
maximum	18	1.2	2.4	.55	421	240	8.5	1.6	700	30	100	5.9	300
mean	8.4	.64	1.5	.30	249	150	7.4	1.2	432	18	38	2.6	28
minimum	4.7	.36	.69	.20	167	90	6.1	.9	260	4	20	1.5	23
n	4	6	6	6	4	6	3	4	6	6	6	5	6

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
15	12507510	Toppenish Creek	maximum		40	20	19	9.7	283	[illegible]
		near Satus	mean		27	12	22	3.9	171	[illegible]
			minimum		18	8.6	12	2.6	128	[illegible]
			n		23	23	23	23	23	[illegible]

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Total Coliform (col/100 ml)
maximum	26	1.4	2.5	.63		180	17	2.2	650	130	35	6.7	[illegible]
mean	7.1	.51	.88	.18		120	10	.9	350	43	13	3.1	[illegible]
minimum	3.1	.33	.02	.11		82	5.7	.5	220	13	5	.3	56
n	23	23	23	23		23	5	23	23	22	23	9	23

Satus Creek Basin

Stream System

The Satus Creek basin has only two perennial streams--Satus Creek and Logy Creek--and two intermittent streams of importance--Dry Creek and Mule Dry Creek. Satus Creek is the main stream, and all others flow into it in the order listed above. In the eastern lowland of the basin, water from Satus Creek and Marion Drain in the Toppenish Creek basin is diverted to the lowland farms for irrigation. Downstream, lower Satus Creek and South Drain receive much of the irrigation return flow and return it to the Yakima River. Mule Dry Creek, and two smaller drains to the Yakima River were not studied.

Upper Satus, Logy, and Dry Creeks

The three mountain streams studied all contain similar waters. The dissolved-solids concentrations are ~~very~~ similar to those in the mountain streams of the Ahtanum and Toppenish Creek basins, with upper Satus, Logy, and Dry Creeks averaging 90, 76, and 104 mg/L, respectively.

Not only are the dissolved-solids concentrations very similar but their percentage compositions, in terms of the common constituents, also are very similar, as illustrated in plate 2. The three predominant constituents in decreasing order are bicarbonate, silica, and calcium. These constituents are characteristic of all the mountain streams on the reservation, reflecting the similarity of the chemical character of the basalt across which they flow.

The two major concerns related to the common constituents are the hardness of water and the suitability of its use for irrigation. The water from the three mountain streams studied is soft, and is of the C1-S1 irrigation-water classification, indicating excellent quality for the purpose.

Concentrations of fecal-coliform bacteria in upper Satus, Logy, and Dry Creeks averaged 14, 200, and 38 col/100 mL, respectively. Satus Creek water is quite low in fecal-coliform concentrations, being within the expected range for mountain streams. Both Dry and Logy Creeks, however, contain higher-than-normal concentrations, which probably are due to range cattle or sheep, although a marshy area on Logy Creek may receive additional fecal coliforms from wild ducks, known to be a significant source of these bacteria.

The waters of upper Satus and Dry Creeks appear to be bacteriologically suitable for primary recreation use on the basis of the samples collected. (See ~~Appendix I,~~ p. 191.) Logy Creek, however, exhibits the potential of exceeding primary recreation criteria, as indicated by one sample containing 720 col/100 mL.

DO concentrations in Logy and upper Satus Creeks appear to remain adequate for healthy fish life. The diel variations in DO concentrations and stream temperatures in June and August are listed below:

Site Number	Station Name	JUNE DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temperature °C	AUGUST DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temperature °C
16	Satus Creek above	June 5	June 6	max	10.6	16.0	Aug. 28	Aug. 29	max	9.6	24.
	Logy Creek near	at	at	min	9.2	8.8	at	at	min	6.8	17.
	Toppenish	1045 hrs	0535 hrs	range	1.4	7.2	0940 hrs	0600 hrs	range	2.8	7.
17	Logy Creek near	June 5	June 6	max	10.6	14.0	Aug. 28	Aug. 29	max	9.2	24.
	Toppenish	at	at	min	9.7	8.4	at	at	min	7.9	16.
		1055 hrs	0540 hrs	range	0.9	5.6	0950 hrs	0615 hrs	range	1.3	7.

In early June photosynthetic activity was minimal, and DO saturation remained near 95 percent. In late August Logy Creek had noticeable, although not pronounced, photosynthetic and respiration activity, and upper Satus Creek had pronounced activity. Average DO saturation remained near 95 percent. The cause of the large variation in DO saturation in upper Satus Creek probably is related to the higher-than-average nitrate concentrations and stream temperatures which may tend to increase biological productivity. The diel variations are illustrated in figure 18.

fig 18

Nitrate (as N) concentrations were low in Logy Creek and Dry Creek, with averages of 0.07 and 0.08 mg/L, respectively. Such low concentrations suggest that the streams probably are not very productive of aquatic vegetation. Upper Satus Creek, however, had somewhat higher nitrate concentrations, with an average of 0.25 mg/L. Productivity was somewhat higher, as indicated by the pronounced diel variation in percentage DO saturation.

The following table summarizes the data collected at sites on each of the mountain streams:

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
16	12507990	Satus Creek above Logy Creek near Toppenish	maximum	36	11	6.0	6.4	2.1	80	3.8
			mean	33	9.4	4.8	5.2	1.7	65	2.8
			minimum	29	7.0	3.2	3.9	1.3	48	2.0
			n	4	4	4	4	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (Col/100 ml)
maximum	2.1	.27	.93	.05	104	52	6.2	.4	130	20	4	2.1	35
mean	1.4	.14	.25	.04	90	43	4.2	.4	112	8	2	1.5	14
minimum	1.1	.09	.01	.02	71	31	2.3	.3	77	4	1	1.1	1
n	4	4	4	4	4	4	4	4	4	4	4	4	4

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
17	12500950	Logy Creek near Toppenish	maximum	29	8.3	4.9	6.1	1.3	62	3.3
			mean	28	7.5	4.2	5.0	1.2	55	2.4
			minimum	26	6.2	3.3	4.3	1.0	48	1.6
			n	4	4	4	4	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (Col/100 ml)
maximum	1.9	.21	.22	.06	83	40	8.2	.4	100	20	6	3.8	720
mean	1.2	.16	.07	.05	76	36	5.4	.4	95	11	3	2.2	20[illegible]
minimum	.8	.10	.01	.03	67	29	2.7	.3	80	7	1	.5	1
n	4	4	4	4	4	4	4	4	4	4	4	3	4

Site number on map (figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
16	12507990	Satus Creek above Logy Creek near Toppenish	maximum	36	11	6.0	6.4	2.1	80	3.8
			mean	33	9.4	4.8	5.2	1.7	65	2.8
			minimum	29	7.0	3.2	3.9	1.3	48	2.0
			n	4	4	4	4	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (Col/100 ml)
maximum	2.1	.27	.93	.05	104	52	6.2	.4	130	20	4	2.1	35
mean	1.4	.14	.25	.04	90	43	4.2	.4	112	8	2	1.5	14
minimum	1.1	.09	.01	.02	71	31	2.3	.3	77	4	1	1.1	1
n	4	4	4	4	4	4	4	4	4	4	4	4	4

Site number on map (figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
17	12500950	Logy Creek near Toppenish	maximum	29	8.3	4.9	6.1	1.3	62	3.3
			mean	28	7.5	4.2	5.0	1.2	55	2.4
			minimum	26	6.2	3.3	4.3	1.0	48	1.6
			n	4	4	4	4	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (Col/100 ml)
maximum	1.9	.21	.22	.06	83	40	8.2	.4	100	20	6	3.8	720
mean	1.2	.16	.07	.05	76	36	5.4	.4	95	11	3	2.2	20[illegible]
minimum	.8	.10	.01	.03	67	29	2.7	.3	80	7	1	.5	1
n	4	4	4	4	4	4	4	4	4	4	4	3	4

Site number (on map figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
18	12505480	Dry Creek near Toppenish	maximum	40	15	8.9	7.8	2.1	110	2.4
			mean	36	11	6.4	5.9	1.6	78	2.1
			minimum	33	7.0	3.8	4.0	1.2	46	1.8
			n	2	2	2	2	2	2	2

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (μg/l)	Fecal Coliform (col/100 ml)
maximum	2.1	.33	.14	.05	132	74	12	.4	167	5	3	2.0	44
mean	1.8	.31	.08	.05	104	54	8.8	.4	128	4	2	1.4	38
minimum	1.6	.28	.02	.05	76	33	5.5	.3	90	4	1	.7	31
n	2	2	2	2	2	2	2	2	2	2	2	2	2

Lower Satus Creek and South Drain

The waters of lower Satus Creek and South Drain are a composite of the natural water of Satus Creek, irrigation return-flow water diverted from Marion Drain in Toppenish Creek basin, and ground water. Overall changes in water quality were studied, but the differentiation of the changes due to each type of inflow was not determined.

On the basis of specific conductance, the estimated average dissolved-solids concentration in lower Satus Creek is about 160 mg/L. The average of observed dissolved-solids concentrations in South Drain was 372 mg/L. For comparison, the average dissolved-solids concentrations in waters of Logy, Dry, and upper Satus Creeks probably was about 85-95 mg/L, and that in Marion Drain was about 200 mg/L. The greater increase in dissolved solids in South Drain probably is mostly attributable to the soil, which is largely silt. This soil tends to yield waters containing greater dissolved-solids concentrations than do coarser alluvial soils.

The predominant constituents in South Drain, in decreasing order of percentage composition, are bicarbonate, sodium, calcium, and magnesium. Silica content was not determined for lower Satus Creek and, therefore, the exact order of the predominant constituents could not be determined. The percentage of sulfate is significantly higher in South Drain water (pl. 2) than in the other streams studied in this basin. The high percent sulfate is probably related to the soil type, as indicated by the similar high percentage of sulfate in Mud Lake Drain water, which crosses the same soil type.

Lower Satus Creek water averaged moderately hard, and South Drain water averaged very hard. The average irrigation classification of these streams is C2-S1, indicating good quality for this use.

The average of observed concentrations of fecal-coliform bacteria in South Drain was 800 col/100 mL. Fecal-coliform concentrations were not analyzed in lower Satus Creek, but the average of observed total coliform was 5,400 col/100 mL. These are high concentrations compared with those in the mountain streams. The feces of cattle, horses, and other farm animals are the most probable sources of fecal coliform. On the basis of available data, it appears that lower Satus Creek and South Drain are bacteriologically unsuitable for primary recreation use most of the time, and for secondary recreation and even irrigation use some of the time. (See ~~Appendix I.)~~ p. 199-200.)

Diel variations in DO and stream temperatures for the stream and drain were determined in early June and in late August. The variations are listed below:

South Drain apparently has warm temperatures and sufficient nutrients, but photosynthesis and respiration are only slight. The cause for this is probably at least twofold. First, a lack of water clarity, as indicated by the June and August turbidity values of [illegible] JTU each, reduces the available light to aquatic plants, and photosynthesis is reduced. [illegible] affords little opportunity for the attachment of algae or the [illegible] oxygen production. Lower Satus Creek [illegible] a slight [illegible] variation in June, but quite a pronounced variation in August. The reasons are probably the same as for [illegible] Creek and lower [illegible] Creek--the growth of additional attached algae and submerged aquatic plants during the warm summer months. The diel variations in percentage DO saturation are illustrated in figure 19. Lower Satus Creek and South Drain probably maintain adequate DO for healthy fish populations.

SITE NUMBER	Station Name	JUNE Sampling Start	DIEL Interval Stop		PROFILE Dissolved oxygen, mg/L	Temperature °C	AUGUST Sampling Start	Interval Stop	DIEL	PROFILE Dissolved oxygen mg/L	Temp °C
19	Satus Creek at	June 3	June 4	max	9.0	18.0	Aug. 26	Aug. 27	max	9.8	21.
	Satus	at	at	min	8.2	14.0	at	at	min	6.9	17.
		0830 hrs	0635 hrs	range	0.8	4.0	0855 hrs	0715 hrs	range	2.9	3.
20	South Drain	June 3	June 4	max	8.5	19.8	Aug. 26	Aug. 27	max	8.7	21
	near Satus	at	at	min	8.0	15.0	at	at	min	7.6	18.
		0850 hrs	0645 hrs	range	0.5	4.8	0915 hrs	0605 hrs	range	1.1	2.

