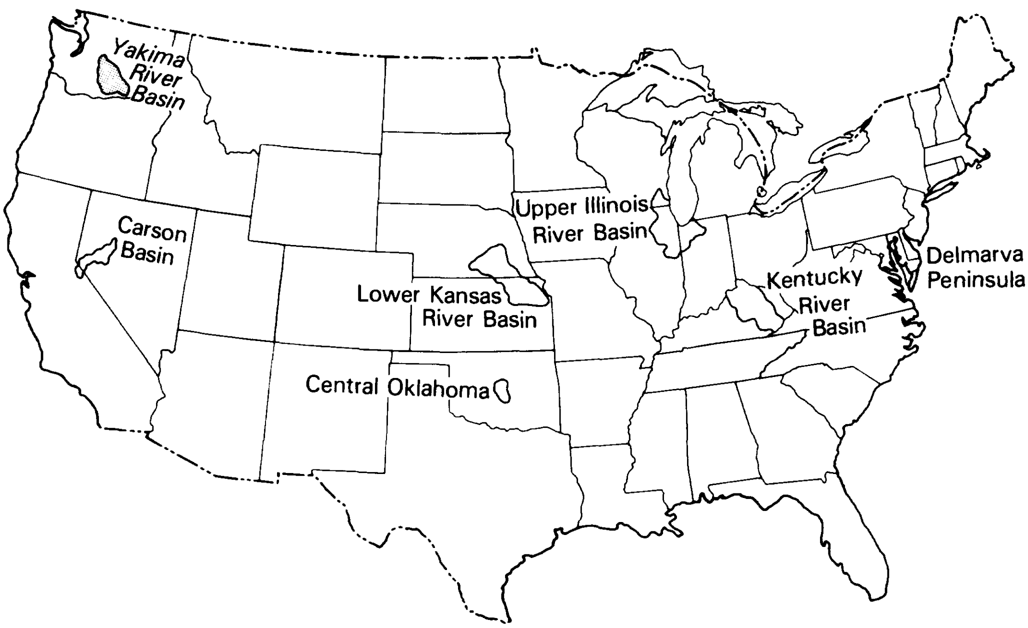
SURFACE-WATER-QUALITY ASSESSMENT OF THE YAKIMA RIVER BASIN, WASHINGTON: PROJECT DESCRIPTION

by S.W. McKenzie and J.F. Rinella



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[Plate is in pocket]

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound units	By	To obtain metric units
	Length	
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.405	hectare (ha)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre-foot (acre-ft)	0.001234	hectare-meter (ha-m)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
	Temperature	
degree Fahrenheit (°F)	(°F - 32) 5/9	degree Celsius (°C)

SEA LEVEL: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

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ABSTRACT

In April 1986, the U.S. Geological Survey began the National Water Quality Assessment program to (1) provide a nationally consistent description of the current status of water quality, (2) define water-quality trends that have occurred over recent decades, and (3) relate past and present water-quality conditions to relevant natural features, the history of land and water use, and land- and waste-management practices.

At present (1987), the National Water Quality Assessment program is in a pilot studies phase, in which assessment concepts and approaches are being tested and modified to prepare for possible full implementation of the program. Seven pilot projects (four surface-water projects and three ground-water projects) have been started.

The Yakima River basin in Washington is one of the pilot surface-water project areas. The Yakima River basin drains an area of 6,155 square miles and contains about 1,900 river miles of perennial streams. Major land-use activities include growing and harvesting timber, dryland pasture grazing, intense farming and irrigated agriculture, and urbanization. Water-quality issues that result from these land uses include potentially large concentrations of suspended sediment, bacteria, nutrients, pesticides, and trace elements that may affect water used for human consumption, fish propagation and passage, contact recreation, livestock watering, and irrigation.

The objectives of this pilot project are to use existing data and collect new data, as needed, to (1) describe spatial and temporal changes in water-quality conditions; (2) develop conceptual models that relate observed water-quality conditions to sources and causes, both natural and human-controlled, and (3) iteratively update the conceptual models. Data will be collected in a 9-year cycle. The first 3 years of the cycle will be a period of concentrated data acquisition and interpretation. For the next 6 years, sample collection will be done at a much lower level of intensity to document the occurrence of any gross changes in water quality. This 9-year cycle would then be repeated.

Three types of sampling activities will be used for data acquisition: fixed-location station sampling, synoptic sampling, and intensive-reach studies. Data from seven fixed-location stations will be used to determine mass loadings and seasonal variations of constituent concentrations. Synoptic studies will provide a snapshot of water-quality conditions over a broad geographical area through collection of data at numerous sites during a brief time interval, characteristic of a specific hydrologic condition. Synoptic studies in the Yakima River basin will include sampling for dissolved oxygen, indicator bacteria, trace elements, nutrients, suspended sediment, pesticides, and in-stream biology. Some water-quality problems probably will require intensive-reach investigations to better define their causes. Such studies would be concerned primarily with the origin, movement, and fate of particular contaminants.

INTRODUCTION

Background

The continued growth and vitality of the Nation is linked to the maintenance or improvement in the quality of its water resources. Public awareness of the importance of water quality has increased greatly in the past two decades and has resulted in the passage by Congress of major legislative controls, such as the Clean Water Act, the Safe Drinking Water Act, the Resource Conservation Recovery Act, and the Toxic Substances Control Act. State and local governments and industry also have made significant commitments to water-pollution abatement. Through these combined efforts, the quality of the Nation's rivers and streams has improved substantially during the past 15 years. This improvement has been achieved even though industrial activity and population have been increasing, with corresponding increases in water use and waste-effluent volumes. Fifteen years ago, low dissolved-oxygen concentrations were common in rivers and streams because of discharge of large loadings of oxygen-demanding wastes. Today, as a result of the construction of new waste-treatment plants and the upgrading of existing plants, low dissolved-oxygen concentrations are less common (Association of State and Interstate Water-Pollution Control Administrators, 1984).

Despite progress, several important water-quality issues still remain. Among them are the contamination of surface- and ground-water from nonpoint source pollution, acid precipitation, and the disposal of hazardous wastes. Cost-effective solutions to many of these problems are becoming more difficult to achieve because effluent-treatment solutions are not feasible; future solutions may involve changes in industrial processes or land-use practices. As a result, additional progress in water-quality improvement will require increased knowledge of the nature and extent of these problems, as well as knowledge of the physical, chemical, and biological processes that affect water quality in streams and aquifers.

National Water-Quality Assessment Program

The U.S. Geological Survey has initiated a pilot program for data aquisition and interpretation to assess the quality of the Nation's surface- and ground-water resources. The program is known as the National Water Quality Assessment (NAWQA) program. The long-term goals of the NAWQA program are to:

(1) Provide nationally consistent descriptions of the current status of water quality for a large, diverse, and geographically distributed part of the Nation's water resources;

(2) Where possible, define water-quality trends that have occurred over recent decades and provide a baseline for evaluating future trends in water quality; and

(3) Relate the status and the trends in water quality to (a) relevant natural factors, (b) the history of land and water use, and (c) land- and waste-management practices. These relations will be useful for examining the likely consequences of future management actions.

The NAWQA program is organized into study units on the basis of known hydrologic systems. The surface-water study units are drainage basins or parts of basins, and the ground-water study units are large parts of aquifers or aquifer systems. These study units are large, involving hundreds of miles of stream reaches for surface-water projects and thousands of square miles for ground-water projects.

In most general terms, the approach of the NAWQA program will be to make maximum use of existing data to (1) provide, to the extent possible, a description of trends in water-quality conditions and (2) develop conceptual models that relate observed water-quality conditions (concentrations, transport of substances, and biology) to natural and human-related causes. New data will be collected to:

- Measure long-term trends relative to historical data and future data,

- Determine if the conceptual model that results from historical data is current and appropriate,

- Iteratively update conceptual models so that planned work is always based on the most current knowledge,

- Reduce the uncertainty in describing water quality by intensifying temporal or spatial sampling densities, and

- Improve the understanding of the linkages between causative factors and water quality, using analyses of physical, chemical, and biological processes and statistical methods.

Data will be collected in a 9-year cycle. The first 3 years of the cycle will be a period of concentrated data acquisition. For the next 6 years, sample collection will be done at a much lower level of intensity to document the occurrence of any gross changes in water quality. This 9-year cycle would then be repeated.

Because the NAWQA program is national in scope, there will be common approaches, methods, and reporting procedures among the study units. This commonality is critical to assure consistent and comparable information that can be integrated and analyzed in a national context. However, project personnel will investigate the water-quality problems in their individual study units, and, in the design of the NAWQA program, will consider the unique hydrologic and geochemical conditions in each study unit.

A technical quality-assurance plan is being prepared for the National Water-Quality Assessment program. This plan will address all aspects of sample collection, analysis, and reporting needed to produce reliable and verifiable data in a nationally consistent manner. The plan will probably draw heavily on existing Geological Survey quality-assurance policies and procedures described in manuals by the Department of Interior (1977) and Friedman and Erdmann (1982).

At present (1987), the NAWQA program is in a pilot phase, in which water-quality assessment concepts and approaches are being tested and modified as necessary to prepare for full implementation of the program. The pilot program also provides an opportunity to evaluate potential benefits and costs of a fully-implemented program. Seven pilot projects (four surface-water projects and three ground-water projects) have been started.

The surface-water pilot project areas are the Yakima River basin in Washington; Lower Kansas River basin in Kansas and Nebraska; Upper Illinois River basin in Illinois, Indiana, and Wisconsin; and the Kentucky River basin in Kentucky. The ground-water pilot project areas are in the Carson Basin of western Nevada and eastern California; the central Oklahoma aquifer of Oklahoma; and the Delmarva Peninsula of Delaware, Maryland, and Virginia.

Yakima River Basin Project

The Yakima River basin of central Washington was selected for pilot study in the NAWQA program because of (1) the availability of long-term and current data on quantity and quality of water, (2) extensive water use in the basin and competing demands for the limited water supply, (3) a water-quality environment that has and will continue to be measurably affected by human activity, and (4) diversity of hydrologic conditions and water-quality problems. Study techniques developed for the diverse range of conditions in the basin and the experience and results obtained should have transfer value throughout much of the country, particularly in arid areas with irrigated agriculture.

