# SUMMARY OF WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY IN WASHINGTON: FISCAL YEAR 1991

*Compiled by Judith A. Wayenberg and Virginia F. Renslow*

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U.S. GEOLOGICAL SURVEY
Open-File Report 92-92

Tacoma, Washington
1992

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

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For additional information
write to:

District Chief
U.S. Geological Survey
1201 Pacific Avenue, Suite 600
Tacoma, Washington 98402

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# CONTENTS

CONTENTS--Continued

## ILLUSTRATIONS



## TABLE

**Page**



## ACRONYMS AND ABBREVIATIONS COMMONLY USED IN THIS REPORT

| | |
|---|---|
| ARC/INFO | A Geographic Information Data Base |
| EPA | U.S. Environmental Protection Agency |
| GIS | Geographic Information System |
| GWSI | Ground Water Site Inventory |
| NASQAN | National Stream Quality Accounting Network |
| NOAA | U.S. National Oceanographic and Atmospheric Administration |
| NWIS | National Water Information System |
| RASA | Regional Aquifer-System Analysis Program (USGS) |
| USGS | United States Geological Survey |
| WATSTORE | National Water Data Storage and Retrieval System (USGS) |
| WDOE | Washington Department of Ecology |
| WDOH | Washington Department of Health |

# SUMMARY OF WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY IN WASHINGTON: FISCAL YEAR 1991

## INTRODUCTION

Water-resources-related activities of the U.S. Geological Survey (USGS) in Washington consist of collecting water-resources data and conducting interpretive hydrologic investigations and research. The water-resources data and the results of the interpretive investigations and research are published or released by the USGS or by cooperating agencies. This report describes the data-collection activities and water-resources investigations in Washington for the 1991 fiscal year (October 1, 1990, to September 30, 1991).

The Washington District office is located in Tacoma, Wash., and Carl R. Goodwin is the Washington District Chief. The district has three field offices, located in Tacoma, Spokane, and Pasco. The Washington District, along with the Oregon and Idaho Districts, constitutes the Pacific Northwest Area, under the direction of Assistant Regional Hydrologist Garald G. Parker, Jr. Requests for information should be addressed to:

District Chief
U.S. Geological Survey
Water Resources Division
1201 Pacific Avenue, Suite 600
Tacoma, Washington 98402
Telephone: (206) 593-6510

Tacoma Field Office
U.S. Geological Survey
Water Resources Division
1201 Pacific Avenue, Suite 520
Tacoma, Washington 98402
Telephone: (206) 593-6520

Pasco Field Office
U.S. Geological Survey
Water Resources Division
403 W. Lewis, P.O. Box 1344
Pasco, Washington 99301-1344
Telephone: (509) 547-2571

Spokane Field Office
U.S. Geological Survey
Water Resources Division
Room 694, U.S. Court House
West 920 Riverside Avenue
Spokane, Washington 99201
Telephone: (509) 353-2633

# MISSION OF THE U.S. GEOLOGICAL SURVEY

The U.S. Geological Survey was established by an act of Congress on March 3, 1879, in order to answer the need for a permanent government agency at the Federal level to conduct, on a continuing, systematic, and scientific basis, investigations of the "geological structure, mineral resources, and products of the national domain." Although a number of laws and executive orders have expanded and modified the scope of the Survey's responsibilities during its 110-year history, the Survey has remained principally a scientific and technical investigation agency, as contrasted with a developmental or regulatory one. Today the Survey is mandated to provide information for society to mitigate the impact of floods, earthquakes, landslides, volcanoes, and droughts; to monitor the Nation's ground- and surface-water supplies; to study the impact of man on the Nation's water resources; to provide mapped information on the Nation's landscape and land use; and to assess onshore and offshore energy and mineral resources. The Survey is the principal source of scientific and technical expertise in the earth sciences within the Department of the Interior and the Federal Government. The Survey's activities span a wide range of earth science research and services in the fields of geology, hydrology, and cartography, and represent the continuing pursuit of the long-standing scientific missions of the Survey. [1]

[1] Source: Adapted (and updated December 1984) from U.S. Geological Survey Yearbook for Fiscal Year 1983.