The averages of observed nitrate (as N) concentrations in lower Satus Creek and South Drain were 0.58 and 1.6 mg/L, respectively. This is about a fivefold increase in the Satus Creek waters probably mostly attributable to agricultural fertilizers and animal wastes. South Drain's average concentration is higher than that of either of its surface-water sources (Satus Creek and Marion Drain), but the increase over that in Marion Drain is slight. Nitrate concentrations are more than sufficient for large growths of aquatic plants and algae.

South Drain apparently has warm temperatures and sufficient nutrients, but photosynthesis and respiration are only slight. The cause for this is probably at least twofold. First, a lack of water clarity, as indicated by the June and August turbidity values of 30 JTU each, reduces the available light to aquatic plants, and photosynthesis is reduced. Second, the mud bottom affords little opportunity for the attachment of algae or the rooting of aquatic plants, which are both so important in oxygen production. Lower Satus Creek had only a slight DO variation in June, but quite a pronounced variation in August. The reasons are probably the same as for Ahtanum Creek and lower Toppenish Creek--the growth of additional attached algae and submerged aquatic plants during the warm summer months. The diel variations in percentage DO saturation are illustrated in figure 19. Lower Satus Creek and South Drain probably maintain adequate DO for healthy fish populations.

The averages of observed nitrate (as N) concentrations in lower Satus Creek and South Drain were 0.58 and 1.8 mg/L, respectively. This is about a fivefold increase in the Satus Creek waters probably mostly attributable to agricultural fertilizers and animal wastes. South Drain's average concentration is higher than that of either of its surface-water sources (Satus Creek and Marion Drain), but the increase over that in Marion Drain is slight. Nitrate concentrations are more than sufficient for large growths of aquatic plants and algae.

The following table summarizes the data collected at sites on lower Satus Creek and South Drain:

Station number	Station Name		Dissolved Silica (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO3) (mg/l)
[illegible]21	Satus Creek at Satus	Maximum		43	14	25	4.7	197
		Mean		18	8.4	13	3.3	118
		Minimum		7.2	3.9	4.8	1.1	52
		n		22	22	22	22	22

Total Kjeldahl Nitrogen (N) (mg/l)	Total nitrite plus nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca,Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (mg/l)
.58	1.3	.21		130	18	1.0	390	70	35	7.0
.31	.58	.13		79	7.5	.6	225	36	12	2.1
.16	.06	.07		34	4.6	.4	100	19	5	.01
23	23	23		22	8	22	23	23	23	10

Station number	Station Name		Dissolved Silica (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO3) (mg/l)
[illegible]630	South Drain near Satus	Maximum	41	67	29	86	9.5	386
		Mean	36	44	19	52	6.2	275
		Minimum	32	19	9.1	18	2.8	120
		n	4	12	12	12	4	4

Total Kjeldahl Nitrogen (N) (mg/l)	Total nitrite plus nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca,Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (mg/l)
2.0	2.8	.32	548	290	9.8	2.3	880	20	30	7.4
.65	1.8	.23	374	190	7.9	1.6	532	10	15	3.2
.35	.50	.17	161	81	5.9	.9	240	4	2	1.2
12	12	12	4	12	4	12	12	12	12	11

Site Number on map (Figure)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
19	12508621	Satus Creek	maximum		29	14	25	4.7	197	16
		at Satus	mean		18	8.4	13	2.3	118	7.9
			minimum		7.2	3.9	4.8	1.1	52	2.4
			n		22	22	22	22	22	22

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Coliform Fecal/100ml
maximum	6.6	.58	1.3	.21		130	10	1.0	390	70	25	7.0	21000
mean	3.5	.31	.58	.13		79	7.5	.6	225	34	12	2.1	5400T
minimum	1.3	.16	.06	.07		34	4.6	.4	100	19	5	0.	240
n	22	23	23	23		22	5	22	23	23	23	10	23

Site Number on map (Figure)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
20	12508630	South Drain	maximum	41	67	29	86	9.5	386	96
		near Satus	mean	36	44	19	52	6.2	275	58
			minimum	32	19	8.1	18	2.8	120	17
			n	4	12	12	12	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Coliform Fecal/100ml
maximum	30	2.0	2.8	.132	543	290	9.8	2.3	880	20	30	7.4	500
mean	1.7	.65	1.8	.23	372	190	7.9	.6	532	10	15	3.2	300
minimum	5.2	.35	.50	.17	161	81	5.9	.9	240	4	2	1.2	11
n	4	12	12	12	4	12	4	12	12	12	12	11	12

Klickitat River Basin

Stream System

The streams in the Klickitat River basin include the Klickitat River and many mountain streams which enter it at various points, plus a small irrigation network. Hellroaring Ditch, the main source of water for the small irrigation network, begins at Big Muddy Creek in T. 8 N., R. 12 E., and intercepts some streamflow from Hellroaring, Couger, Dairy, Bacon, Bird, Frazier, and Holmes Creeks before delivering the water for irrigation on Camas Prairie. Irrigation return water flows through Conboy Lake and a millpond before flowing through Outlet Creek to the Klickitat River.

Big Muddy Creek

Big Muddy Creek is a glacier-fed stream rising on the east slope of Mount Adams. The average of observed dissolved-solids concentrations was 56 mg/L, only slightly less than the 60-mg/L average for the eight streams studied in the Klickitat River basin. The dissolved-solids concentrations are low because of high precipitation in the Klickitat River basin, and because of the low solubility of the predominantly basaltic and andesitic rock from which the streams drain.

Water composition in Big Muddy Creek is different from that in all other streams studied in the basin (pl. 2). It contains nearly seven times the sulfate percentage (28 percent) of the average of the other streams, and about twice the average potassium percentage (7 percent) of the other streams. The additional sulfate may come from sulfur deposits on Mount Adams. Sulfur deposits are known to exist on the west side of the volcano and probably are also present to a lesser extent on the east side. The predominant consitutents in decreasing order of percentage composition are silica, bicarbonate, and calcium.

Big Muddy Creek waters are soft. The irrigation classification is C1-S1, indicating excellent water for that use.

No fecal-coliform bacteria were found in any samples from Big Muddy Creek.

DO concentrations were not determined for Big Muddy Creek. The stream flows through a totally uninhabited area, and logging is about the only man-induced influence on the basin. The stream tumbles down a steep, boulder-bottomed channel; aeration is so complete that presumably the water has 100 percent DO saturation at all times.

Nitrate (as N) concentrations were consistently low, with an average of 0.04 mg/L. Such low concentrations indicate that the stream is not very productive of aquatic vegetation or fish life.

The following table summarizes the data collected at Big Muddy Creek:

River mile	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
13	14109000	Big Muddy Creek	maximum	32	6.3	2.4	3.5	2.0	27	9.1
		near Glenwood	mean	27	4.1	1.8	3.0	1.5	2.2	7.2
			minimum	20	2.6	1.3	2.5	.9	14	4.8
			n	4	4	4	4	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (col/100 mL)
max	1.1	.10	.05	.10	67	26	8.5	.4	62	70	70	1.6	<1
mean	.8	.08	.04	.05	56	18	5.1	.4	54	21	19	1.2	<1
min	.3	.06	.02	.03	44	12	1.0	.3	46	4	1	1.0	<1
	4	4	4	4	4	4	4	4	4	4	4	3	4

[illegible] and flows southeasterly across Camas Prairie to the Klickitat River. It receives all the irrigation return flow from Camas Prairie. Natural flow into Conboy Lake and [illegible] is sufficiently large [illegible] the irrigation effects, and the water in Outlet Creek is similar to that of other mountain streams in the basin. It has an average dissolved-solids concentration of [illegible] mg/l, the lowest of all the streams studied. However, probably most of the streams that contribute water to Hellroaring Ditch--besides Big Muddy Creek--are even more dilute.

The percentage composition is essentially the same as that in all the other streams, excluding Big Muddy Creek (pl. 7). The predominant constituents in descending order of percentage composition are bicarbonate, silica, and calcium.

The water is soft, and is of the C1-S1 irrigation classification, indicating excellent quality for that purpose.

Concentrations of fecal-coliform bacteria averaged 34 col/100 mL, which, although not high, was the highest observed in the Klickitat River basin. Because the other effects of irrigation are so masked, it is doubtful that all the

Outlet Creek

Outlet Creek drains the southwestern part of the reservation and flows northeasterly across Camas Prairie to the Klickitat River; it receives all the irrigation return flow from Camas Prairie. Natural flow into Conboy Lake and Outlet Creek is sufficiently large to dilute the irrigation effects, and the water in Outlet Creek is similar to that of other mountain streams in the basin. It has an average dissolved-solids concentration of only 48 mg/L, the lowest of all the streams studied. However, probably most of the streams that contribute water to Hellroaring Ditch--besides Big Muddy Creek--are even more dilute.

The percentage composition is virtually ~~essentially~~ the same as that in all the other streams, excluding Big Muddy Creek (pl. 2). The predominant constituents in descending order of percentage composition are bicarbonate, silica, and calcium.

The water is soft, and is of the C1-S1 irrigation classification, indicating excellent quality for that purpose.

Concentrations of fecal-coliform bacteria averaged 34 col/100 mL, which, although not high, was the highest observed in the Klickitat River basin. Because the other effects of irrigation are so masked, it is doubtful that all the coliforms are attributable to irrigation. Conboy Lake includes a wildlife refuge, and many ducks reside there. Ducks are notable producers of fecal-coliform bacteria and may have a considerable influence on the bacterial concentrations. The water is suitable for primary recreational use, on the basis of the samples collected. (See ~~Appendix I~~ page 191.)

DO concentrations and stream temperatures were monitored for diel variations in early June and early September. The variations are listed below:

percentage DO saturation are illustrated in Figure [illegible].

Average DO saturation was [illegible] percent, indicating [illegible] consumption by decay of organic matter [illegible] probably occurs mainly in Conboy Lake. The DO concentrations in Outlet Creek may not [illegible] The lowest observed concentration was 5.[illegible] mg/L, only slightly more than the 5 mg/L recommended lower limit.

SITE NUMBER	Station Name	JUNE DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen mg/L	Temperature °C	~~August~~ September DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen mg/L	Temp °C
22	Outlet Creek	June 10	June 11	max	8.2	21.4	Sept. 3	Sept. 4	max	8.8	23.
	near Glenwood	at	at	min	5.9	14.3	at	at	min	6.6	16
		0830 hrs	0810 hrs	range	2.3	2.1	0810 hrs	0655 hrs	range	2.2	6.

The average of observed nitrate (as N) concentrations in Outlet Creek was only 0.02 mg/L, far less than that necessary to produce the abundant growth of aquatic algae and vegetation necessary to cause the pronounced diel variation in DO observed in Outlet Creek. Probably larger concentrations of nitrate occur in the inflow waters to Conboy Lake, but the nitrate is utilized and bound up in organic material in the lake. Floating algae from the lake could still produce pronounced diel variations in DO concentrations.

The following table summarizes the data collected at Outlet Creek:

In early June and again in early September photosynthetic and respiration activity was pronounced. The diel variations in percentage DO saturation are illustrated in figure 20. Average DO saturation was near 80 percent, indicating oxygen consumption by decaying organic matter. The DO depletion probably occurs mainly in Conboy Lake. The DO concentrations in Outlet Creek may not remain adequate for the maintenance of healthy fish populations. The lowest observed concentration was 5.9 mg/L, only slightly more than the 5 mg/L recommended lower limit.

The average of observed nitrate (as N) concentrations in Outlet Creek was only 0.02 mg/L, far less than that necessary to produce the abundant growth of aquatic algae and vegetation necessary to cause the pronounced diel variation in DO observed in Outlet Creek. Probably larger concentrations of nitrate occur in the inflow waters to Conboy Lake, but the nitrate is utilized and bound up in organic material in the lake. Floating algae from the lake could still produce pronounced diel variations in DO concentrations.

The following table summarizes the data collected at Outlet Creek:

Map no.	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
26	14110720	Outlet Creek near Glenwood	maximum	24	4.5	3.9	3.2	1.3	33	2.6
			mean	21	3.9	2.2	2.7	.9	30	2.1
			minimum	18	3.3	1.7	2.3	.5	23	1.8
			n	4	6	6	6	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Fecal Coliform (col/100 ml)
maximum	1.2	.68	.04	.08	55	26	16	.3	58	40	8	10	110
mean	.8	.38	.02	.04	48	19	7.2	.3	50	32	4	3.3	34
minimum	.5	.03	.01	.02	42	15	2.9	.2	44	20	1	.8	2
n	4	6	6	6	4	6	4	6	6	6	6	5	6

The foregoing dissolved-solids concentrations are low, and there is little variation between streams. The variation may result mostly from the differences in amount of precipitation in the stream basin, the streams farthest east receiving less precipitation and having slightly higher dissolved-solids concentrations.