The objectives of the Yakima River basin NAWQA project are to (1) describe the quality of water in the basin with sensitivity to persistent and measurable changes in 50-mile reaches; (2) describe the seasonal and long-term variability of water-quality constituents of interest; (3) investigate the relations between water-quality conditions and hydrologic systems, land use, water use, and other pertinent basin attributes; and (4) develop new techniques for characterizing regional water quality in a manner consistent with other surface-water pilot studies.

Purpose

The purposes of this report are to describe (1) the hydrology and related factors in the Yakima River basin; (2) the pilot water-quality assessment project, including the need for the study, the water-quality issues, and current status of water-quality knowledge; and (3) the study approach for assessing water-quality conditions in the Yakima River basin.

Acknowledgments

The Yakima River NAWQA project team wishes to acknowledge the aid and advice provided by members of the Liaison Committee. During 1986 this committee included Dave Zimmer and Onni Perala, U.S. Bureau of Reclamation; Tom Wilson and Rick Albright, U.S. Environmental Protection Agency; Gus McCutchen, Phillip McColley, and Bill Garrigues, U.S. Forest Service; Terry Berkompas, U.S. Bureau of Indian Affairs; Mike Stempel, U.S. Fish and Wildlife Service; Robert Olney, Wendell Hannigan, and Larry Wasserman, Yakima Indian Nation; Carol Jolly, Bob Moen, Jerry Thielen, Russ Taylor, and Jim Milton, Washington State Department of Ecology; Phil Peterson, Washington State Department of Fisheries; Gene Tillett, Washington State Department of Game; Dr. Clint Duncan, Washington Water Research Center; and Paul Chasco and Gary Weatherly, Yakima River Basin Association of Irrigation Districts. The project team also wishes to thank Dr. Jim Pankow, Oregon Graduate Center, for his technical advice concerning analyses of organic compounds.

DESCRIPTION OF THE YAKIMA RIVER BASIN

Topography and Drainage

The Yakima River basin is located in south-central Washington and contains a diversity of landforms, including the high, glaciated peaks and deep valleys of the Cascade Range to the west, the broad river valleys to the south and east, and the lowlands of the Columbia Plateau to the east. The altitude of the basin ranges from 8,184 feet in the Cascade Range (pl. 1) to about 340 feet at the Columbia River (Lake Wallula).

The Yakima River has a total drainage area of 6,155 square miles (Columbia Basin Inter-agency Committee, 1964). There are about 1,900 miles of perennial streams mapped at the 1:250,000 scale. The Yakima River is more than 214 miles in length, flows southeasterly, and passes through three distinct subbasins as it travels from the eastern slope of the Cascade Range through the lower plateau and river-bottom lands to the Columbia River. The upper Yakima River begins at the outlet of Keechelus Lake, a glaciated lake enlarged and operated as a reservoir. The headwaters of the lake and other tributaries flow from glaciers and snowfields near the 5,000- to 7,000-foot crest of the Cascade Range. Bordered on the west by the Cascades and on the north by the Wenatchee Mountains, the upper Yakima River flows through foothills into the Kittitas Valley. Principal tributaries to the upper Yakima River are the Cle Elum and Teanaway Rivers, and the Swauk, Taneum, Manashtash, and Wilson Creeks.

The river flows from Kittitas Valley through 25 miles of canyon into a middle-basin area that includes (in downstream order) the Wenas Valley and Selah area, Naches Valley, Moxee area, and Ahtanum Valley. In this middle basin, the Naches River (a major tributary with 1,106 square miles of drainage area) is confluent to the Yakima River at RM (river mile) 116.3. The headwaters of the Naches River originate near the Cascade Range crest; major tributaries flow into the Naches only from the south, a region characterized by ridges and peaks with areas above timberline that contain snowfields and a few glaciers. Principal tributaries to the Naches River include (in downstream order): Little Naches River, Bumping River (includes American River), Rattlesnake Creek, Tieton River, and Cowiche Creek. All of these streams are perennial and are fed by snowmelt and (or) glaciers. Valley streams such as Wenas Creek, Wide Hollow Creek, Moxee Drain, and Ahtanum Creek commonly include irrigation return flows.

The river flows through a gap in the basalt ridges into the lower basin at Union Gap. The lower basin includes valley lands that are intensively farmed; the Yakima River receives flow from several streams and drains that are often augmented with irrigation return flow. In downstream order, these major tributaries are East Toppenish Drain, Sub-Drain 35, Granger Drain, Marion Drain, Toppenish Creek, Coulee Drain, Satus Creek, Sulphur Creek wasteway, Spring Creek, Snipes Creek, and Corral Canyon Creek (Sylvester and Seabloom, 1962; CH2M Hill, 1977; Molenaar, 1985; and Pearson, 1985).

Climate

The climate of the Yakima River basin ranges from maritime along the crest of the Cascade Range to arid in the lower valleys. The mountainous western and northern part of the basin receives precipitation principally as snow during the period November to March and as rain during the remainder of the year. Much of the snowfall in the mountains is retained in the snowpack through the winter; some is retained for longer periods in the perennial snowfields and glaciers at higher elevations (Pearson, 1985). Chinook winds--warm air descending the eastern slopes of the Cascade Range--occasionally cause rapid melting of the snowpack, which can result in severe erosion of soils and flooding along lowland stream channels.

Precipitation varies considerably across the basin and throughout the year. Mean-annual precipitation ranges from about 140 inches in the higher mountains of the northwestern part of the basin to less than 10 inches in the Kennewick area (U.S. Weather Bureau, 1965). Mean-monthly and annual precipitation data for nine sites during the 1951-to-1980 time period (30 years) are shown in table 1. The amount of precipitation that occurs during the October-to-March time period, in both the arid and maritime parts of the basin, ranges from 61 to 81 percent of the annual precipitation. The variation in precipitation at stations from year to year can be large (fig. 1).

Mean monthly temperatures (in degrees Fahrenheit) for January and July ranged from 24 to 63 at Lake Kachess and 31 to 77 at Kennewick; minimum January and maximum July temperatures ranged from 18 to 76 at Lake Kachess and 24 to 93 at Kennewick (Landes, 1917). The temperatures are generally inversely related to altitude.

Table 1.--Mean monthly and annual precipitation for selected weather stations in the Yakima River basin, Washington, 1951-1980

[See plate 1 for location of weather stations]

Site no.	Station name	County	Altitude (feet)	Mean monthly precipitation (inches) Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean annual precipitation (inches)
1	Stampede Pass	Kittitas	3,958	14.59	10.19	8.88	6.28	3.97	3.84	1.56	2.85	4.65	7.74	12.14	15.88	92.57
2	Cle Elum	Kittitas	1,930	4.14	2.46	1.91	1.27	0.77	0.70	0.27	0.59	0.81	1.63	3.51	4.59	22.65
3	Moxee City	Yakima	1,550	1.00	0.65	0.61	0.66	.61	.65	.26	.49	.43	.58	0.96	0.99	7.89
4	Yakima	Yakima	1,064	1.44	.74	.65	.50	.48	.60	.14	.36	.33	.47	.97	1.30	7.98
5	White Swan Ranger Sta.	Yakima	970	1.74	.92	.68	.50	.36	.37	.24	.28	.28	.48	1.18	1.68	8.71
6	Wapato	Yakima	850	1.20	.64	.56	.51	.45	.53	.19	.36	.34	.43	.93	1.10	7.24
7	Sunnyside	Yakima	747	1.03	.58	.42	.51	.53	.45	.20	.30	.37	.49	.83	.99	6.70
8	Prosser	Benton	903	1.05	.63	.50	.60	.68	.54	.24	.33	.36	.64	.98	1.15	7.70
9	Kennewick	Benton	392	1.17	.66	.54	.46	.59	.44	.19	.40	.37	.56	.99	1.18	7.55

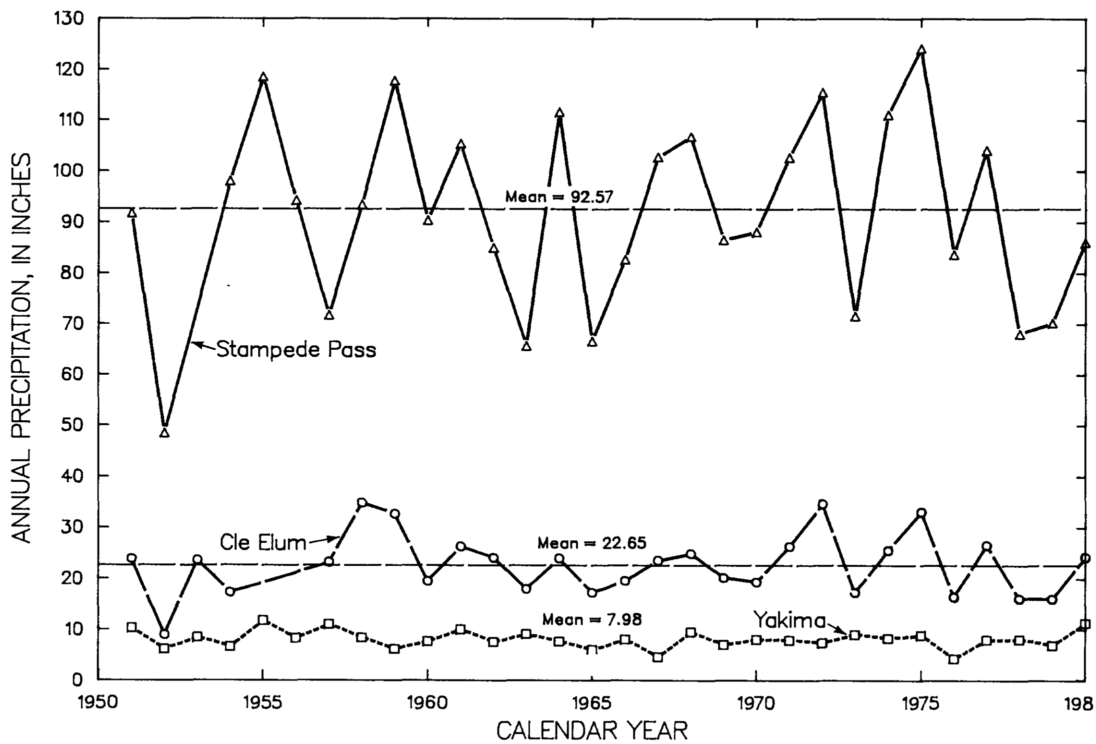

Figure 1.--Graph showing annual precipitation at selected locations in the Yakima River basin.