# MISSION OF THE WATER RESOURCES DIVISION

The mission of the Water Resources Division, which supports the mission of the Geological Survey and the U.S. Department of the Interior, is to develop and disseminate scientific knowledge and understanding of the Nation's water resources. The activities carried out by the Water Resources Division fall into three broad categories: (1) resource assessment; (2) research; and (3) coordinating the activities and cataloging the products of numerous other entities involved in water research, data acquisition, or information transfer.

Resource Assessment. Resource assessment consists of:

- o Collecting data on the quantity, quality, and use of surface water (rivers, streams, lakes, reservoirs, estuaries, and glaciers); the quantity, quality, and use of ground water (including water in the unsaturated zone); the quantity and quality of precipitation (as related to specific hydrologic investigations); and the quantities of evaporation, transpiration, and ablation.

- o Storing and disseminating these data.

- o Interpreting these data and publishing the results of these interpretations. This interpretation involves the inference of hydrologic causes, effects, and probabilities; and the extension, over space and time, of information contained directly in the data.

- o Developing and applying new methods of hydrologic data collection, analysis, and interpretation.

- o Conducting areally focused interpretive investigations and appraisals at national, regional, State, or local scales. These include characterizations of ground and surface waters and of precipitation chemistry; evaluation of natural hydrologic hazards; and studies of other water-related topics. Frequently, these investigations involve the development, testing, and application of mathematical models capable of predicting the hydrologic consequences of management actions, development plans, or natural phenomena. These investigations are carried out through specific Federal programs or in cooperation with State and local governments or other Federal agencies. Results are published in State, local, U.S. Geological Survey, or other Federal agency publications or in technical journals.

- o Reporting to the Nation, on a regular basis, on the overall status of water resources and on hydrologic events and water-resource issues.

Research. The Division conducts research in a wide variety of scientific disciplines--geochemistry, ecology, geomorphology and sediment transport, water chemistry, ground-water hydrology, and surface-water hydrology--particularly as these disciplines relate to the quantity, flow, and quality of surface water and ground water and to other aspects of the hydrologic cycle. The research is directed toward:

- o Improving the overall understanding of the pathways, rates of movement, and the physical, chemical, and biological processes in the hydrologic cycle.

- o Improving the overall understanding of the physical, chemical, and biological factors, both natural and anthropogenic, that affect the water resource.

- o Providing new strategies of data collection, analysis, and interpretation, in the light of new knowledge and evolving scientific instruments and capabilities.

- o Improving methods of predicting the response of hydrologic systems to stresses, whether hydraulic or chemical, and whether of natural or human origin.

Coordinating the Activities and Cataloging the Products of Other Entities Involved in Water Research, Data Acquisition, or Information Transfer. This function has four major components:

- o Coordinating water-data acquisition activities of Federal agencies (as mandated by Office of Management and Budget Circular A-67).

- o Acquiring water-use data and developing State and national water-use data bases in cooperation with State governments.

- o Operating water information exchanges and centers, which provide all interested parties with indexing and access to many sources of water data and information.

- o Administering extramural water-resources research, technology, development, academic training, and information-transfer programs mandated by the Water Resources Research Act of 1984 (Public Law 98-424). The Act mandates research oriented to the environmental values associated with the resource. The research promoted by the Act involves many disciplines and activities other than those required in the assessment, research, and coordinating functions of the Water Resources Division.[2]

[2] Mission statement by the Chief Hydrologist, September 18, 1984, updated to reflect recent additions.