The percentage compositions of the stream waters are closely similar. As with all the mountain streams in the reservation except Big Muddy Creek, the predominant constituents in decreasing order are bicarbonate, silica, and calcium.

Similar Streams

The remaining streams studied and their average dissolved-solids concentrations are as follows, in downstream order:

Klickitat River (site 22)-----	56 mg/L
Trout Creek-------------------	57 mg/L
Elk Creek---------------------	65 mg/L
White Creek-------------------	74 mg/L
Summit Creek------------------	59 mg/L
Klickitat River (site 29)----- (just below reservation)	62 mg/L

The foregoing dissolved-solids concentrations are low, and there is little variation between streams. The variation may result mostly from the differences in amount of precipitation in the stream basin, the streams farthest east receiving less precipitation and having slightly higher dissolved-solids concentrations.

The percentage compositions of the stream waters are closely similar. As with all the mountain streams in the reservation except Big Muddy Creek, the predominant constituents in decreasing order are bicarbonate, silica, and calcium.

The waters are all soft, and are of the C1-S1 irrigation classification, indicating excellent quality for the purpose.

Concentrations of fecal-coliform bacteria were all quite low, with the highest observed concentrations being 15 col/100 mL and 25 col/100 mL in upper and lower Klickitat River, respectively. The waters all appear to be bacteriologically suitable for primary recreational use, on the basis of the samples collected. (See page 191 ~~Appendix I~~.)

For this group diel variations in DO concentrations and stream temperatures were determined in early June and early September only on the upper Klickitat River (site 22). The variations are listed below:

(Sta)tic (Num)ber	Station Name	JUNE DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/l	Temperature °C	SEPTEMBER ~~August~~ DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen mg/l	Temperature °C
12	Klickitat River	June 10	June 11	max	11.8	9.1	Sept. 3	Sept. 4	max	10.9	10.8
	below Soda Springs	at	at	min	10.6	4.8	at	at	min	10.0	7.8
	Creek near Glenwood	0930 hrs	0450 hrs	range	1.2	4.3	0915 hrs	0600 hrs	range	0.9	3.0

The diel variations in percentage DO saturation are illustrated in figure 21. In both early June and early September photosynthetic activity was minimal and DO saturation remained near 98 percent. The DO concentrations remain adequate for healthy fish populations.

Nitrate (as N) concentrations were low in all the streams of this group, with 0.12 mg/L being the highest average concentration. Such low concentrations indicate that the streams are probably not very productive of aquatic vegetation or fish life.

The following table summarizes the data collected at sites on each of the streams:

River map (no.)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
2	14108200	Klickitat River	maximum	29	7.2	2.5	3.6	1.7	38	2.5
		below Soda Springs	mean	26	5.1	2.0	3.1	1.2	32	2.4
		Creek near	minimum	21	3.9	1.5	2.4	.8	26	2.1
		Glenwood	n	4	4	4	4	4	4	4

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (col/100 ml)
max	1.4	2.0	.05	.11	66	28	10	.3	64	20	10	5.2	15
m	1.1	.58	.04	.05	56	21	6.1	.3	56	9	4	2.1	5
min	.8	.09	.01	.02	46	16	2.9	.2	48	3	1	.2	<1
	4	4	4	4	4	4	4	4	4	4	4	4	4

River map (no.)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
4	14110480	Trout Creek	maximum	27	5.9	2.4	3.1	.9	41	1.3
		near Glenwood	mean	26	5.4	2.2	3.0	.8	38	1.2
			minimum	24	5.0	2.0	2.9	.8	34	1.1
			n	2	2	2	2	2	2	2

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (col/100 ml)
max	.6	.14	.02	.03	61	25		.3	67	20	3		3
m	.6	.08	.02	.02	57	23	1.8	.3	62	12	2	.8	2
min	.5	.03	.01	.02	53	21		.3	57	4	2		<1
	2	2	2	2	2	2	1	2	2	2	2	1	2

Site number on map	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
15	14110490	Elk Creek near Glenwood	maximum	33	4.9	2.7	3.6	.9	39	2.1
			mean	32	4.8	2.5	3.6	.9	39	1.4
			minimum	31	4.6	2.3	3.5	.9	39	.8
			n	2	2	2	2	2	2	2

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (Col/100)
maximum	1.1	.07	.02	.05	65	23		.3	83	50	20		1
mean	1.1	.06	.01	.04	65	22	2.3	.3	73	35	12	1.6	1
minimum	1.0	.06	.00	.03	65	21		.3	62	20	5		1
n	2	2	2	2	2	2	1	2	2	2	2	1	2

Site number on map	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
27	14110800	White Creek near Glenwood	maximum	25	11	6.7	7.6	1.3	85	1.1
			mean	24	7.7	4.4	5.2	1.0	58	1.0
			minimum	24	4.4	2.2	2.9	.7	32	.9
			n	2	2	2	2	2	2	2

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (Col/100)
maximum	1.5	.16	.05	.04	96	50		.4	139	5	4		4
mean	1.0	.14	.02	.04	74	35	3.7	.4	97	4	2	1.6	2
minimum	.6	.12	.00	.03	52	20		.3	55	4	0		<1
n	2	2	2	2	2	2	1	2	2	2	2	1	2

Site number on map (figure)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
28	14111100	Summit Creek	maximum	25	6.7	4.0	3.2	.9	49	1.3
		near Glenwood	mean	24	5.6	3.2	3.1	.8	41	1.3
			minimum	23	4.5	2.3	3.0	.7	33	1.3
			n	2	2	2	2	2	2	2

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (col/100ml)
maximum	1.2	.20	.13	.06	66	33		.3	78	7	6		10
mean	.9	.18	.12	.05	59	27	3.3	.2	68	6	6	5.8	7
minimum	.6	.15	.12	.04	52	21		.2	57	4	5		4
n	2	2	2	2	2	2	1	2	2	2	2	1	2

Site number on map (figure)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
29	14111500	Klickitat River	maximum	31	6.1	3.1	7.2	1.6	46	2.3
		below Glenwood	mean	27	4.8	2.4	5.0	1.3	38	1.8
			minimum	23	3.6	1.7	2.7	1.0	30	1.3
			n	2	2	2	2	2	2	2

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (col/100ml)
maximum	1.0	1.0	.05	.12	75	28	8.6	.6	74	20	30		25
mean	1.0	.55	.05	.08	62	22	6.0	.4	63	12	16	4.8	14
minimum	1.0	.10	.05	.04	49	16	3.4	.3	52	5	2		2
n	2	2	2	2	2	2	2	2	2	2	2	1	2

Outflows and Inflows

The Yakima River adjacent to the reservation is the only reach of the river of interest to this study. Ahtanum Creek flows into the Yakima River where the river becomes a border to the reservation. Less than a mile downstream a major part of the riverflow is diverted into the Main Canal for irrigation in the Toppenish and Satus Creek basins. Downstream from the Main Canal diversion point, the river itself receives municipal, industrial, and agricultural wastes. Major inflows from the reservation include the sewage effluent from the city of Toppenish and water from Toppenish and Satus Creeks and from Marion and South Drains. Inflow from the land on the east side of the river (outside the reservation) is mainly from Sulfur Creek Wasteway (which is a major drain) and from a few small drains.

Yakima River at Parker

Waters in the Main Canal (site 4) and the Yakima River at Parker (site 5) are chemically nearly the same. However, the Main Canal is dry in the winter and, consequently, averages will not be the same. The Main Canal water was previously discussed (p. 76-81). A few characteristics of water in the Yakima River at Parker are discussed here.

An average dissolved-solids concentration of about 100 mg/L was estimated from specific conductance of the Yakima River at Parker.

The average of observed total coliform bacteria was 3,400 col/100 mL, making the water unsuitable much of the time for primary recreation, and some of the time for secondary recreation and irrigation. (See page 191 ~~Appendix I.~~)

The average of observed nitrate (as N) concentrations was 0.25 mg/L, somewhat higher than those in most of the mountain streams on the reservation, but probably still insufficient for the waters to be very productive of aquatic life.

Yakima River near Toppenish

An average dissolved-solids concentration of about 110 mg/L was estimated from the specific-conductance values for the Yakima River near Toppenish (site 6). This is about a 10-percent increase in dissolved solids in the reach between Parker and Toppenish.

The average of observed total coliform bacteria was 2,500 col/100 mL, having decreased by about 30 percent between Parker and Toppenish. The data indicate that the water near Toppenish may be unsuitable most of the time for primary recreation and some of the time for secondary recreation and irrigation.

DO concentrations appear to remain adequate for healthy fish life. Diel variations in DO concentrations and stream temperatures were determined in early June and late August. The variations are listed below:

SITE NUMBER	Station Name	JUNE DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temperature °C	AUGUST DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/L	Temperature °C
6	Yakima River	June 5	June 6	max	11.0	11.2	Aug. 28	Aug. 29	max	10.0	22.7
	near Toppenish	at	at	min	10.4	8.8	at	at	min	7.6	17.7
		0645 hrs	0645 hrs	range	0.6	2.4	0810 hrs	0655 hrs	range	2.4	5.0

~~106~~ 129 ~~117~~

Average DO saturation remained near 95 percent in both June and August. The diel variations in percentage DO saturation are illustrated in figure 22. The diel variations in June were small, but in August they were moderately pronounced, due to photosynthetic and respiration activity. The variation in August was somewhat greater than for the Main Canal. This probably is due in part to the slightly warmer temperatures and slightly higher nitrate concentrations, but it is due mostly to the stream channel shape, which provides more favorable conditions for biological activity.

The average of observed nitrate (as N) concentrations was 0.28 mg/L, indicating only moderate increase from the upstream station (site 5).

Yakima River at Mabton

An average dissolved-solids concentration of about 160 mg/L was estimated from the specific-conductance values of the Yakima River at Mabton (site 21). This is about a 45-percent increase in dissolved solids in the reach between Toppenish and Mabton. A large part of this increase is attributable to inflow from the reservation, but the Sulfur Creek Wasteway on the east side of the river is also a large contributor.

The percentage composition of constituents in the water of Yakima River at Mabton is similar to that in the Main Canal. Sodium and sulfate are increased slightly, as is illustrated in plate 2.

On the average, the water is moderately hard and the irrigation classification is C1-S1, indicating excellent quality for the purpose.

Concentrations of total coliform bacteria was about 8,200 col/100 mL on the average, but were as high as 41,000 col/100 mL. The average is about 330 percent higher than in the Yakima River near Toppenish, indicating a very significant change in this reach of river. The data indicate that the waters may be unsuitable for primary and secondary recreation, and for irrigation a large part of the time.

DO concentrations appear to remain adequate for healthy fish life. Diel variations in DO concentrations and stream temperatures in early June and late August are listed below:

SITE NUMBER	Station Name	JUNE DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/l	Temperature °C	AUGUST DIEL PROFILE Sampling Interval Start	Stop		Dissolved oxygen, mg/l	Temperature °C
21	Yakima River	June 3	June 4	max	9.4	16.1	Aug. 26	Aug. 27	max	8.3	21.8
	at Mabton	at	at	min	8.8	13.6	at	at	min	7.6	19.7
		0920 hrs	0535 hrs	range	0.6	2.5	0935 hrs	0625 hrs	range	0.7	2.1

Average DO saturation remained near 90 percent in both June and August. The diel variations in percentage DO saturation are illustrated in figure 23. Both the June and August diel variations indicated little change due to photosynthetic and respiration activity. The lesser variation when compared to the variations for the two upstream sites is unusual, as temperatures are comparable and the nutrient concentrations are higher. Color and turbidity appear to be the main cause of the decreased variations, as they decrease photosynthesis by reducing available light.

The average of observed nitrate (as N) concentrations was 0.71 mg/L, more than twice that at Toppenish (site 6). This concentration is sufficient for large growths of aquatic vegetation and algae. However, the nitrate concentration apparently is not the main controlling factor, as the diel variations in DO indicated little photosynthetic or respiration activity, as would be expected with large amounts of aquatic growth.

The following table summarizes the data collected at each site on the Yakima River, and may be used to observed the downstream changes in each constituent.