Geology

The Yakima River basin lies within the Cascade Range and the Columbia Plateau physiographic provinces and therefore exhibits the diversity of rock types and soils characteristic of the two regions. The basin is underlain by a great variety of consolidated rocks that range in age from Precambrian to Tertiary, as well as by unconsolidated materials and volcanic rocks of Quaternary age. These consolidated rocks include metamorphic, sedimentary, and intrusive and extrusive igneous rocks in the basin's headwater areas in the Cascade Range, and basalt lava flows and some interbedded and weakly consolidated sediments in the central and eastern parts of the basin. Unconsolidated valley-fill materials--lacustrine deposits and alluvium--underlie the basin lowlands, and some eolian deposits occur locally along lower valley sides. Lava flows of Quaternary age occur in the headwater areas of the Toppenish Creek and Satus Creek subbasins (Swanson and others, 1979a; Molenaar, 1985; Pearson, 1985).

The basalt lava flows and the valley-fill deposits are important aquifers in the study area. The basalt consists of a series of flows of Miocene age (between 24 and 5 million years ago) that erupted from fissures in the central part of the Columbia Plateau. Individual flows are a few feet to more than 100 feet thick; the total thickness of the basalt series is probably greater than 10,000 feet in the central part of the Plateau. Along the western margins of the Plateau--which include the Yakima Basin--some of the upper basalt flows are locally interbedded with sediments (mostly sand, gravel, silt, and clay) that were eroded from the rising Cascade Range on the west and from several east-west trending ridges that formed from the buckling of the basalt sequence (Swanson and others, 1979b).

Overlying and, in places, interbedded in the upper parts of the basalt are unconsolidated to poorly consolidated sedimentary rocks of the Ellensburg Formation of Miocene age--clay, gravel, siltstone, and conglomerate. Unconsolidated deposits of sand, gravel, silt, and clay underlie the flood plains and channels of the major streams and the broad Kittitas Valley (Swanson and others, 1979a; Pearson, 1985).

Deformation of the basalt and the Ellensburg Formation has resulted in several structural features that are reflected in the landforms, particularly those in the lower part of the basin. Warping of the earth's crust has formed the Kittitas Valley and several northwest-to-southeast trending anticlinal ridges. These include, from north to south, the Manastash, Umtanum, and Yakima Ridges, Cleman Mountain, and Selah Butte. The lower parts of the Kittitas Valley and valleys between the ridges were subsequently filled by unconsolidated materials (Pearson, 1985).

Glaciation during the Pleistocene Epoch (between 10,000 and 2,000,000 years ago) caused deep erosion in the mountains and deposition of the resulting rock material in the lower valleys of the study area. Cutting by alpine glaciers produced sharp peaks and ridges along the Cascade crest and deep, steep-walled cirques and valleys. The eroded material was then carried by the valley glaciers and deposited by the ice and meltwater streams in the valley bottoms (Pearson, 1985). Subsequent formation in the late Pleistocene of large, ice-dammed glacial lakes across lower parts of the Columbia Plateau caused the deposition of silt and clay beds in much of the lowland of the study area. After the lakes drained, the exposed fine sediments were subjected to wind erosion and some of the material was transported to become eolian deposits, particularly over the lower, eastern parts of the the study area (Molenaar, 1985).

Present-day geologic changes in the area include the slow but continuing erosion of the mountains by streams and small glaciers and the associated deposition of the materials along stream channels and flood plains and in lowland lakes. Also, the 1980 eruption of the Mount St. Helens volcano, in the Cascade Range to the west, deposited ash over large parts of the study area (Molenaar, 1985).

The soils of the basin area were formed by the physical and chemical weathering of rock materials. Basalt in the semiarid climate of the southeastern part of the basin does not weather rapidly enough for the development of a deep soil profile. Large areas in the eastern part of the basin consist of basalt outcrops with little or no soil cover, particularly on the ridges and upper slopes.

In the valley bottoms of the central west part of the basin, soils have developed principally from unconsolidated, glacially deposited material (Pearson, 1985). Types and characteristics of the soils in Kittitas County are described by Sibley and Krashevski (1957); similar studies were made in Yakima County by Maytin and Starr (1960) and in Benton County by Rasmussen (1971). Moen (1978) has given locations of rock types in the basin, showing andesites, basalts, and metamorphic rocks such as greenschist, phyllite, and slate in the Cle Elum and Teanaway River basins and in Swauk Creek basin near Cle Elum; andesites and basalts are located in the American, Bumping, and Tieton River basins. Trace-element enrichments identified within the Yakima Basin in the Cascade Range include chromium, copper, gold, iron, lead, mercury, molybdenum, nickel, silver, and zinc.

Population and Land Use

Changes in the area's economic base over past years have affected the current population in the Yakima River basin. The first settlers entered the basin in the late 1860's, initially as farmers and cattlemen. The discovery of gold in Swauk Creek, development of coal mines near Roslyn, and the completion of the railroad across the mountains enhanced the continued growth. Other factors, such as the expansion of Central Washington University and Hanford Reservation, caused urban areas to expand. The Washington State Office of Financial Management (1984) lists the 1983 populations for Kittitas County as 24,900; for Yakima County as 177,000, and for Benton County as 108,700 (borders of these counties extend slightly beyond the basin's boundaries).

The populations of each county--incorporated (urban) and unincorporated (rural)--are as follows: Kittitas--15,730 and 9,170; Yakima--88,800 and 88,200; and Benton--77,600 and 31,100. The 1983 populations of the larger towns in the basin are as follows: Yakima--48,500; Kennewick--35,700; Richland--32,000; Ellensburg--11,550; Sunnyside--9,450; Toppenish--6,575; Grandview--6,300; Selah--4,520; Prosser--4,150; West Richland--3,864; Wapato--3,310; Union Gap--3,120; Benton City--1,880; Granger--1,810; Cle Elum--1,775; Zillah--1,685; and Mabton--1,234.

Major land-use activities in the basin include growing and harvesting timber, dryland pasture grazing, intense farming and irrigated agriculture, and urbanization. Even though the areas covered by irrigated agriculture (approximately 1,000 square miles) and urbanization (50 square miles) are smaller than areas of timber harvesting (2,200 square miles) or grazing (2,900 square miles), the intensity of activity makes agriculture and urbanization of primary importance with respect to water-quality effects.

The irrigated agricultural area is one of the most important fruit-producing areas of the United States. Of the 3,072 counties in the United States, Yakima County ranks first in the production of apples, mint, and hops; in total agriculture production, the county ranks fifth. Acreages for all major crops in each major irrigation division receiving water from U.S. Bureau of Reclamation projects are shown in table 2. Dominant crops (making up 76 percent of the irrigated area) are irrigated pasture, apples, wheat, alfalfa, hops, dry corn, grapes, and hay.

Table 2.--Acreage of crops in selected irrigation projects in the Yakima River basin, Washington, for 1984

[Data source is Bureau of Reclamation, written commun., 1986]

	Kittitas Division	Roza Division	Yakima-Tieton Division	Wapato Division	Sunny-side Division	Kenne-wick Division	Special and Warren Act contracts	Total
Barley	1,190	451	15	2,254	229	50	100	4,289
Corn	53	4,065	--	14,804	1,908	60	205	21,095
Oats	1,171	--	--	97	40	65	140	1,513
Wheat	5,620	3,847	10	20,592	3,431	1,260	3,080	37,840
Other	8	161	0	0	0	0	28	197
Total cereals	8,042	8,524	25	37,747	5,608	1,435	3,553	64,934
Alfalfa	6,354	3,866	888	9,632	7,343	2,390	4,160	34,633
Other hay	11,628	75	0	2,411	180	260	4,049	18,603
Irrigation pasture	24,637	3,874	2,096	14,258	16,597	1,220	8,823	71,505
Silage	232	3,207	0	1,800	5,304	22	280	10,845
Other	95	0	0	0	0	0	100	195
Total forage	42,946	11,022	2,984	28,101	29,424	3,892	17,412	135,781
Beans	0	664	0	1,637	134	0	0	2,435
Hops	0	6,583	0	8,167	5,936	0	2,464	23,150
Peppermint	0	1,366	0	8,215	71	0	0	9,652
Spearmint	0	2,610	0	2,300	2,292	0	0	7,202
Total field crops	0	11,223	0	20,319	8,433	0	2,464	42,439
Asparagus	0	2,341	0	4,206	5,871	93	0	12,511
Sweet corn	500	784	0	7,954	432	0	1,620	11,290
Melons	0	0	0	242	16	0	0	258
Peas	0	0	0	0	72	0	0	72
Potatoes	500	1,280	0	1,157	57	0	0	2,994
Squash	0	0	0	320	106	0	0	426
Tomatoes	0	22	0	372	10	0	0	404
Other vegetables	0	225	0	226	181	0	0	632
Total vegetables	1,000	4,652	0	14,477	6,745	93	1,620	28,587

Table 2.--Acreage of crops in selected irrigation projects in the Yakima River basin, Washington, for 1984--Continued

[Data source is Bureau of Reclamation, written commun., 1986]

	Kittitas Division	Roza Division	Yakima-Tieton Division	Wapato Division	Sunny-side Division	Kenne-wick Division	Special and Warren Act contracts	Total
Apples	400	13,836	18,306	7,387	2,997	980	7,844	51,750
Apricots	0	163	0	67	158	17	77	482
Cherries	0	2,571	230	518	2,602	580	895	7,396
Grapes	0	8,525	0	2,966	8,477	45	324	20,337
Peaches	0	457	0	803	238	150	590	2,238
Pears	150	1,828	1,761	1,160	1,287	82	2,692	8,960
Prunes & plums	0	450	0	364	718	230	125	1,887
Other	0	152	0	765	43	30	30	1,023
Total fruits	550	27,982	20,297	14,030	16,520	2,114	12,577	94,070
Seeds	85	100	0	72	0	5	0	262
Nursery	0	783	0	65	143	25	62	1,078
Family gardens	20	43	0	336	179	560	744	1,882
Total seeds, nursery, and gardening	105	926	0	473	322	590	806	3,222
TOTAL CROPS	52,643	64,329	23,306	115,147	67,052	8,124	38,432	369,033

Agricultural practices have changed and continue to change slowly. The change from row crops to hay in the Kittitas Valley has been gradual, and there has been a shift from row crops to permanent crops (such as grapes, apples, and pears) in the lower Yakima Valley. These changes affect the amount of water needed for irrigation, the methods of applying irrigation water, and the quality of the water draining from fields and returning to the Yakima River (Ron Van Gundy, Manager, Roza Irrigation District, oral commun., July 1986).

Major industries of the Yakima Basin are agriculture and lumbering. Industrial activities related to agriculture include the packing and processing of fruits, vegetables, hops, meat, and other farm products.

Surface-water Hydrology

The Yakima River basin has perennial streamflow (principally the Yakima and Naches Rivers) as a result of summertime melting of snowfields and glaciers in the Cascade Range. For the prediction of annual runoff, several snow courses in the basin are measured annually for water content of the snowpack (U.S. Department of Agriculture, 1986).

The discharge of streams fed by snowmelt declines during the November-January period, when air temperatures are low and melting is minimal. As the temperatures increase from February through July, the snowmelt gradually increases and provides increasing stream discharges. Peak snowmelt and runoff of streams draining the eastern slope of the Cascade Range generally occurs in May and June. By July, most of the snow has melted and rainfall has decreased; a subsequent decrease in streamflow occurs through September.

Reservoirs are used today to (1) augment summer flows (most of which are diverted for irrigation), (2) augment fall and winter flows for instream habitat, and (3) reduce flooding during winter storms and spring snowmelt. The reservoirs provide most of the water for irrigation during the July-October period, when natural streamflows are minimal and irrigation of agricultural crops creates maximum demand for water.

Basin characteristics for 10 gaging stations are listed in table 3 (Williams and Pearson, 1985). Subbasins upstream of the Yakima River at Cle Elum, Bumping River near Nile, and American River near Nile experience relatively large amounts of precipitation and runoff per square mile, compared to Naneum Creek near Ellensburg and Toppenish Creek near Fort Simco. Of these five sites, the American River, Naneum Creek, and Toppenish Creek are not controlled by reservoirs and have high flows from April to May and low flows during the August-October period. Low flows occur in Toppenish Creek in July, while low flows are observed at other sites in August and September, because of the basin's lower altitudes and limited snowpack. Low flows in Naneum Creek and American River continue through March because the high-altitude snowpacks do not start melting until later in the year.

The precipitation leaving the basin as surface-water runoff (mean annual flow, in inches per basin-drainage area, divided by annual precipitation and expressed as percent) shows a steady decrease from Bumping River, Yakima River at Cle Elum, and American River to Naneum Creek, Toppenish Creek, Naches River, and Yakima at Umtanum (table 3). This decrease is the result of increased surface-water losses due to evapotranspiration and ground-water infiltration. Diversions of water for irrigation upstream of the Yakima River at Umtanum station and the Naches River below Tieton station have resulted in increased evapotranspiration and lower percentage of precipitation leaving the basin as surface water. Ratios of mean annual flow to drainage area ($ft^3/s/mi^2$) show results similar to the percent of precipitation leaving the basin as surface-water runoff, for many of the same reasons.

Table 3.--Selected basin, climatic, and streamflow characteristics for 10 gaging stations in the Yakima River basin, Washington

["--" indicates no data available. See plate 1 for location of gaging stations. Information from Williams and Pearson, 1985]

	Yakima River at Cle Elum 12479500	Naneum Creek near Ellensburg 12483800	Yakima River at Umtanum 12484500	Bumping River near Nile 12488000	American River near Nile 12488500	Naches River below Tieton 12494000	Yakima River at Union Gap 12500450	Yakima River at Parker 12505000	Toppenish Creek near Ft. Simco 12506000	Yakima River at Kiona 12510500
Period of record	1907-78	1957-78	1099-79	1909-78	1909-15 1940-79	1909-79	1967-79	1908-78	1909-23	1906-15, 1933-79
Drainage area, in square miles	495	69.5	1,594	70.7	78.9	941	3,479	3,660	122	5,615
Mean basin altitude, in feet	3,700	4,830	2,800	4,830	4,860	4,440	--	--	3,550	--
Mean annual precipitation in subbasin, in inches	78	25	43	82	74	60	--	--	29	--
Mean annual flow, in cubic feet per second	1,780	57	1,470	295	240	1,260	3,867	2,530	98	3,661
Mean annual flow/annual precipitation, in percent	63	45	29	69	56	30	--	--	38	--
Mean annual flow/drainage area, in ft3/s per mi2	3.60	.82	.92	4.17	3.04	1.34	1.11	.69	.80	.65

Water Use

Irrigation Development

The earliest records of irrigation in the basin are reported for Ahtanum Creek in the vicinity of a Catholic mission in 1852 and for Indian Ditch near Tampico in about 1853. With the entry of settlers into the basin in 1861, the first accurate records of irrigation were made for Nelson Ditch, where water was diverted from the lower Naches River. This ditch exists today on the Chapman-Nelson Canal, although it carries only a small amount of water. Prior to 1890, most of the canals diverted water from the Naches River, although some canal diversions occurred in the vicinity of Prosser and Kiona in about 1878 (Flaherty, 1975).

By 1902, an estimated 121,000 acres were under irrigation in the Yakima River basin, representing about 25 percent of the present irrigation development. This acreage was served by natural flows in the river and tributaries, with none of the present large storage reservoirs yet in existence. Natural runoff was inadequate to insure a dependable water supply for development, even at the turn of the century (CH2M Hill, 1977).

The Federal Reclamation Act of 1902 made possible the construction of Federal water-storage dams and canal systems. In 1905 Congress authorized the Yakima Federal Reclamation Project, to cover nearly one-half million acres in the Yakima River basin. Construction of the Sunnyside and Tieton distribution systems was authorized with funding of $1,750,000 on March 27, 1906. Succeeding appropriations permitted construction, by the Bureau of Reclamation, of the five major irrigation divisions (namely Kittitas, Tieton, Sunnyside, Roza, and Kennewick Divisions) that use water from six storage reservoirs. Construction periods noted for the six storage reservoirs were as follows: Keechelus, 1913-1917; Kachess, 1910-1912, and present spillway in 1936; Cle Elum, 1931-1933; Bumping, 1909-1910; Clear Creek, 1914 and 1918; and Rimrock, 1917-1925. The Wapato Project was constructed by and is managed by the Bureau of Indian Affairs, which has a contract with the Bureau of Reclamation to supply water for the project.

Storage has not been added to the irrigation projects since 1933--53 years ago. Low flows in 1973 and 1979, extreme low flows in 1977, and a court order in 1980 that mandated use of stored water to help fisheries have caused the Bureau of Reclamation to examine the feasibility of increasing Bumping Lake storage capacity from its present capacity of 33,700 acre-ft to a capacity of 250,000 to 460,000 acre-ft by construction of a higher dam downstream from the existing dam. Some of the benefits of this proposed dam would be (1) fish and wildlife enhancement, (2) water for supplemental irrigation of Roza Division lands during periods of unusually low flow of the Yakima River, (3) additional storage capacity for flood control, and (4) additional recreation development (U.S. Bureau of Reclamation and Washington State Department of Ecology, 1982 and 1985).

Irrigation districts without adequate natural-flow rights obtain additional water through contracts with the Bureau of Reclamation. The Bureau furnishes the water from storage and other sources (such as return flows). Some major districts, such as Roza and Kittitas, have no natural-flow rights; their entire supply is contracted water, for which they pay a proportionate share of the reservoir costs.

Other districts that need a supplemental supply are furnished contract water under terms of the Warren Act of February 21, 1911, which authorized the United States to contract the sale of water to various districts, corporations, associations, and individuals. At present, the contract water supply is fully subscribed, and any additional sales would require construction of more storage facilities. Also, the available natural flows in the basin are fully appropriated during the irrigation season.

Today, the Yakima River basin is one of the most intensively irrigated areas in the United States. The basin has six storage reservoirs, 14 major diversions on the main stem (many of which originate from seven diversion dams), more than 1,900 miles of canals and laterals, two hydroelectric plants, six major governmental irrigation projects, plus numerous small private irrigation systems and districts. The total irrigable area in the Yakima River basin (1984) is approximately 500,000 acres, of which about 450,000 acres are actively irrigated.

A list of major irrigation projects and a summary of lands irrigated are shown in table 4. Table 5 lists the irrigation districts in the Yakima Basin, the acreages receiving irrigation water, and the annual diversion from surface water. An undefined amount of water also is pumped from wells, the number of which increased significantly after the 1977 drought.

Irrigated land is drained by surface and subsurface drains; many natural streams act as the surface drains. Surface drains have the advantage of carrying large flows at very little slope, but have the disadvantages of (1) transporting surface land waste, (2) incurring expense for maintenance, (3) warming the drainage water, and (4) carrying off considerable amounts of top soil. Principal surface drains in the Yakima River basin, their locations, and their approximate flows are listed in table 6.

The irrigation season usually extends from late March into early October. The mean monthly rates of water application to the six principal irrigation project areas--the Kittitas, Tieton, Roza, Sunnyside, Wapato, and Kennewick projects--are shown in table 7. As can be seen in the table, most of the irrigation water is applied in the months of May through August. Water is applied to the land primarily by the ridge and furrow method, although a significant and increasing portion is applied by sprinklers.

The difference between the quantities of water diverted and delivered to farms is attributed to controlled spillage back to the Yakima River and to losses that include evapotranspiration and seepage. The Roza Canal diverted 390,140 acre-ft of water for power generation during the 1984 calendar year; this water is in addition to the water diverted for irrigation and returns to the Yakima River at Terrace Heights. About 46 percent of the total water delivered by the Kennewick District goes to urban areas for irrigation of lawns and gardens. The Sunnyside District receives an unmeasured amount of irrigation return flow and spillage from the Roza system. The unmeasured flow explains the apparently high percentage of water that the Sunnyside District delivered to farms. The Wapato District uses water diverted from the Yakima River, supplemented with diversions from small drainages, such as Toppenish Creek, and drainage water pumped into canals for use a second time as irrigation water.