Site number on map (symbol)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
4	12503500	Main ~~New Reservation~~	maximum	25	20	8.3	13	2.5	118	7.6
		Canal near	mean	19	11	4.5	5.9	1.5	72	4.7
		Parker	minimum	14	6.0	2.2	2.6	1.0	46	2.9
			n	3	9	9	9	3	3	3

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total nitrite plus nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Fecal Coliform (Col/100 ml)
maximum	5.2	2.2	.140	.15	140	84	9.6	.6	210	20	30	66	1000
mean	2.9	.48	.20	.09	88	47	6.0	.4	126	9	9	2.8	230
minimum	1.7	.11	.09	.05	62	24	3.7	.2	78	2	1	1.2	11
n	3	9	9	9	3	9	3	9	9	9	9	8	9

Site number on map (symbol)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
5	12503950	Yakima River	maximum							
		at Parker	mean							
			minimum							
			n							

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total nitrite plus nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (ug/l)	Total Coliform (Col/100 ml)
maximum			.55	.19					230	65	40		16,000
mean			.25	.10					138	28	12		3400
minimum			.06	.06					75	12	3		70
n			23	23					23	22	23		23

135

~~142~~ ~~127~~

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
6	12505300	Yakima River near Toppenish	maximum							
			mean							
			minimum							
			n							

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Total Coliform (Col/100 ml)
maximum		.79	.68	.21			11		250	55	45	9.0	8200
mean		.34	.28	.10			8.4		146	27	12	2.6	2500
minimum		.09	.06	.06			6.0		79	13	4	.5	36
n		24	24	24			5		24	23	24	10	24

Site number on map (Figure 1)	Station Number	Station Name		Dissolved Silica (SiO_2) (mg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Dissolved Sulfate (SO_4) (mg/l)
21	12508990	Yakima River at Mabton	maximum		27	11	20	4.3	154	20
			mean		19	7.3	12	2.4	105	11
			minimum		8.9	3.0	4.0	.9	51	4.8
			n		23	23	23	23	23	23

	Dissolved Chloride (Cl) (mg/l)	Total Kjeldahl Nitrogen (N) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Phosphorus (P) (mg/l)	Dissolved Solids (Sum) (mg/l)	Hardness (Ca, Mg) (mg/l)	Total Organic Carbon (C) (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Color (platinum cobalt units)	Turbidity (JTU)	Chlorophyll a (µg/l)	Total Coliform (Col/100 ml)
maximum	7.7	.90	1.1	.24		110	9.4	.9	330	65	45	7.8	21,000
mean	4.3	.39	.71	.14		77	8.0	.6	228	32	17	3.1	8,200
minimum	1.7	.27	.20	.09		35	7.2	.3	110	11	4	1.1	1300
n	23	23	23	23		23	4	23	23	21	22	9	23

PART III. GROUND-WATER QUALITY, BY BASIN

Ahtanum Creek Basin

Young Valley Fill

Specific conductance values ranged from 98 to 610, and averaged 310 micromhos per centimeter at 25°C for water from six wells tapping the young valley fill.

As illustrated by the diagram in figure 24, the three wells tapping the young valley fill, for which complete common-ion analyses were made, contain similar water. The percentage composition tends to be somewhat different than for water from either the old valley fill or basalt in this basin.

The hardness classification of water in the young valley fill ranged from soft to moderately hard, with concentrations ranging from 49 to 120 mg/L (as $CaCO_3$) in three samples. The irrigation classification of water is C2-S1.

Iron concentrations ranged from 20 to 110 μg/L (micrograms per liter) in three samples. The highest value observed is considerably below the 300 μg/L recommended upper limit for drinking water.

Manganese concentrations ranged from less than 5 to 280 ug/L. Although the highest value indicates that the waters exceeded the recommended limit for drinking water in places, the other samples indicate that it is not a uniformly distributed problem.

No fecal-coliform bacteria were found in any of the waters from the young valley fill.

Concentrations of nitrate (as N) ranged from 0.01 to 1.8 mg/L in six samples. These values are well below the recommended limit of 10 mg/L for drinking water.

The water-quality data collected for the young valley fill are summarized below:

Stream Basin	n	~~Aquifer Type~~			Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Ahtanum		~~Young Valley~~		maximum	52	110	280	24	14	19	5.6	180
		~~Fill~~		mean	50	50	~~100~~ 40	19	11	~~13~~ 14	4.9	138
				minimum	47	20	<5	10	5.8	5.6	3.7	74
				n	3	3	3	3	3	3	3	3

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C				
8.0	11	.3	1.8	120	0	.27	610	13.2				
5.2	4.7	.2	.73	91	0	.23	310	12.7				
2.4	.7	.2	.01	49	0	.19	98	12.2				
3	3	3	6	3	3	3	6	3				

Old Valley Fill

Specific-conductance values ranged from 98 to 775, and averaged 456 micromhos for water from 11 wells tapping the old valley fill

As illustrated by figure 24, the five wells tapping the old valley fill for which complete common-ion analyses were made contain waters of higher percentage calcium than does the young valley fill or basalt. Two wells (12/18-8B1 and 12/18-11E1) contain higher percentages of sulfate and chloride than the other ground waters; the causes of these high percentages are not known. Due to the scantiness of the data available, the difference could not be linked to any variations in the water yielding materials or other overlying materials.

Water in the old valley fill ranged from soft to very hard--41 to 240 mg/L hardness (as $CaCO_3$) for five samples. The irrigation classification was C1-S1 for all but one well, 12/18-8G1, which contains C2-S1 waters. In general, the waters are excellent to good for irrigation.

Iron concentrations ranged from 50 to 4,200 ug/L in five samples, with two being above ~~the~~ 300 ug/L, the upper concentration recommended for drinking water. The high values indicate local iron problems, but the three wells that yielded samples with lower concentrations show the problem does not occur everywhere.

Manganese concentrations ranged from 0 to 190 ug/L in waters from five wells tapping the old valley fill. Two of the five exceeded the recommended limit of 50 ug/L for drinking water. The valley fill in places yields water containing excessive manganese.

No fecal-coliform bacteria were found in any of the water from the old valley fill.

Concentrations of nitrate (as N) ranged from 0.02 to 11 mg/L in the 11 samples. Except for the 11 mg/L in a sample from well 12/18-8K1, the concentrations are all well below the 10 mg/L recommended limit for drinking water. However, water from another well, 12/18-8G1, had a concentration of nitrate (as N) of 5.8 mg/L concentration of nitrate as N of 5.8 mg/L, about six times the average of the remaining wells sampled.

The water-quality data collected from the old valley fill are summarized below:

Stream Basin	n	~~Aquifer~~ Type			Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Ahtanum		Old ~~Valley~~ ~~Fill~~ alluvium		maximum		340a	140a	54	26	16	5.9	308
				mean	61	120a	90a	35	18	12	4.3	188
				minimum		50	0	9.8	4.0	3.5	3.2	54
				n	1	4	4	5	5	5	5	5

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C			
29	18	.3	11	240	32	.5	775	17.0			
17	9.7	.3	2.3	160	12	.4	456	13.5			
23	.7	.1	0.2	41	0	.2	98	10.4			
5	5	5	11	5	5	5	11	10			

a/ does not include 12/18-11K1 (Fe, 4200µg/l; Mn, 190µg/l).

Basalt

Specific conductance ranged from 102 to 194 micromhos in water from three wells tapping the basalt, indicating dissolved-solids concentrations similar to the minimums found in water from the old and young valley fill in this basin.

Figure 24 shows that the three wells tapping the basalt contain waters similar in percentage chemical composition to the water in the young valley fill in this basin. However, well 12/17-16D3 contains a higher percentage of sodium than the others.

Water in the basalt ranged from soft to moderately hard, with hardness concentrations ranging from 54 to 80 mg/L (as $CaCO_3$) in three samples. The irrigation classification was C1-S1 for all the wells sampled, indicating excellent quality for the purpose.

Iron concentrations ranged from 50 to 270 ug/L in three samples; all were below the 300 ug/L recommended limit for drinking water.

Manganese concentrations were determined to be less than 5 ug/L in two samples, indicating concentrations well below the 50 ug/L recommended limit for drinking water.

No fecal-coliform bacteria were found in any of the waters from the basalt.

Concentrations of nitrate (as N) ranged from 0.01 to 0.36 mg/L in four samples, indicating lower average concentrations than those found in the old and young valley fill in this basin.

The water-quality data collected from the basalt are summarized below:

Stream Basin	~~Aquifer Type~~		Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Ahtanum	Basalt	maximum	54	270	<5	16	9.7	17	3.2	116
		mean	48	130	<5	14	7.2	11	2.7	105
		minimum	38	50	<5	12	5.3	7.2	1.8	85
		n	3	3	2	3	3	3	3	3

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C			
4.4	3.0	.5	.36	80	0	1.0	194	17.2			
3.1	2.0	.3	.11	64	0	.6	154	15.4			
0.4	1.2	.2	.01	54	0	.4	102	13.4			
3	3	3	4	3	3	3	4	3			

Toppenish Creek Basin

Young Valley Fill

Specific conductance of water from 172 wells tapping the young valley fill ranged from 140 to 1,250 ~~micromhos~~ and averaged 304 micromhos per centimeter at 25°C. The highest observed specific conductance in the young valley fill ~~of~~ (1,250 micromhos per centimeter at ~~of water~~ from well 10/20-33L1 indicates an anomolous situation, as the water is much more mineralized than is normal for water in the young valley fill. The cause of the anomaly is not known. Only 6 of the 172 wells contained waters with specific conductance greater than 500 micromhos per centimeter at 25°C. Figure 25 shows the relationship between the geology of the basin and specific conductance of ground water in the various aquifers. As shown in the figure specific conductance does not increase uniformly from west to east--the general direction of ground-water movement in the basin.

The variations in specific conductance are probably due to the following factors:

(1) The influence of agricultural practices may be different in different locations. The young valley fill contains water with specific conductance predominantly less than 500 micromhos per centimeter at 25°C, as indicated by the 500-micromho contour line near the Main Canal and the dividing line between young and old valley fill.

(2) Variations may occur in the amount of water entering the aquifer from the surface, or from another aquifer.

(3) Differences may exist in the particle size of the water-yielding material, which affects both the rate at which water may move and the surface area of the particles in contact with a given volume of water. Generally, the finer the material the slower the water movement and the more water-ontact area, which both tend to increase the dissolved-solids and specific-conductance values for a given aquifer.

(4) The soil or rock type through which the water passes may be somewhat different.

The diagram of figure 26 illustrates the percentage composition of water from wells tapping the three major aquifers in the Toppenish Creek basin. As can be seen, water in the young valley fill averages slightly higher in percentage of calcium than does water in the basalt or old valley fill. Cation percentages are fairly consistant, but anion percentages tend to be slightly scattered.

The water in the young valley fill ranged from moderately hard to very hard, with hardness concentrations ranging from 78 to 230 mg/L (as $CaCO_3$) in 18 samples. The irrigation classification is C1-S1 for about 30 percent of the wells sampled, and C2-S1 for the remaining 70 percent. The single exception, well 10/20-33L1, contains water in the C3-S1 classification. In general, the water is excellent to good for irrigation.

Iron concentrations in 18 samples ranged from 20 to 1,900 ug/L and averaged 280 ug/L. Five of these samples contained iron concentrations above the 300 ug/L recommended limit for drinking water. The high values appear not to be associated with any particular location, well depth, or elevation.

Manganese concentrations in 16 samples ranged from 0 to 1,500 ug/L and averaged 130 ug/L. Four of these samples contained manganese concentrations above the 50 ug/L recommended limit for drinking water. Two samples were associated with excessive iron and two were not. The high manganese concentrations, like the high iron concentrations, did not appear to be associated with any particular location, well depth, or elevation.

No fecal-coliform bacteria were found in any of the waters from the young valley fill.

Concentrations of nitrate (as N) in 172 samples ranged from 0.00 to 7.6 mg/L and averaged 2.1 mg/L. All samples were below the 10 mg/L recommended limit for drinking water. The water in the young valley fill contained the highest average nitrate concentration in the basin; this is predominantly attributable to agricultural practices.

In an area 2 to 3 miles south of Harrah several wells in the young valley fill reflected concentrations of nitrate much higher than average.

The water-quality data from the young valley fill are summarized below:

Stream Basin	n	~~Aquifer Type~~			Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Toppenish		alluvium ~~Young Valley Fill~~		maximum	35	1900	1500	54	23	28	4.9	244
				mean	34	280	130	32	12	15	3.4	165
				minimum	32	20	0	20	6.9	5.9	1.4	100
				n	2	18	16	18	18	18	18	18

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C				
43	19	.5	7.6	230	29	1.0	1250	26.4				
12	5.3	.2	2.1	130	3	.6	304	13.8				
5.1	2.6	.0	.00	78	0	.3	140	9.5				
18	18	18	172	18	18	18	172	18				

Old Valley Fill

Water deep in the old valley fill has a distinctly lower dissolved-solids concentration than the shallower water in this aquifer. The hydraulics of the aquifer, described in a report on the water resources of the Toppenish Creek basin (U.S. Geological Survey, 1975), probably explain the reason for the difference. Prior to extensive irrigation development in the western part of the lowland area, the old valley fill received water from infiltrating precipitation and from the underlying basalt. Precipitation infiltrating through the surface soils tended to leach minerals, and resulted in more mineralized water entering the shallower parts of the old valley fill. However, the artesian pressure in the underlying basalt caused less mineralized water to move from the basalt into the lower parts of the old valley fill.