Table 4.--Major irrigation Divisions and acres irrigated in 1984 in the Bureau of Reclamation Yakima Project, Washington

[From Bureau of Reclamation Crop Production Reports, written commun., 1986]

Land use	Acres								
	Kittitas Division	Roza Division	Yakima-Tieton Division	Wapato Division	Sunnyside Division	Kennewick Division	Special and Warren Act Contracts	Other	Total, Yakima Project
Harvested cropland and pasture	52,643	64,329	23,306	115,147	67,052	8,124	38,432	80	369,113
Cropland not harvested and soil building	300	2,221	2,275	4,500	5,145	400	90	0	14,931
Acres irrigated	52,943	66,550	25,581	119,647	72,197	8,524	38,522	80	384,044
Dry cropped, fallow, or idle	1,700	2,276	0	5,930	5,756	0	175	0	15,837
Total area in irrigation rotation	54,643	68,826	25,581	125,577	77,953	8,524	38,697	80	399,881
Dry cropped, idle, fallow, or grazed	1,061	0	316	2,818	2,488	3,085	825	0	10,593
Farmsteads, roads, ditches, and drains	3,000	3,196	244	6,600	14,061	224	1,597	11	28,933
Urban and suburban lands	300	489	1,130	1,005	9,060	7,338	6,321	0	25,643
Total area not receiving irrigation	4,361	3,685	1,690	10,423	25,609	10,647	8,743	11	65,169
Irrigable area not for service	0	0	0	0	0	6,300	0	0	6,300
TOTAL AREA	59,004	72,511	27,271	136,000	103,562	25,471	47,440	91	471,350

Fishery

Prior to the settlement and development of the Yakima River valley, the river was one of the most important fish producers in the Columbia River system. Much of the decrease in fish population can be attributed to the construction of irrigation dams, loss of fingerlings to unscreened diversions, and high temperatures combined with reduced flows when water is diverted for irrigation. In the past few years, State and Federal agencies--most recently the Northwest Power Planning Council--have been working to improve conditions for spawning, rearing, upstream adult-fish passage, and downstream migration passage. Since 1980, notable improvements have occurred and even greater future improvement is anticipated (John Easterbrook, Washington Department of Fisheries, oral commun., March 4, 1986).

Table 5.--Major irrigation districts and divisions in Yakima River basin, Washington

[Data are for 1984 irrigation season, provided by U.S. Bureau of Reclamation, written commun., 1986]

Name of irrigation unit	Irrigated area (acres)	Annual diversion from surface water (acre-feet)
Kittitas Reclamation Division	52,900	322,000
Cascade Irrigation District	12,700	28,000
Ellensburg Town Canal Unit	19,530	46,000
West Side Irrigation Company	7,000	24,000
Roza Irrigation Division	66,600	360,000
Yakima-Tieton Irrigation Division	25,600	91,000
Naches-Selah Irrigation District	9,800	38,000
Selah-Moxee Irrigation District	4,500	23,000
Moxee Sub "A"	300	2,000
Terrace Heights Irrigation Districts	400	2,000
Union Gap Irrigation Districts	3,100	12,000
Yakima Valley Canal Company	3,200	17,000
Broadway Irrigation District	200	1,000
Special and Warren Act Contractors	38,500	21,000
Wapato Irrigation Division	119,600	632,000
Sunnyside Valley Irrigation Division	72,200	411,000
Granger Irrigation District	1,300	7,000
Snipes Mountain Irrigation District	1,500	8,000
Sunnyside Irrigation District	2,900	16,000
Outlook Irrigation District	4,200	23,000
Grandview Irrigation District	3,100	17,000
Prosser Irrigation District	1,600	9,000
Kennewick Irrigation Division	1/ 15,900	92,100

1/ Includes irrigated cropland plus urban and suburban lands receiving irrigation water.

Table 6.--Principal irrigation return-flow surface drains discharging directly to the Yakima River, Washington

[ft³/s = cubic feet per second]

Name	Location: Latitude	Location: Longitude	Discharge (ft³/s)	Date measured
Taneum Cr nr mouth	47° 04′ 57″	120° 43′ 57″	0.28	8-12-86
Reecer Cr at Ellensburg	47° 00′ 03″	120° 34′ 28″	33	8-12-86
Manashtash Cr at Brown Rd nr Ellensburg	46° 59′ 44″	120° 35′ 23″	2.8	8-13-86
Wilson Cr at BR gage at Thrall	46° 55′ 35″	120° 30′ 01″	128	8-12-86
Cherry Cr at BR gage at Thrall	46° 55′ 34″	120° 29′ 51″	192	8-14-86
Wenas Cr at mouth nr Selah	46° 42′ 32″	120° 31′ 11″	.26	8-14-86
Unnamed drain nr Birchfield Rd	46° 33′ 26″	120° 26′ 32″	19.4	8-14-86
Wide Hollow Cr at Union Gap	46° 33′ 01″	120° 28′ 48″	16	8-15-86
Moxee Drain at Thorp Rd nr Union Gap	46° 32′ 18″	120° 27′ 19″	75	8-14-86
Ahtanum Cr at Union Gap	46° 32′ 10″	120° 28′ 20″	8.5	8-15-86
East Toppenish Drain at Wilson Rd	46° 22′ 04″	120° 15′ 00″	58	8-18-86
Sub drain 35 at Parton Rd	46° 20′ 11″	120° 13′ 48″	54	8-16-86
Granger Drain at Granger	46° 20′ 10″	120° 11′ 38″	67	8-17-86
Marion Drain at Granger	46° 19′ 52″	120° 11′ 54″	141	8-17-86
Toppenish Cr nr Satus	46° 18′ 52″	120° 11′ 53″	20.5	8-16-86
Coulee Drain at N Satus Rd	46° 17′ 49″	120° 08′ 42″	14	8-16-86
Satus Cr at Satus	46° 16′ 23″	120° 08′ 44″	71	8-16-86
South Drain nr Satus	46° 15′ 35″	120° 07′ 57″	3.0	8-16-86
Satus Drain 302 at Hwy 22	46° 13′ 32″	120° 03′ 14″	1.2	8-17-86
Satus Drain 303 at Hwy 22	46° 13′ 02″	120° 01′ 08″	14.5	8-17-86
Sulphur Cr Wstwy at Holady Rd	46° 15′ 03″	120° 01′ 07″	259	8-16-86
Grandview Drain nr Grandview gage	46° 13′ 27″	119° 55′ 48″	12.2	8-17-86
Unnamed drain at Prosser	46° 11′ 44″	119° 51′ 02″	9.3	8-17-86
Wamba drain at Prosser	46° 12′ 45″	119° 46′ 40″	5.9	8-17-86
Spring Cr plus Snipes Cr at mouth	46° 13′ 58″	119° 40′ 31″	69	8-18-86

Table 7.--Water diverted from Yakima River basin streams and delivered to farms, of principal irrigation projects, Yakima Basin, Washington, 1984

[Source of data is Bureau of Reclamation, written communication, 1986; "--" indicates no data available]

Month	Kittitas Diverted, acre-ft/acre	Kittitas Delivered, acre-ft/acre	Tieton Diverted, acre-ft/acre	Tieton Delivered, acre-ft/acre	Roza Diverted, acre-ft/acre	Roza Delivered, acre-ft/acre	Sunnyside Diverted, acre-ft/acre	Sunnyside Delivered, acre-ft/acre
April	0.12	0.04	0.13	0.01	0.48	0.10	0.52	0.20
May	.80	.53	.46	.27	.76	.38	.81	.57
June	.95	.65	.69	.49	.94	.56	.94	.74
July	1.32	.95	.76	.61	1.09	.78	1.06	.91
August	1.46	1.05	.80	.63	1.09	.75	1.08	.89
September	1.11	.64	.71	.54	.73	.40	.90	.70
October	.32	.17	--	--	.31	.12	.39	.28
Total, Apr-Oct	6.08	4.03	3.55	2.56	5.40	3.09	5.70	4.29

Month	Wapato Diverted, acre-ft/acre	Wapato Other sources, acre-ft/acre 1/	Wapato Delivered, acre-ft/acre	Kennewick Diverted, acre-ft/acre 2/	Kennewick Estimated delivery to urban area, acre-ft/acre 3/	Kennewick Delivered, acre-ft/acre
March	0.08	--	0.02	--	--	--
April	.41	0.23	.36	0.55	0.36	0.36
May	.94	.66	1.01	.90	.55	.55
June	.94	.70	1.08	.89	.61	.62
July	.96	.60	.99	1.12	.84	.85
August	.90	.63	.94	1.11	.84	.85
September	.73	.51	.79	.86	.51	.52
October	.18	.17	.22	.36	.23	.23
Total	5.14	3.56	5.44	5.79	3.94	3.98

1/ Water diverted from Toppenish and Simcoe Creeks and drainage water pumped into canals for additional usage as irrigation water.

2/ Water diverted for cropland plus urban area divided by cropland plus urban acreage.

3/ It is estimated that urban area receives 46 percent of delivered water (oral commun., Gary Wetherley, Kennewick Irrigation District, 1986), expressed as water delivered to urban area divided by urban and suburban acreage = 7,338 acres.

DESCRIPTION OF THE YAKIMA RIVER BASIN SURFACE-WATER-QUALITY ASSESSMENT PROJECT

Need for Water-quality Assessment

Water-quality Concerns

Concerns, or issues, arise when water-quality conditions impact intended water uses. Water use in the basin includes public drinking supply in the upper Yakima River and Naches River; fish propagation and fish passage in the main stem and tributaries; contact recreation, livestock watering, and irrigation throughout the basin; drainage of municipal, industrial, agricultural and livestock waste downstream of the Cle Elum and Naches Rivers; and aesthetic uses throughout the basin.

Potential water-quality concerns upstream of Ellensburg and in the Naches River basin include the presence of contaminants that would make treatment of the water expensive or possibly would prevent the water from being used as raw water for a public water supply. These contaminants include turbidity, bacteria, nutrients, trace metals, and pesticides (man-made trace organics). With timber harvesting, agriculture, and limited urban areas, any of these contaminants could be present. Upstream of Union Gap, where the water is used for "natural" fish propagation and contact recreation, large contaminant concentrations of suspended sediment, bacteria, nutrients, and pesticides are potential concerns because the streams and main stem receive agricultural drainage from the Kittitas, Wenas, Naches, and Ahtanum Valleys. Indirect effects from acid precipitation could also be a potential concern in some parts of the basin. The main stem also may be impacted by point (sewage-treatment plant) and nonpoint (urban storm-water runoff) sources from the city of Yakima.