The hydraulic situation has changed, however, due to irrigation development. Two factors which contributed to changing the hydraulic situation may result in the more mineralized water moving farther downward in the aquifer. First, the additional application of water on the surface causes larger volumes of relatively more mineralized water to enter the aquifer, and second, wells pumping from the basalt have lowered the artesian pressure and caused a reversal of flow direction, and the water deep in the old valley fill now enters the basalt. Movement of the more mineralized water downward in the aquifer probably will be gradual, taking several tens of years to significantly change the dissolved-solids content of the deeper water.

Shallow water.--Specific conductance of water from 88 wells and springs in the upper part of the valley fill ranged from 104 to 1,540 ~~micromhos~~ and averaged 409 micromhos per centimeter at 25°C. This water is, on the average, the most mineralized ground water in the basin. This is probably because water percolating downward through the fine-grained silt and clay that overlies much of the old valley fill tends to leach more minerals than does water percolating through the coarser alluvial soils overlying the young valley fill. The young valley fill being coarser, permits larger volumes of water to move through per unit of time, resulting in a diluting effect. Figure 25 may be used to compare the variations in specific conductance in waters in the young valley fill, and in the upper parts of the old valley fill.

Figure 26 shows the differences in percentage composition of the waters in the three major aquifers. Although they have different dissolved-solids concentrations the shallow and deep waters in the old valley fill were found to have no significant differences in percentage compositions.

Well 10/18-21D1 (fig. 26) contains water of unusual composition, with almost 72 percent sodium, much more than any other ground water observed in the basin. The cause for this difference is unknown; the nitrate and chloride concentrations were not unusual, as would be expected if local septic-tank contamination were the source of the higher percent sodium.

The hardness of water in nine samples from the shallow parts of the old valley fill ranged from 68 to 420 mg/L (as $CaCO_3$), moderately hard to very hard. The irrigation classification was C1-S1 for about 40 percent of the wells sampled, C2-S1 for about 50 percent of the wells, and C3-S1 for about 10 percent of the wells. About 90 percent of the water is excellent to good for irrigation; the other 10 percent is acceptable for crops that are not salt sensitive.

Iron concentrations in nine samples ranged from 20 to 1,500 µg/L, but only two were greater than 100 µg/L. The recommended limit for drinking water is 300 µg/L. The high iron concentrations are randomly distributed, and are not associated with any particular well depth, or elevation.

Manganese concentrations ranged from 0 to 360 µg/L, but only one exceeded the recommended limit of 50 µg/L for drinking water.

Of more than 80 wells sampled, only one well (10/17-18H1) contained fecal-coliform bacteria, in a concentration of 1 col/100 mL. This bacterial occurrance is considered to be localized, and probably related to seepage into the well along the well casing.

Concentrations of nitrate (as N) in 88 samples ranged from 0.01 to 20 mg/L and averaged 1.4 mg/L. There is a significant area 3 to 4 miles northwest of Harrah with considerably higher-than-average concentrations in the shallow water of the old valley fill.

The water-quality data from the shallow water in the old valley fill are summarized below:

Stream Basin		Aquifer Type			Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (μg/l)	Dissolved Manganese (Mn) (μg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Toppenish		Old alluvium ~~Valley~~		maximum		1500	360	95	45	160	5.2	650
		~~Fill~~		mean	–	260	57	44	20	51	4.4	304
		(shallow zone ~~wells~~)		minimum		20	0	14	7.6	6.7	3.0	102
				n	0	9	9	9	9	9	9	9

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrite (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C				
140	69	1.4	20	420	6	5.5	1540	20.5				
29	16	.7	1.4	190	1	1.6	409	13.7				
2.5	1.0	.1	.01	68	0	.4	104	10.8				
9	9	9	88	9	9	9	88	9				

from the lower part of the valley fill

Deep~~er~~ water.--Specific-conductance values in nine samples ranged from 233 to 280 ~~micromhos~~, and averaged 251 micromhos per centimeter at 25°C. The narrow range indicates a very uniform mineralization of the waters; the slight differences are randomly distributed.

The percentage chemical composition of the water, as discussed earlier, is virtually the same as that in the shallow waters of the old valley fill. Figure 26 shows the difference in the percentage composition of the waters in the three water-yielding materials.

The five water samples from deep in the old valley fill are moderately hard, ranging from 78 to 95 mg/L (as $CaCO_3$). The irrigation classification is C1-S1 for one-third of the wells, and C2-S1 for two-thirds of the wells sampled. In general, the waters are excellent to good for irrigation.

Iron concentrations in the five samples ranged from 20 to 450 ug/L, with only one greater than the 300 ug/L recommended limit for drinking water.

Manganese concentrations ranged from 0 to 680 ug/L, with three of the five samples equaling or exceeding the 50 ug/L recommended limit for drinking water. The other two samples had 0 ug/L manganese concentrations.

No fecal-coliform bacteria were found in any of the samples collected from deep in the old valley fill.

Nitrate (as N) concentrations in nine samples ranged from 0.01 to 1.1 mg/L and averaged 0.26 mg/L.

The water-quality data collected from deep in the old valley fill are summarized below:

Stream Basin	n	~~Aquifer Type~~ ~~Deep~~		Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Toppenish		Old ~~Valley~~	maximum	—	450	680	25	9.2	25	4.6	163
		~~Fills~~ alluvium	mean	—	160	200	21	8.2	20	4.1	148
		(Deep wells)	minimum		20	0	19	7.4	11	2.5	124
			n	0	5	5	5	5	5	5	5

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C				
13	4.5	.7	1.1	95	0	1.2	280	23.0				
5.3	3.7	.5	.26	87	0	1.0	251	16.4				
.5	3.1	.3	.01	78	0	.5	233	11.4				
5	5	5	9	5	5	5	9	5				

Basalt

Specific conductance of water in 35 samples collected from the basalt ranged from 152 to 530 ~~micromhos~~ and averaged 290 micromhos per centimeter at 25°C. The variations in concentrations were not associated with well depth or the elevation of the well bottom, as ~~may~~ occurs ~~elsewhere~~ in basalt in some other parts of Washington. ~~with its commonly distinct and separate water-yielding zones.~~ The water in the basalt in the Toppenish Creek basin contains more dissolved solids, on the average, than does water in the basalt in Ahtanum Creek or Klickitat River basins, but it has about the same as that in the basalt in Satus Creek basin. Less precipitation over the Toppenish and Satus Creek basins probably accounts in part for the higher concentrations.

Figure 26 shows that the basalt contains water having less percentage calcium and more percentage bicarbonate, on the average, than do the young or old valley fill in the basin.

The water in 14 samples from the basalt is moderately hard, with hardness ranging from 62 to 120 mg/L (as $CaCO_3$). The irrigation classification was C1-S1 for about 45 percent and C2-S1 for about 55 percent of the samples, indicating excellent to good quality for irrigation.

Iron concentrations in 13 samples ranged from 20 to 200 ug/L, all below recommended drinking-water limits. A sample not included in this range (well 11/16-34K2) contained 2,200 µg/L of iron; the reason for this high concentration was not determined.

Manganese concentrations in 14 samples ranged from 0 to 360 µg/L; the water in 6 samples equaled or exceeded the 50 µg/L recommended limit for drinking water.

Two wells tapping the basalt contained fecal-coliform bacteria. Water from well 10/16-15N1 contained an estimated concentration of more than 500 col/100 mL, and water from well 10/18-31N1 contained 6 col/100 mL. Both wells probably are contaminated locally, by seepage along the well casing.

Concentrations of nitrate (as N) in 35 samples ranged from 0.00 to 1.5 mg/L and averaged 0.20 mg/L, very similar to that found in the deeper water in the old valley fill.

The water-quality data collected from the basalt are summarized below:

Stream Basin	~~Aquifer Type~~		Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Toppenish	Basalt	maximum	---	200*	360	23	16	35	5.1	217
		mean	—	80*	80	19	10	21	3.8	156
		minimum		20	0	14	5.9	7.9	2.5	101
		n	0	13	14	14	14	14	14	14

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C				
18	11	1.2	1.5	120	0	1.8	530	29.6				
4.0	4.1	.6	.20	89	0	1.0	290	18.9				
.8	1.0	.1	.00	62	0	.3	152	10.3				
14	14	14	35	14	14	14	35	35				

* does not include 11/16-34K2, Fe = 2200 µg/l.

Satus Creek Basin

Young Valley Fill

Specific conductance of water from 30 wells tapping the young valley fill in the Satus Creek basin ranged from 100 to 930 ~~micromhos~~ and averaged 468 micromhos per centimeter at 25 °C.

fig 27 Figure 27 illustrates the variation in percentage chemical composition of the waters from the three major aquifers in the basin. The single complete sample from the young valley fill has a composition intermediate between those of the waters of the old valley fill and the basalt.

The water of the single sample was very hard, with a hardness concentration of 200 mg/L (as $CaCO_3$). The irrigation classification is C1-S1 for about 10 percent of 28 samples, C2-S1 for about 75 percent, and C3-S1 for about 15 percent. The water is mostly excellent to good, except for that in the C3-S1 classification which is acceptable only for salt-tolerant crops.

Iron concentration in the single sample was 40 µg/L and manganese concentration was 0 µg/L; both of these values are well below recommended drinking-water limits.

No fecal-coliform bacteria were found in water from any of 21 wells sampled.

Nitrate (as N) concentrations in 28 samples ranged from 0.00 to 4.8 mg/L and averaged 0.92 mg/L, all well below recommended limits.

The water-quality data collected from the young valley fill are summarized below:

Stream Basin	n	~~Aquifer Type~~			Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (ug/l)	Dissolved Manganese (Mn) (ug/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
SATUS	5	Young ~~Alluv~~ ~~Eff~~ alluvium		maximum								
				mean	-	40	0	41	23	25	3.1	247
				minimum								
				n		1	1	1	1	1	1	1

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C			
			4.8				930	21.2			
28	16	.2	.92	200	0	.8	468	14.1			
			.00				100	8.1			
1	1	1	28	1	1	1	27	28			

Old Valley Fill

Specific conductance of water from 38 wells and springs in the old valley fill of Satus Creek basin ranged from 310 to 1,250 ~~micromhos~~, and averaged more than 790 micromhos per centimeter at 25°C. The average concentration of dissolved solids was higher in water from old valley fill in the Satus Creek basin than in any of the other major aquifers in the reservation. The high dissolved solids concentrations probably are due to the deposits of silt and clay which overlie most of the old valley fill in the Satus Creek basin as explained on p. 56.

Figure 27 illustrates the strong similarity in percentage composition of cations and the contrasting variability in percentage composition of anions in the waters of the old valley fill; this may indicate that an ion-exchange process is affecting the percentage composition of cations.

The water in six samples ranged from hard to very hard, with hardnesses ranging from 130 to 480 mg/L (as $CaCO_3$) and averaging 360 mg/L, more than three times the average for all the reservation's ground waters. The irrigation classification of water is C2-S1 for 50 percent of 38 samples, and C3-S1 for the other 50 percent. This indicates that one-half of the water sampled was good for irrigation, and one-half was acceptable for salt-tolerant crops.

Iron concentrations in water of six samples ranged from 20 to 260 µg/L, with none exceeding recommended drinking-water standards. However, manganese in the water ranged from 0 to 650 µg/L, and exceeded the iron concentration in one sample, the only one in which manganese exceeded the recommended drinking-water standard of 50 µg/L.

No fecal-coliform bacteria were found in any of the waters from the old valley fill.

Concentrations of nitrate (as N) ranged from 0.11 to 170 mg/L, and averaged 23 mg/L, in water from 38 samples. The recommended limit for drinking water (10 mg/L) was exceeded in many of the samples. The problem is widespread, covering several square miles. Figure 11 delineates the area having water exceeding the recommended limits. The cause of the high nitrate concentrations is not certain, but natural buildup of nitrate is not uncommon in the soils of arid areas such as this, and may be the cause here. the origin of such natural buildup of nitrate is still a matter of controversy (RANKAMA + Sahama, 1950). In both the Toppenish Creek and Satus Creek basins known high nitrate concentrations occur predominantly where the soils or aquifers are composed of lake-laid silt and clay; in this part of the Satus Creek basin, the silt and clay beds are several tens of feet thick. After irrigation began the nitrates which had previously built up in the soils would begin to percolate downward. However, the silt and clay may have delayed percolation of the nitrates in this area to the extent that the nitrates are still observable at the present time. This implies that nitrate buildup may have occurred over a more widespread area, and that rapid percolation and dilution has removed most evidence of this except in the areas underlain by the less permeable silts and clays. There are three reasons for suspecting a natural surficial source for the nitrate increase. First, there is no identifiable man-induced source for such widespread high-level nitrate contamination; second, there is no known source of high nitrate concentration within the silt and clay beds in this basin or in the other basins in the State containing these beds; and, third, the vertical permeability and head gradients are compatible with a near-surface source of nitrate in ~~this~~ the high-nitrate area.

The water-quality data collected from water in the old valley fill are summarized below:

Stream Basin		~~Aquifer Type~~			Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Satus		Old ~~Alluvium~~ ~~Fill~~		maximum	62	260	650	120	44	33	6.2	215
				mean	52	80	130	90	33	27	4.4	163
				minimum	39	20	0	33	12	18	1.5	111
				n	3	6	5	6	6	6	6	6

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C			
240	70	.8	170	480	380	.7	1250	22.0			
130	41	.5	23	360	230	.6	7790	15.9			
29	13	.2	.11	130	41	.4	310	10.2			
6	6	6	38	6	6	6	38	38			

11

Basalt

Specific conductance of water in the basalt ranged from 115 to 420 ~~micromhos~~ and averaged 267 micromhos per centimeter at 25°C, excluding that of water from well 8/22-3K1. This well water, with a specific conductance of 655 micromhos per centimeter at 25°C and a nitrate (as N) concentration of 11 mg/L, was excluded from the averaging as it was considered to be a localized contamination, probably by leakage around the well casing resulting in water from the old valley fill entering the basalt.

Figure 28 shows that in the Satus Creek basin the water in the basalt contains a higher percentage of sodium and bicarbonate than does the water in the young or old valley fill.

The water in five samples from the basalt had hardness ranging from 43 to 180 mg/L (as $CaCO_3$), from soft to hard. The irrigation classification of 20 samples was C1-S1 for about 35 percent of the samples and C2-S1 for the remaining 65 percent. The waters generally are excellent to good for irrigation.

Iron concentrations in water from four samples ranged from 20 to 230 µg/L, all less than the 300 µg/L recommended limit for drinking water.

Manganese concentrations in the four samples ranged from 0 to 50 μg/L, the high value equaling the recommended limit in drinking water.

The number of fecal-coliform bacteria found in six springs flowing from the basalt are listed below:

Spring	Colonies per 100 milliliters
6/18-9B1s----	>500 estimated
7/18-8K1s----	21
7/19-25N1s---	199
7/19-29A1s---	>500 estimated
7/20-21J1s---	28
7/21-9Q1s----	9

The fecal-coliform contamination undoubtedly originates from range cattle that often walk directly through the water.

Nitrate (as N) concentrations ranged from 0.00 to 3.0 mg/L, excluding the previously mentioned sample from well 8/22-3KL, which contained 11 mg/L. The average of 20 samples was 0.79 mg/L.

The water-quality data collected from the basalt are summarized below:

Stream Basin	n	Aquifer Type			Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
SATUS	5	Basalt		maximum	50	230	50	42	17	43	9.0	226
				mean	48	100	10	26	11	24	3.6	174
				minimum	47	20	0	10	4.3	5.3	1.5	55
				n	2	4	4	5	5	5	5	5

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrate plus Nitrite (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C				
17	11	.8	3.0 1/	180	0	1.9	420 1/	19.8				
11	6.6	.5	.79 1/	110	0	1.0	267 1/	12.7				
2.3	1.3	.1	.00	43	0	.4	115	7.5				
5	5	5	20	5	5	5	20	19				

1/ does not include 8/22-3K1 (specific conductance = 655 micromhos per centimeter at 25°C, nitrate plus nitrite (as N) = 11 mg/l)

Valley Fill

Specific conductance of water in four samples ranged from 62 to 82 ~~micromhos~~ and averaged 72 micromhos per centimeter at 25°C. These values indicate that the valley fill in the Klickitat River basin contains the most dilute ground water in the reservation. Figure 28 shows that in the Klickitat River basin the water from the valley fill is similar in percentage composition to water from the basalt.

The water is classified as soft, with hardness of water from three samples ranging from 19 to 30 mg/L (as $CaCO_3$). The irrigation classification is C1-S1, indicating excellent quality water for the purpose.

Iron concentrations in three samples ranged from 70 to 330 ug/L, only the highest exceeding the recommended drinking-water limit of 300 ug/L. Manganese concentrations for these three samples were all 0.0 ug/L.

No fecal-coliform bacteria were found in any of the waters from the valley fill.

Nitrate (as N) concentrations in four samples ranged from

0.04 to 1.3 mg/l. These low concentrations indicate minimal impact from the very localized agricultural development in the basin.

The water-quality data collected from water in the valley fill are summarized below:

Stream Basin	Aquifer Type		Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Klickitat	~~Unconsolidated~~	maximum		330	0	7.9	2.7	3.2	2.2	50
	Alluvium	mean		170	0	6.9	2.5	3.1	1.9	43
	~~Klung Valley~~	minimum		70	0	5.1	2.1	2.8	1.6	36
	~~Till?~~	n		3	3	3	3	3	3	3

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C				
2.0	1.5	.1	1.3	30	0	.3	82	12.3				
1.7	1.0	.0	.38	24	0	.3	72	10.8				
1.5	.5	.0	.04	19	0	.3	62	9.7				
3	3	3	4	3	3	3	4	4				

Basalt

Specific conductance of water in 53 samples ranged from 20 to 195 ~~micromhos~~ and averaged 79 micromhos per centimeter at 25°C. The basalt in the Klickitat River basin contains water that has only slightly more dissolved solids than does water in the valley fill in that basin. Four springs flowing from the basalt were not included in the above range or average because they are believed to originate in a much deeper basalt. These springs are discussed in detail later. Figure 28 shows that, except for these springs, the percentage compositions of the waters in the basalt and the valley fill are very similar.

The water in 23 samples from the basalt ranged from soft to moderately hard, with hardness concentrations ranging from 8 to 120 mg/L (as $CaCO_3$); only two samples had water exceeding the soft classification.

Iron concentrations ranged from 10 to 2,100 µg/L and averaged 210 µg/L. Two springs and two wells exceeded the recommended limit of 300 µg/L for drinking water.

Manganese concentrations in 23 samples ranged from 0 to 170 µg/L and averaged 10 µg/L. The high value was the only one exceeding the 50 µg/L recommended limit for drinking water.

Fecal-coliform bacteria were present in water from two srpings flowing from the basalt. These springs (11/13-3E1s and 11/13-4K2s) both contained 3 col/100 mL. Range cattle are the most probable source of the contamination.

Nitrate (as N) concentrations in 42 samples ranged from 0.00 to 2.0 mg/L and averaged 0.16 mg/L, the lowest average concentration in ground waters in the reservation.

The water-quality data collected from water in the basalt are summarized below:

Stream Basin	~~Aquifer Type~~		Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
Klickitat	Basalt	maximum 1/		2100	170	33	10	8.5	4.7	124
		mean 1/	35	210	10	8.4	3.3	3.7	1.6	49
		minimum		10	0	2.1	.6	.8	.6	10
		n	1	23	23	23	23	23	23	23

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C
2.0	1.5	.2	2.0	120	22	.3	195	12.3
1.0	.8	.0	.16	35	1	.3	79	16.8
.1	.2	.0	.00	8	0	.1	20	2.4
23	23	23	42	23	23	23	53	53

1/ does not include 6/13-4H1S, 9/13-18P1S, 11/12-24L1S, or 11/13-4K1S; all ~~unusual~~ springs, believed to originate in a much deeper basalt and for which individual analyses are listed later. ~~in Appendix~~ —.

Deep-Basalt Springs

Four springs--6/13-4H1s, 9/13-18P1s, 11/12-24L1s (Soda Springs), and 11/13-4K1s--~~are believed to~~ issue water that may originate~~s~~ deep in the basalt beneath the Klickitat River basin. This is suggested by the following observations.

1. The water is of relatively high~~er~~ temperature, indicating greater depth due to the temperature gradient in the earth--the springs ranged from 4° to 15°C warmer than other nearby springs. ~~Also, iron concentrations were high to extremely high in water from three of the springs. High concentrations of iron, and elevated temperatures are characteristic of thermal springs in volcanic zones.~~ The warmer temperatures may also suggest fault zones, but such a determination is beyond the scope of this present study.

2. The presence of carbon dioxide gas (CO_2) bubbling from the springs suggests ~~indicates~~ a release of pressure ~~that~~ resulting ~~results~~ from a rise of the water from great depth. Soda Springs (11/12-24L1s) has long been known to release large quantities of carbon dioxide. Gas bubbles, assumed to be carbon dioxide, were observed in springs 6/13-4H1s and 11/13-4K1s. Only a few gas bubbles were observed at spring 9/13-18P1s, but a large amount of gas could have been released in the loose sands and gravels which surround the spring.

3. ~~Another observation, although not directly an indication of depth, is supportive.~~ The four springs all yield water containing much higher dissolved-solids concentrations than the usual springs in the basin. Also, the waters are slightly different in percentage composition, with spring 11/13-4K1s containing water very materially different in percentage composition from any other ground water sampled in the reservation. Although the higher dissolved-solids contents and the differences in percentage composition (fig. 28) suggest a different source but not necessarily a different depth, it is reasonable to assume, in conjunction with the other observations, that the water is coming from considerable depth in the basalt.

The four ~~deep-basalt~~ springs had both the highest and the lowest observed concentrations of several of the common ions. Spring 11/12-24L1s had the highest calcium concentration, 120 mg/l. Spring 6/13-4H1s had the highest magnesium, sodium, potassium, and bicarbonate concentrations--95, 160, 16, and 1,130 mg/l, respectively. Spring 9/13-18P1s also had a potassium concentration of 16 mg/l. Spring 11/13-4K1s had the lowest magnesium concentration, 0.4 mg/l.

The chemical and physical characteristics of water from the four springs are summarized below:

~~Stream Basin~~	Spring	~~Aquifer Type~~			Dissolved Silica (SiO_2) (mg/l)	Dissolved Iron (Fe) (µg/l)	Dissolved Manganese (Mn) (µg/l)	Dissolved Calcium (Ca) (mg/l)	Dissolved Magnesium (Mg) (mg/l)	Dissolved Sodium (Na) (mg/l)	Dissolved Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)
	6/13-4H1S					2200	60	110	95	160	16	1130
	9/13-18P1S					23,000	760	97	86	150	16	951
	11/12-24L1S					19,000	370	120	78	130	2.2	806
	11/13-4K1S					70	0	2.7	.4	100	3.5	279

Dissolved Sulfate (SO_4) (mg/l)	Dissolved Chloride (Cl) (mg/l)	Dissolved Fluoride (F) (mg/l)	Total Nitrite plus Nitrate (N) (mg/l)	Total Hardness (Ca, Mg) (mg/l)	Noncarbonate hardness (mg/l)	Sodium Adsorption Ratio	Specific Conductance (micromhos)	Temperature °C				
2.6	49	.4	.49	670	0	2.7	1660	23.8				
2.2	92	.3	.01	600	0	2.7	1800	12.2				
2.6	150	.2	.00	620	0	2.3	1500	9.5				
.8	1.0	.5	.10	8	0	15	440	13.8				

As can be seen from the specific conductance of water in the first three springs listed, the springs contain the most mineralized ground water found on the reservation. Water from the fourth spring is only about one-third as mineralized, but still far more mineralized than the waters found in the major aquifers.

The percentage composition of the waters from the first three springs is slightly different from that of nearby springs, in that they contain water of higher percentage magnesium and lower percentage calcium. Springs 9/13-18P1s and 11/12-24L1s also contain a higher percentage chloride. The fourth spring (11/13-4K1s) is very unusual, as it contains water whose chemical composition is 93 percent sodium and 99 percent bicarbonate. The cause of this difference is not known.

The water of the first three springs listed is classified as very hard, and that of the fourth spring is soft. The first three had the hardest waters observed, and the fourth had among the softest. Water from the first three springs was classified as C3-S1 for irrigation and that from the fourth spring was C2-S3. For irrigation, the first three springs indicate a salinity hazard, and the fourth spring a sodium hazard.