Downstream from Union Gap, small streamflows during late summer cause the main stem to be very sensitive to large point or nonpoint source loadings. Downstream from Toppenish, return flows are large relative to the main-stem flows upstream of Toppenish; consequently, water quality in the main stem is similar to that observed in the drains. Potentially large concentrations of bacteria, nutrients, suspended sediment, trace elements, and pesticides from inflowing drains in the lower reaches of the Yakima River are considered to be water-quality concerns.

Status of Water-quality Knowledge

Water-quality conditions in the Yakima River basin are affected by intense land- and water-use activities. Management and resource agencies have monitored and are continuing to monitor these conditions at many sites for a variety of reasons.

Sources of data

Water-quality data have been collected in the Yakima River basin by the U.S. Geological Survey since 1910. The Geological Survey has historical data for water temperature, suspended-sediment concentration and load, and specific conductance on a daily basis at several sites; in addition, more than 126,000 determinations (constituent analyses) are stored as instantaneous data in WATSTORE (National WATer Data STOrage and REtrieval Computer System).

Determinations were made for nearly 300 constituents collected from 130 locations. Major groupings of instantaneous water-quality data are

(1) 37,000 determinations, including discharge, water temperature, specific conductance, dissolved oxygen, color, turbidity, and pH;

(2) 35,000 determinations of major constituents;

(3) 14,000 determinations of nutrients, including nitrogen and phosphorus;

(4) 14,000 determinations of suspended-sediment concentrations, loads, and particle size;

(5) 7,500 determinations of trace elements, including dissolved and total recoverable constituents;

(6) 2,000 measurements of indicator bacteria; and

(7) 1,800 determinations of organic compounds.

Additional water-quality data from the Bureau of Reclamation, Washington Department of Ecology, U.S. Forest Service, and other agencies have been stored in STORET (STOrage and RETrieval Computer System), a U.S. Environmental Protection Agency (EPA) data base. These data were collected from about 300 locations in the basin and represent some of the same locations in the WATSTORE dataset. Major groupings of the 134,000 constituent determinations of instantaneous data are

(1) 58,000 determinations of discharge, water temperature, specific conductance, dissolved oxygen, color, turbidity, and pH;

(2) 26,000 determinations of major constituents;

(3) 32,000 determinations of nutrients;

(4) 4,500 determinations of suspended-sediment concentrations and loads;

(5) 2,800 determinations of trace elements;

(6) 4,800 measurements of indicator bacteria; and

(7) 2,400 determinations of organic compounds.

Some of the determinations listed above were cooperatively collected by the Washington Department of Ecology and the U.S. Geological Survey; these data are stored in the WATSTORE files under a Geological Survey site code and also stored in STORET under a Washington Department of Ecology site code.

An additional 15,000 data values from water-treatment plants, consultants, and Washington State University Experiment Station at Prosser are currently being stored in the Geological Survey computer at the Water Resources Division Office in Portland, Oregon.

Interpretation of all of the existing data will be used (to the extent possible) to:

(1) Develop a conceptual understanding of historical water-quality conditions,

(2) Quantify seasonal variations and long-term trends of selected water-quality constituent concentrations,

(3) Quantify the spatial variability of water-quality constituent concentrations and loads, and

(4) Provide information for (a) selecting NAWQA sites for fixed-location-station and synoptic sampling, (b) selecting target variables, and (c) determining the sampling frequency at fixed-location stations.

Other available water-quality data include atmospheric-deposition data from Central Washington University and biological data from the Washington Department of Fisheries, Washington Department of Game, U.S. Fish and Wildlife Service, and Yakima Indian Nation. These data, along with STORET and WATSTORE data, will be useful for documenting water-quality changes in the basin and examining the potential impact of water quality on stream biota. However, the temporal, spatial, and constituent coverage of the historical data base is quite limited, relative to many of the toxic elements and compounds; consequently additional data-collection is required to better define existing conditions and causative factors that are affecting water quality.

Previous studies

Many studies have been completed on the quality of water in the Yakima River basin. A few of the major studies are summarized below.

(1) Sylvester and Seabloom (1962) collected data from 46 sites in 1959 and 1960 for measurement of major ions, nutrients, dissolved oxygen, temperature, and coliform bacteria. The amount of water diverted in July and August compared to the amount of water available for diversion indicated that water was being re-used for irrigation. Annual evapotranspiration loss was calculated to be 40 percent of diverted water. Irrigation had the effect of raising the ground-water table; the resulting concentration of dissolved solids in ground water was about five times that of adjacent surface waters. Nitrate yields (as nitrogen) in the return flows to the Yakima River were 7 pounds per acre during the irrigation season and and 8 pounds per acre during the non-irrigation season.

(2) McGaughy and Cunningham (1973) found large concentrations of coliform bacteria and nutrients (relative to those found in the rest of the basin) from December 1970 through September 1971 in the reach of the Yakima River from Terrace Heights to Richland and also in Wide Hollow Creek. During summer months, the investigators found high water temperatures and small dissolved-oxygen concentrations between Parker and Granger and between Prosser and Kiona, and large nutrient concentrations downstream of areas of irrigation return flow.

(3) CH2M Hill (1977) found that, at certain times of the year, water quality and quantity were degraded to the extent that recreation and fisheries were impaired at some locations in the basin. Storage and use of water for irrigation were described as the primary activities that impacted the quality and quantity of water. The quality of the Yakima River upstream of Union Gap was described as fairly good, with few beneficial uses impaired. Between Parker and Mabton, the streambed gradient flattens, main-stem summer flows were reduced by diversion, water temperatures were high, and nutrient- and sediment-rich return flows entering the Yakima River were described as producing less than desirable water-quality conditions relative to health and aesthetic considerations.

(4) Fretwell (1979) described the quality of surface and ground water of the Yakima Indian Nation from November 1973 to October 1974. Surface waters in the mountain streams were low in concentrations of dissolved solids and nitrate and generally had small concentrations of bacteria relative to irrigated areas. Lowland streams and drains had large concentrations of bacteria, dissolved solids, and nitrate. At 13 of 18 mountain-stream sites and at all lowland sites in the Yakima Indian Nation, total phosphorus concentrations were larger than the background concentrations (0.02 to 0.04 mg/L) that were commonly found in other mountain streams in the Yakima River basin.

(5) Boucher and Fretwell (1982) monitored flow, suspended sediment, nutrients, and temperature in the irrigation water of Sulphur Creek basin during the 1976 irrigation season and the following non-irrigation season. Sulphur Creek basin had a sediment yield of 2.0 tons per acre of irrigated cropland; 97 percent of the yield occurred in the irrigation season (April to October). Nutrient yields from Sulphur Creek basin for nitrogen and phosphorus were 30 and 3 pounds, respectively, per acre of irrigation cropland. About 65 percent of the nitrogen load and 85 percent of the phosphorus load occurred during the irrigation season. Nitrate plus nitrite constituted 70 percent of the nitrogen load during the irrigation season.

(6) Boucher (1984) evaluated sediment transport in four drains in the Sulphur Creek drainage during the 1979, 1980, and 1981 irrigation seasons. The sediment yield from the four drains, combined during the three irrigation seasons, was 0.89 tons per acre. A major storm (February 16-21, 1980) produced 11 to 51 percent of the sediment discharged during the 3-year study in the four drains, illustrating the importance of sampling during storms and non-irrigation season to obtain annual sediment discharge. Regression analysis showed that sediment yield related best to the total acres of row crops in each of the drainages.

(7) Mueller and George (1984) calibrated and verified two streamflow transport models, using data from four synoptic surveys in 1981 and 1982. The models will be used as part of the U.S. Bureau of Reclamation's Enhancement Project to test the effects on downstream water quality when headwater flows are varied.

(8) Gough and others (1986) analyzed vegetable and fruit produce for 24 elements following the Mount St. Helens ash-fall episodes and compared their results with similar tests conducted in 1973. Sodium, potassium, phosphorus, boron, aluminum, copper, and manganese commonly occurred at larger concentrations in 1980 than in 1973. Concentrations of environmentally important elements (arsenic, boron, cadmium, mercury, molybdenum, nickel, lead, and selenium) were found to be well within the range considered to be normal for plant tissues (Gough and others, 1979).

(9) Johnson and others (1986) analyzed for pesticides in bottom material, water, and fish. They found DDT, DDE, dieldrin, and PCB-1260 in fish in the lower reaches of the Yakima River. DDT, DDE, dieldrin, and endosulfan were found in surface-water samples from creeks or drains containing irrigation return flow. DDT compounds and dieldrin also were found in bottom material in the main stem and tributaries.

(10) Vaccaro (1986) calibrated a streamflow-routing model and Lagrangian streamflow temperature model. A sensitivity analysis indicated that water temperature at any point in the basin is affected more by air temperature and reservoir outflow temperatures than by other factors. Air temperature is the dominant influence in the lower basin. A scenario of no reservoir storage, diversions, or return flows in the basin (estimate of natural conditions) produced conditions that were least favorable for salmon and steelhead habitat. Mean August 1981 discharges were decreased by 3,260 to 940 ft^3/s at Umtanum and by 50 to 1,340 ft^3/s at Kiona. Mean monthly temperatures for August were increased by 4.0 °C at Umtanum and by 0.5 °C at Kiona. A scenario decreasing diversions to reduce all return flows by 50 percent, assuming an increase in irrigation efficiency of 22 percent, was effective for increasing streamflow and decreasing stream temperatures. The mean irrigation-season discharge increased by 440 ft^3/s and mean irrigation-season temperature decreased by 0.4 °C at Kiona.

Existing Water-quality Conditions

Water-quality conditions in the Yakima River basin can be classified into three categories:

(1) Forested stream reaches where turbidity, bacteria, nutrients, and major ions are at background concentrations. Organic-compound data are limited for these reaches, but these concentrations also are expected to be at background level. Naturally-occurring deposits of trace elements in some specific areas could result in elevated concentrations. Concentrations of suspended sediments, nutrients, and levels of turbidity may be above background during and following periods of intensive activity, such as logging.

(2) Agricultural drains where the largest concentrations of turbidity, nutrients, and major ions occur. These areas also are suspected of having the largest concentrations of bacteria and pesticides. Hydrophobic contaminants will be transported via suspended sediments during the irrigation season, during major rainstorm events, or when chinook (warm) winds melt the snow and cause increased overland runoff and high flows.

(3) Streams and canals that are affected by agricultural runoff, urban areas, or timber harvest. These areas will have a range of contaminant concentrations, from background to those concentrations commonly observed in drains. The amount of change from background will depend on (a) the quantity of incoming load relative to the flow of the receiving stream and (b) the ability of the stream to cleanse itself of the contaminant.