Iron concentrations were very high in springs 9/13-18P1s and 11/12-24L1s, being 23,000 µg/L and 19,000 µg/L, respectively.

Manganese concentrations were also high in these two springs, being 760 ug/L and 370 ug/L, respectively.

No fecal-coliform bacteria were found in any of the four springs.

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Significance of Water Constituents and Characteristics and Water-Quality Criteria

constituents and characteristics

The parameters selected for observation in this study are arranged alphabetically, and a discussion of their significance and of the various criteria is included for each parameter.

Chlorophyll.--Chlorophyll is the green-colored matter in plants that is partly responsible for photosynthesis. A measurement of chlorophyll concentration in water provides an estimation of the amount of free-floating algae in the water. Chlorophyll a and chlorophyll b are the most common types, and only determination of chlorophyll a was considered necessary for this reconnaissance study.

Color.--Color is obtained from dissolved and colloidal substances in the water. The color of natural stream waters commonly results from leaching of organic debris, although it may be due to metallic substances such as iron and manganese. Color is measured on a platinum-cobalt scale and is expressed as color "units."

U.S. Public Health Service (1962) recommends an upper limit of 15 color units for drinking water. Color is undesirable for esthetic reasons and also because it may cause staining of clothes or fixtures. Color does not seem to be hazardous

191—192

to aquatic life, except indirectly by reducing light penetration which decreases biological productivity.

Common ions.--The ions generally of most abundance in water include four positively charged ions--calcium, magnesium, sodium, and potassium--and six negatively charged ions--bicarbonate, carbonate, sulfate, chloride, nitrate, and fluoride.

The ions are significant in several ways. Calcium and magnesium are the principal causes of hardness of water, sodium affects the suitability of its use for irrigation, nitrate is a plant nutrient and at high concentration may be poisonous to animals, and fluoride is beneficial in prevention of tooth decay, but detrimental at too high a concentration. Combined, the common ions contribute most of the dissolved-solids concentration of the water, which affects suitability for uses such as for drinking and irrigation.

Dissolved oxygen.--The DO (dissolved-oxygen) concentration is potentially a major concern for some streams in the reservation, and is one indication of the suitability of the stream for the support of fish and other aquatic life. Fish and other desirable aquatic life must have water with a relatively high DO concentration at all times. A fish's respiration rate increases with increased water temperature, and its oxygen requirements may double or triple for a 10°C rise in water temperature. Also, the higher the water temperature, the lower the solubility of oxygen. The Aquatic Life Advisory Committee of Ohio River Valley Water Sanitation Commission (1955) has recommended that the minimum permissible DO concentration for a well-rounded warm-water fish population (such as that found in many of the lowland streams and drains of the reservation), be as follows:

> "The dissolved-oxygen content of warm water fish habitats shall be not less than 5 mg/1 during at least 16 hours of any 24-hour period. It may be less than 5 mg/1 for a period not to exceed 8 hours within the 24-hour period, but at no time shall the oxygen content be less than 3 mg/1. To sustain a coarse fish population, the dissolved-oxygen concentration may be less than 5 mg/1 for a period of not more than 8 hours out of any 24-hour period, but at no time shall the concentration be lower than 2 mg/1."

The Washington State Department of Ecology (1973) lists the criteria[1] for DO concentrations in lakes and streams as follows:

	Stream class				
	AA (extra-ordinary)	A (excellent)	B (good)	C (fair)	Lake class
DO (mg/1)	>9.5	>8.0	>6.5	> 5.0	No measurable decrease from natural conditions

[1]Observed measurements do not determine a stream's class, but rather determine whether a stream of a given class is in compliance or violation of State criteria. For example, the reach of the Yakima River from about 2 miles below the town of Parker the mouth of the river is designated as a class B reach. No matter how high the DO concentration becomes, the stream class does not change for that time period. But, if DO concentration becomes less than 6.5 mg/l, a violation of the class B criterion occurs.

The solubility of oxygen is mainly a function of temperature and of atmospheric pressure. As water temperatures vary throughout a 24-hour period, the DO concentration in the water will also vary in the direction of maintaining an equilibrium condition of saturation. In addition to the effects of temperature, diel variations (variations within a 24-hour period) may be caused by the photosynthetic action of algae and submersed aquatic plants giving off oxygen during daylight hours and using oxygen during respiration at night. The magnitude of the diel variations caused by this biological activity is a gross indicator of a stream's productivity.

Because it is at warmer water temperatures that oxygen levels become critical, summertime is when an assessment of DO concentration and percentage saturation is most important.

Dissolved solids.--Dissolved-solids concentration is a measure of the amount of dissolved material in the water. The sum of the major dissolved constituents in water, in milligrams per liter, approximates the weight of mineral residue in 1 liter of water evaporated to dryness. However, a correction factor (mg/L bicarbonate x 0.4917 = mg/L carbonate) must be applied to the bicarbonate, as it becomes carbonate in the residue. The factor assumes that one-half of the bicarbonate is volatilized as carbon dioxide and the remainder is converted to carbonate. Drinking water for interstate carriers should contain no more than

500 mg/L of dissolved solids unless a more suitable supply cannot be found (U.S. Public Health Service, 1962). The same limit is commonly suggested for all domestic-water supplies. For use for irrigation, water may have a considerably higher dissolved-solids concentration if proper leaching practices are used.

Fecal-coliform bacteria.--Fecal coliforms are a very significant problem in some of the streams of the reservation. Fecal coliforms are nonpathogenic (not disease-producing) bacteria which normally inhabit the gut and feces of warmblooded animals. Normal human feces will produce, on the average, about two billion fecal-coliform bacteria per day.

The presence of fecal-coliform bacteria is not significantly a good or bad characteristic of water but it is an indicator. A danger associated with drinking water is contamination by sewage or by human or animal excrement. Sewage and feces are known carriers of disease-producing bacteria, and serious disease may result from contact or ingestion of polluted waters. Fecal-coliform bacteria greatly outnumber disease-producing bacteria in the feces of warmblooded animals, and if fecal-coliform bacteria cannot be found in the water, it can, in general, be inferred that disease-producing bacteria also are absent. Bacteriological identification of the fecal coliforms is considerably easier and less time-consuming than individually testing for each possible disease-producing bacteria.

For many years water-quality standards were based on the test for total coliform bacteria, which included fecal-coliform bacteria and also more common bacteria generally of nonfecal origin, and associated with soils and vegetables. Because the test for total coliform bacteria is not necessarily evidence of fecal pollution, it is gradually being replaced by the test for fecal-coliforms as the recommended procedure for determining the bacteriological quality of the water. Total-coliform analysis may be used as an alternative to fecal-coliform analysis with the realization that such data are subject to a wide range of concentration fluctuations of doubtful sanitary significance. The total-coliform analysis is still widely used in evaluating finished drinking water because it provides a more stringent index.

In general, unpolluted stream water has a low concentration of coliform bacteria, normally fewer than 100 total-coliform or 20 fecal-coliform colonies per 100 milliliters.

The following are the criteria of the U.S. Federal Water Pollution Control Administration (1968; now the Environmental Protection Agency) for coliform-bacteria content for various uses.

1. Drinking-water supplies

The presence of any coliform organism in a water supply suggests fecal contamination.

Raw water: Desirable - less than 100 total coliforms/100 mL
less than 20 fecal coliforms/100 mL

Permissible - 10,000 total coliforms/100 mL
2,000 fecal coliforms/100 mL

2. Primary recreation water (contact sports: swimming, water skiing, etc.

Only fecal-coliform data should be used. At least five samples should be taken during a 30-day period. Mean of five samples should be fewer than 200 colonies/100 mL, and no more than 10 percent of samples should exceed 400 colonies/100 mL.

3. Secondary recreation water (non-contact sports: boating, fishing, etc.)

Only fecal-coliform data should be used. At least five samples should be taken during a 30-day period. Mean of five samples should be fewer than 1,000 colonies/100 mL, and no more than 10 percent of samples should exceed 2,000 colonies/100 mL.

4. Irrigation water

Average of at least two consecutive samples examined per month shall not exceed 5,000 total coliforms/100 mL and 1,000 fecal coliforms/100 mL.

For a single sample, concentration shall not exceed 20,000 total coliforms/100 mL and 4,000 fecal coliforms/100 mL.

The State of Washington water-quality criteria (Washington State Department of Ecology, 1973) are as follows:

	AA (extra-ordinary)	A (excellent)	B (good)	C (fair)	Lake class
Total coliform organisms (col/100 mL) median values	< 50	≤ 240	≤ 1,000	≤ 1,000	≤ 240

Fluoride.--Fluoride is one of the common ions, and is dissolved in small quantities from many rocks and soils. Fluoride in drinking water reduces the incidence of tooth decay in children. However, in excessive concentrations it may cause mottling of the teeth. According to the U.S. Public Health Service (1962), the recommended acceptable and rejection limits are dependent on the annual average of maximum daily air temperatures, as follows:

	Average fluoride concentration	
Annual average maximum daily air temperature (°F)	Recommended upper limit (mg/L)	Rejection limit (mg/L)
50.0-53.7	1.7	2.4
53.8-58.3	1.5	2.2
58.4-63.8	1.3	2.0
63.9-70.6	1.2	1.8
70.7-79.2	1.0	1.6
79.3-90.5	.8	1.4

The expected intake of water is higher in warmer climate; therefore a lower concentration gives the same daily fluoride intake.

Hardness.--The hardness of water is an important consideration for domestic, municipal, and industrial uses. It is related almost entirely to the presence of calcium and magnesium ions. Other constituents such as iron, manganese, and strontium also cause hardness but they are not usually present in quantities large enough to have any appreciable effect. Hardness commonly is recognized by the increased quantity of soap required to produce lather. Many industrial uses require soft water. A commonly accepted classification for hardness of water is as follows:

Hardness range (mg/L of $CaCO_3$)	Description
0-60	Soft
61-120	Moderately hard
121-180	Hard
more than 180	Very hard

Iron.--For drinking water, iron in excess of 300 μg/L ~~(micrograms per liter)~~ generally has unpleasant taste; it also is considered undesirable because of staining and formation of deposits and favors growth of iron bacteria. Considerably higher concentrations are not harmful to humans.

Manganese.--For drinking water, manganese in excess of 50 ug/L is generally considered undesirable because of impairment of the taste of beverages such as coffee and tea; staining also occurs. McKee and Wolf (1963) stated that concentrations not exceeding those below do not appear to be deleterious to the stated uses:

Domestic water supply--------	50 ug/L
Industrial water supply------	50 ug/L
Irrigation-------------------	500 ug/L
Stock watering---------------	10,000 ug/L
Fish and aquatic life--------	1,000 ug/L

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Nitrogen.--Nitrates are added to soil and water by microbial fixation of atmospheric nitrogen. Some nitrogen is added to the soil in rainwater. Fertilizers in recent years have become a significant source of additional nitrogen compounds in farm soils.

Nitrogen, like phosphorus, is an essential nutrient, critical to the growth of aquatic and terrestrial vegetation. Insufficient nitrogen may limit the growth of aquatic vegetation.

Nitrogen compounds in irrigation water are generally considered beneficial. In waters used for recreation they may or may not be beneficial depending upon desired uses. Increased nitrogen compounds and other nutrients increase the aquatic vegetation, and increase the suitability of the waters for fish life. However, increased nitrogen in the water is considered detrimental if aquatic plants become too dense and (or) interfere with the beneficial uses of water.

According to Sawyer (1947), algae growths are not troublesome when concentrations of nitrate (as N) are less than 0.30 mg/L if phosphorus (as P) is kept less than 0.015 mg/L. Others (Imhoff, 1955; Mueller, 1953) also indicate that, in addition to the nitrate and phosphorus limits, total nitrogen (as N) must be kept less than 0.6 mg/L to prevent troublesome algal growths.

A high concentration of nitrate in drinking water may be dangerous to humans, especially to infants. For this reason, nitrate is a considerable problem in some areas of the reservation where ground water has high nitrate concentrations. The U.S. Public Health Service (1962) recommends that water with concentrations of nitrate (as N) greater than 10 mg/L should not be used for drinking water.

Nitrogen occurs in water mainly as nitrate, nitrite, and ammonium ions, or it is bound in proteins and other organic compounds. For this study, the analytical methods give concentrations in pairs, as nitrite-plus-nitrate concentrations, or as ammonia-plus-organic concentrations. The ammonia-plus-organic nitrogen is referred to as Kjeldahl-nitrogen, after the inventor of the analytical method. The nitrite-plus-nitrate concentration in addition to the Kjeldahl-nitrogen concentration constitute the total-nitrogen concentration.

Organic carbon.--Organic carbon may be present in waters either as part of dissolved organic compounds, or as suspended particulate matter, generally organic detritus. Organic carbon is distinguished from inorganic carbon in that inorganic carbon exists as carbon dioxide, or as bicarbonate or carbonate--the fully oxidized compounds of carbon--whereas all other forms of carbon that may be oxidized are organic. Organic-carbon concentrations in water indicate the organic content of the water. Generally, unpolluted natural waters contain low concentrations of organic carbon. High concentrations may be indicative of artificial sources and the potential for hazardous organic substances in the water.

Pesticides.--A pesticide may be defined as any substance used to kill pest organisms, and includes insecticides, herbicides, algicides, fungicides, and bacteriacides. Determination of pesticides in water is important because of their potential toxicity; however, this study indicated little problem for the one site studied. Widespread application to land, forest, and water can produce undesirable side effects such as unwanted deaths of aquatic animals or damage to plants. Contamination of surface water by pesticides can be caused by (1) direct application for the control of aquatic weeds or insects, (2) percolation or leaching by rainwater or irrigation water from treated agricultural land, or (3) drift of aerosol sprays during application.

Many pesticides are persistent in that they do not readily decompose. The most widely used persistent pesticides are the chlorinated hydrocarbons, of which the familiar DDT, Chlordane, and Dieldrin are examples. If ingested, chlorinated hydrocarbons are concentrated in fatty parts of organisms' bodies, and can accumulate to many times the concentration at which they were ingested. Because the chlorinated hydrocarbon pesticides are persistent, they can be passed from one organism to another, greatly increasing in concentration in the process.

Phosphorus.--Phosphorus in surface water occurs naturally in small amounts as inorganic phosphates as the result of weathering. Other sources are sewage, animal wastes, and fertilizers. Because phosphorus is essential to metabolism, it is always present as a component of domestic sewage and of animal wastes. Phosphate fertilizers commonly are applied in areas where irrigation is practiced and therefore are a source of phosphate in drainage water.

Phosphorus is critical to the growth of organisms in the aquatic environment. It is frequently a limiting factor in the growth of aquatic plants and algae. Concentrations less than 0.01 mg/L orthophosphorus (as P), or 0.05 mg/L total phosphorus (as P) are generally considered limiting, and those greater may support abundant growths. Phosphate is not harmful to fish life and is generally considered beneficial in irrigation waters. It is harmful mainly in creating nuisance growths of algae and other aquatic vegetation which may be unsightly and which can even deplete the DO supply sufficiently to kill fish.

Silica.--Silica is dissolved in small amounts from nearly all rocks and soils. In concentrations found in natural waters, silica appears to have no adverse physiological affects. However, it is undesirable in boiler feedwaters, as it forms hard scale.

Sodium-adsorption ratio.--The suitability of water for irrigation is in part determined by the degree of mineralization and the character of the minerals dissolved. Most commonly, these important characteristics are classified according to suitability by means of specific conductance, and by means of the sodium-adsorption ratio (SAR). The SAR is a way of expressing numerically the likelihood of sodium entering into ion-exchange reactions with calcium or magnesium in the soil. This exchange process is undesirable because a buildup of sodium in the soil makes it difficult to cultivate and water does not penetrate it well. The SAR is defined as

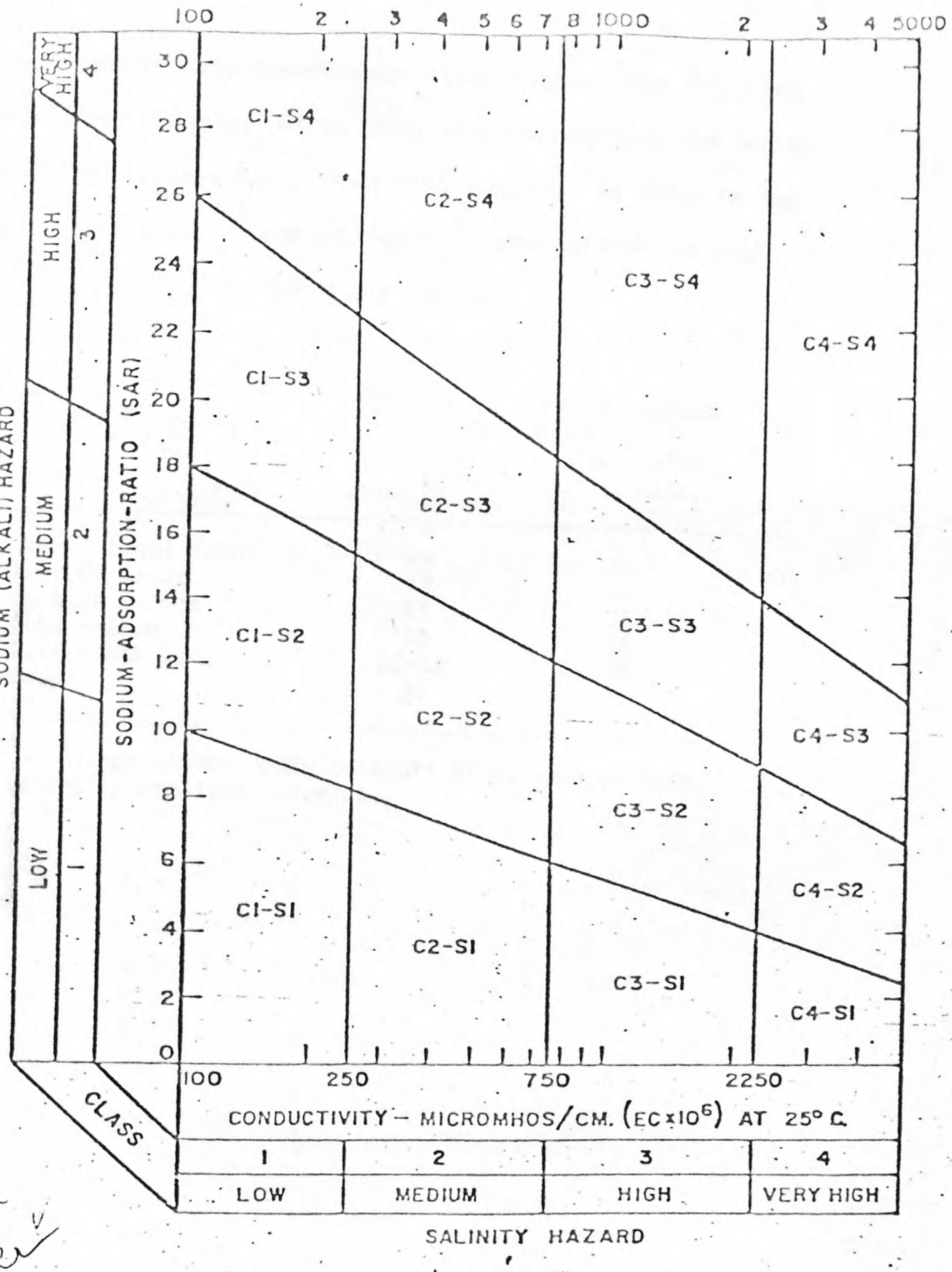
$$SAR = \frac{(Na^{+})}{\sqrt{\dfrac{(Ca^{+2}) + (Mg^{+2})}{2}}}, \text{ where}$$

ion concentrations are expressed in milliequivalents per liter.

The U.S. Department of Agriculture (1954) has developed the diagram shown below, using specific conductance and SAR to
next page
determine the suitability of water for irrigation. As can be seen, it classifies water according to sodium hazard and salinity hazard, with C1-S1 water being low in both specific conductance and in SAR, and the best classification. The higher the numbers, the poorer the water for irrigation, C4-S4 being the poorest classification. Waters that are both above and below these classifications assume the descriptive classification nearest them.

Specific conductance.--Specific conductance is a measure of the capacity of water to conduct an electrical current. It is commonly used as a measure of the mineral content of the water because it is the dissolved minerals (as ions) which increase the water's current carrying capacity. Water of high specific conductance may be unsuitable for use as irrigation water, as can be seen from the diagram on page 210

Temperature.--Temperature is one of the more important water-quality properties ~~parameters~~. Chemical solubilities and reaction rates are a function of temperature, as are many physical properties such as dissolved-gas concentrations at saturation. Biological properties of water also are a function of temperature. Fish and other coldblooded aquatic animals exist at or near the temperature of the water, and some are able to survive and



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~~FIGURE 25~~. DIAGRAM ~~FOR THE~~ showing CLASSIFICATION OF IRRIGATION WATERS (from USDA handbook No. 60)

210 ~~207a (208fols)~~

~~190~~

reproduce over only narrow temperature ranges. The following table (from McKee and Wolf, 1963) indicates optimum and lethal water temperatures for various fish species. As shown in the table, bass and carp are considerably more tolerant of high temperatures than are trout and salmon.

Common name of fish	Optimum preferred temperature (°C)	Lethal temperature[1], in °C (median tolerance limits)
Common brook trout	--	25
Rainbow trout	13	--
Sockeye salmon	15	25
Coho salmon	20	25
Largemouth bass	22-25	36
Carp	32	36

[1]Temperatures apply to adult fish; younger fish generally are less tolerant.

Drinking water with a temperature of 10°C or less is usually satisfactory. Water with temperatures of 15°C or higher is usually objectionable.

Trace metals.--Heavy metals such as copper, lead, mercury and zinc are not major constituents in most natural waters. They are generally present in minute amounts, and through common usage are referred to as "trace metals." Through various natural and man-induced processes, the trace metals sometimes exceed the concentrations considered to be safe for human consumption or for support of healthy fish life. The U.S. Public Health Service (1962) makes no recommendations regarding mercury concentrations in drinking water, but recommends that the concentration of copper should not exceed 1,000 µg/l and that of zinc should not exceed 5,000 µg/l. For lead, manditory grounds for rejection as drinking water were set at 50 µg/l. The Washington State Department of Social and Health Services (1971) has made the above limits mandatory for public water supplies. In addition, mercury must not exceed 5 µg/l.

Copper and zinc are considerably more toxic to aquatic life and to some terrestrial plants than to man and other higher animals. The following tabulation (from McKee and Wolf, 1963) lists approximate threshold concentrations of trace metals in water used by aquatic flora and fauna and for irrigation supplies:

Metal	Threshold concentration for aquatic flora and fauna ($\mu g/L$)	Threshold concentration for irrigation water ($\mu g/L$)
Copper (Cu)	20	100
Lead (Pb)	100	--
Zinc (Zn)	100	--
Mercury (Hg)	4	--

The threshold concentration is reached when a constituent is just strong enough to produce a response. For example, concentrations of copper less than 20 $\mu g/L$ normally would not be expected to cause any measurable harm to the aquatic flora and fauna.

Concentrations of trace metals deleterious to aquatic life, or which will be deleterious when applied in irrigation waters, are not easy to define. The harmful concentration of a metal is not a fixed quantity, but depends on such things as the species of plant or animal and its size, age, state of health, and degree of acclimation. Also, toxicity depends on the physical and chemical characteristics of the water, such as pH, DO, hardness, dissolved solids, and temperature. Some metals also are synergistic; that is, their toxicity is enhanced by the presence of another metal or other substance. The preceding table should be considered only as approximate in view of the above considerations.

Turbidity.--Turbidity is the term used to describe the decrease in light penetration attributable to suspended-particulate matter. The particulate matter may include organic detritus, mineral substances, or microorganisms. Turbidity is measured in Jackson Turbidity Units (JTU).

The U.S. Public Health Service (1962) recommends that drinking water not exceed 5 JTU. The Washington State Department of Social and Health Services (1971) limits unfiltered water to 5 JTU if it is to be used in a public water supply.

The Washington State Department of Ecology (1973) established the following requirements restricting man-induced increases in turbidity for various stream and lake classes:

	Stream class		
	AA and A (extraordinary or excellent)	B and C (good and fair)	Lake class
Turbidity increase (JTU)	5 or less	10 or less	No measurable increase allowed

Turbidity determination is important because the quantity of incident light and the depth to which light penetrates in stream water are significant factors in determining the stream's biological productivity. However, the direct lethal effects of turbidity on fish life is quite low; fish life probably will not be directly harmed until turbidity is well above any turbidity levels found in streams on the reservation. According to data by McKee and Wolf (1963) rainbow trout eggs are destroyed at turbidities between 1,000-2,500 JTU. Turbidities of 3,000 JTU are considered dangerous to fish, and turbidities less than 200 JTU are considered harmless.