Effects of man's activities, including the application of agricultural fertilizers, may be monitored by determining nitrite plus nitrate concentrations in drains, streams, and rivers. Nitrite plus nitrate ions are soluble in water and are readily transported in the water column, acting as a non-conservative tracer of contaminant sources. Background concentrations of nitrite plus nitrate are generally small (<0.10 mg/L) in forested watersheds and tend to become larger with increases in man's activities.

Nitrite-plus-nitrate (as N) concentrations measured in the main stem of the Yakima River in August 1986 are shown in figure 2. Concentrations of nitrite-plus-nitrate nitrogen upstream of Wilson Creek (RM 148) are at background level. Concentrations from Wilson Creek to Parker (RM 148 to 104) are small because of the low incoming load relative to the high flow in the Yakima River. Nitrite-plus-nitrate concentrations in the reach downstream of Parker to Toppenish (RM 104 to 91) have returned to background levels because of minimal loading and the ability of the stream biota to assimilate the inorganic nitrogen from the water. Between Granger and points near the mouth (RM 83 to 8), concentrations increase to approximate the concentrations in the drains. This increase suggests that the main stem downstream of RM 83 consists mainly of water from drains and that nitrogen is not a limiting nutrient to the stream biota.

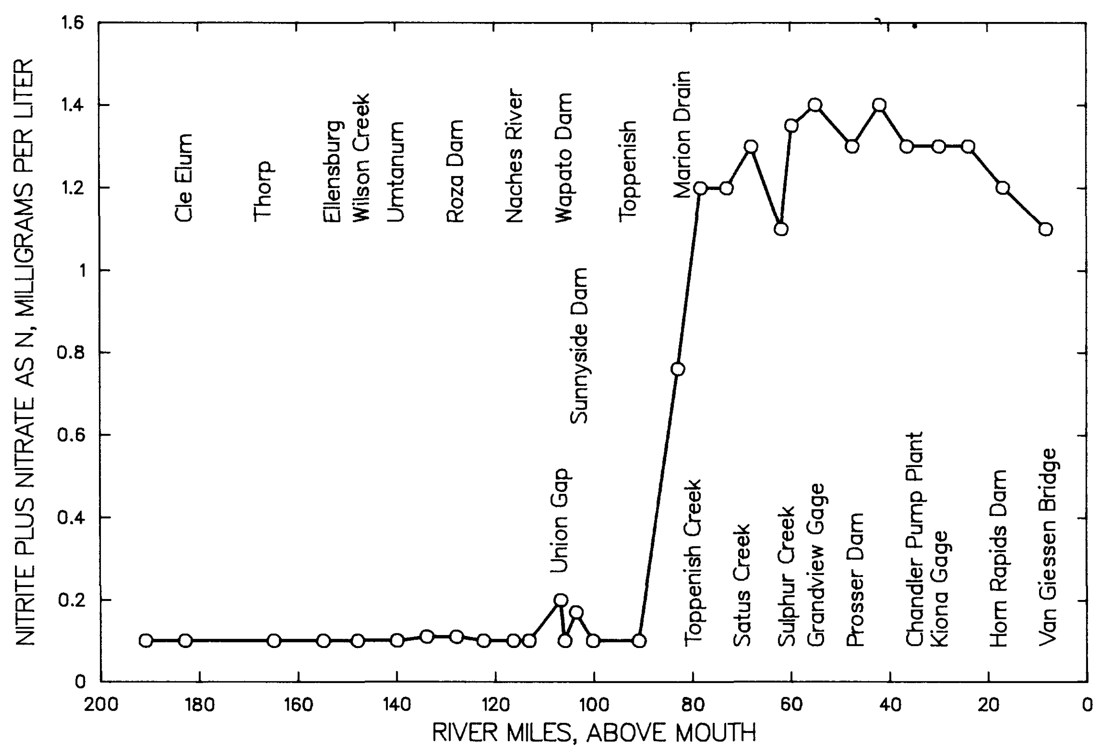

Figure 2.--Graph showing nitrite-plus-nitrate concentrations along the main stem of the Yakima River, August 1986

For the August 1986 synoptic sampling, specific conductance, turbidity, and other nutrient data showed a similar pattern. These recent data, along with historical data, suggest that drains and the main-stem reach downstream from Granger, both of which are associated with irrigated agriculture, have the largest constituent concentrations. Selection of sites for fixed-station monitoring and synoptic sampling initially will be based on these types of associations. As more data are collected, knowledge of these water-quality associations will be iteratively updated.

Study Approach

Three major types of data-acquisition activities will be undertaken during the 3-year period to achieve the NAWQA objectives: fixed-location sampling, synoptic sampling, and intensive-reach studies.

Fixed-location Stations

Fixed-location river-sampling stations may include the following: National Stream Quality Accounting Network (NASQAN) stations, Hydrologic Benchmark Network stations, stations operated under the Geological Survey Federal/State Cooperative Program, stations operated by the Geological Survey on behalf of other Federal agencies, and stations operated by other Federal agencies. Reactivation of selected stations from the EPA National Quality Surveillance System (NWQSS) network also may be desirable. Special consideration will be given to sampling at or near major drinking-water intakes; upstream and downstream from reservoirs, urban areas, and industrial complexes; and in various small and relatively homogeneous (relative to land use) subbasins. Information on point and nonpoint source discharges and on atmospheric deposition (information mostly collected by existing sampling programs) will be used to aid interpretation of the surface-water-quality data.

Fixed-location stations will be sampled for many of the target and support variables at least once a month during the 3-year period of sampling. Additional samples will be collected during high- and low-flow conditions and during selected land-use activities to determine seasonal variability and causal effects. Repetitive sampling is needed because of temporal variability (mainly a result of variations in annual precipitation, river discharge, waste inputs, land- and water-use activities, and temperature). Data from these stations will be interpreted and summarized in terms of frequency distributions of concentrations and mass balances of constituents for comparisons between stations. Hypotheses aimed at relating these conditions to causative factors will be developed and tested.

The Yakima River basin study will operate seven fixed-location sampling sites from April 1987 to March 1990. The sites include Yakima River at Cle Elum, Yakima River at Umtanum, Naches River at Yakima, Yakima River above Ahtanum Creek at Union Gap, Sulphur Creek near Sunnyside, Yakima River near Grandview, and Yakima River at Kiona. Target variables will likely include nutrients, suspended sediment, selected major ions, trace elements, and physical measurements such as water temperature, pH, and specific conductance. These constituents are known to be at measureable levels most of the time. Continuous discharge will be measured as a support variable at all sites.

Data from these sites will be used to determine seasonal variations in water-quality conditions, long-term trends, and annual loads. Annual loads will be related to land- and water-use activities. Site locations, target variables, and sampling frequencies will be reviewed on an annual basis, and changes will be made as needed.

Interpretation of data from fixed-location stations and synoptic stations assumes that the effects of small-scale time variability (on the order of hourly, daily, and weekly) are relatively small compared to the effects of longer-term variations and spatial variations. Selected sites will be monitored hourly for discharge, specific conductance, and other constituents of interest to test this assumption. Sites will be monitored initially for discharge and specific conductance. Site selection will be based on knowledge that the upstream reaches receive a relatively large number of distinct flows and (or) that flows and consequently constituent concentrations are suspected of being significantly variable over a short duration of time. Those sites that show large variations in discharge or specific conductance over a 36-hour period will be selected for collection of samples and analyses of selected constituents (for example, nutrients) on an hourly frequency over a 36-hour period. Additional samplings for daily and weekly variability also will be assessed. No significant variation in the results would confirm that the assumption is correct. Significant temporal variation would cause the project team to reevaluate present assessment approaches.

Synoptic Sampling

The purpose of synoptic sampling is to provide a "snapshot" of water-quality conditions over a broad geographical area by making single measurements at many sites during a brief period of time. Each synoptic study will be tailored to a specific set of water-quality variables. During synoptic sampling, water, suspended sediments, bed material, and biota may be sampled. The synoptic studies also will test the sensitivity of the fixed-station network in detecting potential problems. Adjustments in station location and target variables would be made whenever the synoptic surveys reveal important water-quality conditions which are not apparent from historical or fixed-station data. One of the goals of the synoptic sampling is to identify river reaches of 50 miles or more with chronic water-quality problems.

Trace elements

The objective of this synoptic sampling is to determine the occurrence and spatial distribution of trace-element concentrations in bottom material, suspended and dissolved in the water column, and in biota (plants and fish). These concentrations will be related to rock types (geology), land and water uses, and point and nonpoint sources of contamination.

One of the approaches being considered for sampling bottom material is to collect about 500 to 700 samples in the first year and up to 200 in a second year. Of the 500 to 700 first-year samples, 50 to 70 samples will be used for quality assurance, 7 will come from the fixed-location sampling sites, and 50-100 will come from small and large stream reaches suspected of being enriched because of human activities; the remainder, about 400 to 500 samples, will be used for random stratified sampling. In this random stratified approach, the entire basin is divided into various strata and each stratum is sampled independently.

A stratum will be a subdivision based on geology and land use. This sampling approach increases the accuracy of population estimates because it attempts to sample so that each of the strata are adequately represented. A stratified sampling approach considers (1) rock types and mineralogy as well as land use, and (2) geographical coverage. Where possible, sampling sites will be located in areas with reasonably homogeneous land use and on streams 1.5 to 2 miles in length. The data will be related to land and water uses including forestry; grazing; dry-land farming; multiple-level farming, such as row crop, orchard, vineyard, and irrigated pasture; and urbanization. To help normalize for particle-size effects, samples will be sieved at 62 microns and the sediments finer than 62 microns will be analyzed for total trace-element concentrations (including trace elements that are in the crystal lattice structure as well as those in sediment coatings) and for total organic carbon. Second-year samples will be used for quality assurance, verification of anomalies, and determining the sources and processes that cause areal variability in the basin.

Data on suspended and dissolved trace elements in the water column will also be collected. Suspended-sediment samples will be collected, dewatered, and directly analyzed for total element concentrations. Trace-element concentrations in suspended sediment will be compared to concentrations in the bottom material to help identify the preferred method for determining the occurrence and spatial distribution of trace elements in the basin. Trace-element analyses of suspended sediment also may be used for computing transport loads and for examining the sources and fates of trace elements present in the Yakima River basin. In addition, knowledge of the movement of trace elements may prove to be a relatively inexpensive surrogate for predicting the transport of some man-made organic compounds.

Suspended trace-element samples will be collected initially during high flows (winter and (or) spring months). Water samples will also be collected for analysis of dissolved trace elements to gain a better understanding of total trace-element transport and the proportion of the trace element immediately available for bio-uptake. As dewatering techniques improve, suspended trace-element samples may be collected during other times of the year--perhaps monthly at fixed-location stations--to determine seasonal variations and annual loads. These samples may also be analyzed for total organic carbon and particle size to help explain variations in trace-element concentrations from sample to sample.

Dissolved oxygen

The objective of the synoptic sampling for DO (dissolved oxygen) is to determine whether there presently are reaches with critical (low) DO concentrations in the Yakima River basin. Proposed measurement sites are the seven fixed-location sampling sites plus 10 to 20 sites distributed between (1) slow-moving, deeper reaches of the Yakima River that are receiving point-source effluent and drainage from agricultural, livestock, and urban areas and (2) reaches representative of background sites with a range of slopes, depths, and land- and water-use activities.

To determine whether critical DO concentrations exist, these sites will be sampled during stressed summertime conditions, when stream temperatures are highest and when irrigation return flow and municipal and industrial wastes may make up a significant part of the main-stem flow.

River flows in the lower reaches of the basin are small, providing minimal dilution, and physical aeration in pooled reaches is minimal. Sampling will occur at the sites during early morning hours (no later than 1 hour after dawn), when diel DO concentrations are expected to be small as a result of maximum respiration and minimal photosynthesis.

Indicator bacteria

The objectives of a synoptic sampling for indicator bacteria are to (1) determine areal and temporal variation and (2) develop an improved concept of source, transport, and fate of the organisms. Data will be collected by sampling synoptically during the summer when the river is used for contact recreation and over storm events at selected sites. During the summer, 40 to 60 sites will be sampled to obtain a spatial overview of indicator-bacteria concentrations. A few sites will be selected for hourly or daily samplings to determine short-time variability. Sites will include (1) the seven fixed-location sampling sites; (2) 15 to 25 sites of homogenous land use, that are representative of background conditions for various land- and water-use activities; and (3) 20 to 30 sites likely to be elevated in concentrations because of upstream point-source effluents and upstream nonpoint sources in agricultural, livestock, and urban areas. Storm sampling sites will include a subset of the summer sites. Escherichia coli bacteria counts will be determined in all samples, and fecal coliform and fecal streptococci bacteria counts will be determined at sites with historical data.

Organic compounds

Hydrophobic (water-insoluble compounds) and hydrophilic (water-soluble compounds) man-made organic compounds will be synoptically sampled in the Yakima River basin to determine the occurrence and spatial distribution of constituent concentrations. Both bottom material and suspended sediments will be directly analyzed for the hydrophobic compounds. By use of analytical procedures developed by Dr. Jim Pankow of the Oregon Graduate Center, small amounts of suspended sediments (less than 0.5 grams) will be analyzed to provide estimates of (a) seasonal and long-term variability of constituent concentrations, (b) suspended-constituent loads, and (3) the source, transport, fate, and effects of selected substances within the basin.

The selection of organic compounds to be analyzed will be based on the amount of the compound applied for selected land uses, persistence of the compound in stream sediments, toxicity of the compound, results from previous data-collection activities, and analytical capabilities. Likely candidates for site selection will be stream reaches adjacent to areas that receive large applications of these compounds and whose soils are subject to erosion due to irrigation practices, basin slope, and soil cover. Bottom-material sampling sites will generally be located in depositional zones where fine organically enriched sediments settle out.

The most appropriate time of the year for sampling hydrophobic and hydrophilic organic compounds in the water column will be determined by selecting three broad classes of organic compounds to be analyzed at three to five sites. The classes will include primarily hydrophobic compounds, primarily hydrophilic compounds, and a class of compounds that exhibits in-between characteristics.

Sites will initally be sampled one time during irrigation season, when organic compounds are applied and irrigation-return drains are turbid. Results from this sampling will be used to select one to three sites where organic compounds will be analyzed at a relatively high frequency (monthly plus additional samples during high or low flows) to identify times during the year when a synoptic survey of these compounds would be most productive. Chloride, nitrate, and ammonia also will be sampled to determine the feasibility of using these constituents as indicators for organic-compound contamination.

Bioassessment

The overall goal of the bioassessment is to provide managers of wildlife and managers of water resources with a greater understanding of relations between biota and water chemistry. Specific objectives of the bioassessment have not been defined. However, objectives being considered are to (1) quantitatively describe the habitat as a basis for measuring and evaluating long-term changes, (2) determine the presence or absence of toxics in the biota, (3) examine the feasibility of using biota as accumulators of toxic compounds and as indicators of water-quality conditions, and (4) develop relations between chemical concentrations in the water and the presence of chemicals in biota. Members of the assessment team may consist of Geological Survey biologists and a group of biologists from other Federal, State, or local agencies. The team will design and conduct an intensive synoptic sampling program to meet national and local needs.

Intensive Reach Studies

Intensive studies in specific stream reaches will be aimed at defining the sources or causes of selected contaminants, their fate, and effects on biota. Constituents and stream reaches will be identified by analyzing existing data and newly collected data from the fixed-location and synoptic sampling programs. Not all of the NAWQA basin studies will need intensive reach studies because other sampling activities may be of higher priority within the constraints of available funds. Most intensive reach studies are expected to cover two field seasons and may include mathematical modeling and simulation.

The decision on whether or not to include an intensive investigation of a selected river reach in the Yakima River basin will be delayed until September 1987, when results from more synoptic data collection are known. An intensive study would occur if these results indicate a need to examine a particular reach for specific contaminants.

Photograph Library

The purpose of photograph documentation in the NAWQA program is to characterize water quality and stream quality in the study basins, to provide a permanent record of techniques used to assess water quality, and to identify long-term changes in stream and water-quality conditions.

Photographs will depict sampling techniques and various hydrologic and water-quality characteristics, including low and high flows, point and nonpoint source locations, stream-bed conditions, and algal growth. Repeated photographs, both prints and color slides, will be used to show seasonal variability and long-term changes.

Quality Assurance

Variability in analytical results caused by errors in the sample-collection and analysis process occurs even with rigorously controlled field and laboratory conditions. Quality-assurance programs are used to detect and control these errors and to monitor and document the reliability of results. Errors can be introduced into sample results through (1) selection of a sampling location or method that produces a sample that fails to represent the in situ conditions, (2) improper use of instruments, (3) contamination of the sample, and (4) inappropriate methods of analysis. These errors may be so small that they cannot be measured or so large that their presence is obvious.

The Yakima NAWQA project will develop a quality-assurance (QA) plan to address specific needs and unique aspects not addressed in the NAWQA technical quality-assurance plan (for instance, intensive reach studies). The QA plan will include analyses of blanks, standards, and spikes to measure analytical accuracy and replicate samples to measure analytical and sampling precision. Data interpretation requires knowledge of the accuracy and precision of sampling and analytical procedures.

Agency Coordination

Coordination between Geological Survey personnel and other interested scientists and water-management personnel is an important component of the NAWQA Program.

Each NAWQA study has a local liaison committee to ensure that the scientific information produced is relevant to local and regional interests. The Yakima River NAWQA Liaison Committee was formed in the summer of 1986 and consists of representatives from the following agencies:

U.S. Bureau of Reclamation
U.S. Environmental Protection Agency
U.S. Forest Service
U.S. Bureau of Indian Affairs
U.S. Fish and Wildlife Service
Yakima Indian Nation
Washington State Department of Ecology
Washington State Department of Fisheries
Washington State Department of Game
Washington Water Research Center
Yakima River Basin Association of Irrigation Districts

Specific activities of the Liaison Committee could include (a) exchanging information about local and regional water-quality issues, (b) identifying site locations and constituents for future water-quality samplings, (c) discussing sampling needs and programs of other agencies that may be mutually beneficial, (d) discussing management alternatives and--at the request of the committee members--developing NAWQA products that will be directed toward testing management alternatives, and (e) reviewing and commenting on drafts of NAWQA planning documents and reports.

In addition to the local liaison committees, a National Coordinating Work Group has been established to advise the Geological Survey on the coordination of the NAWQA program.

This work group functions under the general auspices of the Interagency Advisory Committee on Data and the Advisory Committee on Water Data for Public Use. The general purposes of the work group are to advise the Geological Survey on (a) water-quality information needs of Federal and non-Federal water users, and (b) procedures for the timely distribution of NAWQA data and results. The work group currently consists of the Chief Hydrologist of the Geological Survey, eight Federal representatives, seven non-Federal representatives, and some members from the pilot project local liaison committees. The non-Federal agencies represented include the American Water Resources Association, Association of American State Geologists, Association of State and Interstate Water Pollution Control Administrators, Chemical Manufacturers Association, Interstate Conference on Water Programs, and National Association of Conservation Districts. Federal agencies represented are the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, Council on Environmental Quality, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Forest Service, and U.S. Soil Conservation Service.

Proposed Study Products

All data collected by the Yakima NAWQA project will be stored in the Geological Survey WATSTORE Computer System and will be published either in the annual data report or in NAWQA interpretive reports. Any data that suggest possible exceedence of a Federal or State standard or suggest potential problems relative to an intended water use will be verified and then promptly furnished to State or Federal agencies with management responsibility.

A Geographic Information System (GIS) will be available for use on the Geological Survey computer in Portland, Oregon, by personnel from (1) the Geological Survey at the national level, for collecting results from basin studies in a national summary; (2) State and local agencies, for testing of management alternatives; and (3) the Geological Survey Pacific Northwest District, for developing and testing hypotheses. This joint use of the GIS will help in the iterative development of water-quality concepts and determination of priorities for future sampling activities.

Several reports will be published in this project. Presently planned reports include:

(1) Project description of study (this report), and

(2) Analysis of historical data.

Other interpretive reports will be written to describe sample collection and results when sufficient knowledge has been gained to assess the occurrence, the source and transport, or the cause and effect of water-quality constituents. Topics of future reports could include trace elements, indicator bacteria, nutrients, pesticides, aquatic biology, and long-term time trends. A summary report also will be published at the end of the study. Some of the reports may be published as Geological Survey reports and others as journal articles.

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