# COOPERATING AGENCIES

In Washington, many water-resources data-collection activities and interpretive hydrologic investigations are conducted in cooperation with Federal, State, and local agencies. The agencies cooperating with the U.S. Geological Survey on the projects summarized in this report were:

City of Castle Rock
City of Kelso
City of Longview
Cowlitz County
Guemes Island Environmental Trust
King County
Municipality of Metropolitan Seattle
Pacific County
Pierce County
Pierce County Surface Water Management Utility
Puyallup Tribe of Indians
Regional Water Association of South King County
Seattle-King County Health Department
Skagit Conservation District
Snohomish County
Swinomish Tribe
Thurston County Department of Public Works
Thurston County Health Department
Tulalip Tribal Board of Directors
U.S. Department of Energy
U.S. Department of the Interior
  Bureau of Indian Affairs
  National Park Service
U.S. Environmental Protection Agency
Washington Department of Ecology
Washington Department of Health
Washington Department of Natural Resources
Whatcom County Planning Department
Yakima Tribal Council

# COLLECTION OF WATER-RESOURCES QUANTITY AND QUALITY DATA

Hydrologic-data stations are maintained at selected locations throughout Washington and constitute a water-resources data network for obtaining records on stream discharge and stage, reservoir and lake stage and storage, ground-water levels, well and spring discharge, and the quality of surface and ground water (figs. 1 to 3; table 1). Every year new stations are added to the network and other stations are terminated; thus, the USGS has both a current and a historical file of hydrologic data. Most water-resources data are stored in the USGS National Water Data Storage and Retrieval System (WATSTORE) data base, and are available on request to water planners and others involved in making decisions affecting Washington's water resources. Most Washington water-resources data are stored in the Washington District office's National Water Information System (NWIS) data base, and likewise are available to the public. These data can be retrieved in machine-readable form or in the form of computer-printed tables, statistical summaries, and digital plots. Local assistance in the acquisition of services or products from WATSTORE or NWIS can be obtained by contacting the Washington District Chief in Tacoma, Wash.

## Surface-Water Data

Surface-water discharge (streamflow), stage (water level), and quality data are collected for general hydrologic purposes, such as assessment of water resources, areal analysis, determination of long-term trends, research and special studies, or for management and operational purposes. Data-collection platforms (DCP's), used for the transmission of satellite-telemetered river-stage information, have been installed at 119 sites throughout the State. Satellite-telemetry acquisition of the information is essential to many agencies for operating reservoirs, predicting river stage and flood conditions, and optimizing the availability and use of water resources. Data are received directly and in near real time from the USGS ground-receive site located in Tacoma, Wash. After processing, the data are made available in near real time to other agencies.

Information from water-quality stations is used to monitor the quality of surface water in Washington and to detect temporal trends. The frequency of sample collection can vary from continuous, for selected constituents such as temperature, conductivity, and pH, to annual, for data such as pesticide or radiochemical constituents. In addition to the water-quality data collected at recurring intervals from fixed sites, a variety of information is collected at miscellaneous sites as part of interpretive hydrologic studies. This information also is available from USGS files.

Periodic water-quality data such as concentrations of common ions, nutrients, and trace metals were obtained at 28 surface-water stations in fiscal year 1991 (see table 1). Eleven of these stations are part of a USGS nationwide network known as the National Stream Quality Accounting Network (NASQAN), and one is part of the nationwide Bench-Mark network that provides data used in the evaluation of trends in stream quality.

Water temperature is monitored continuously or daily at 19 sites, specific conductance at 9 sites, and pH at 4 sites. Automatic instruments measure the characteristic of interest continuously throughout each day, enabling the information to be summarized for the day as the daily maximum, minimum, and mean.

Suspended-sediment data are collected at 17 stations in Washington. Five stations are operated as daily stations, and of the 12 periodic stations, 11 are NASQAN stations. The other one is operated in cooperation with the Department of Energy. For the daily stations, concentrations of suspended sediment are determined for each daily sample, and particle size is determined in selected samples. For the periodic stations, both concentrations and particle size are determined for each sample collected.

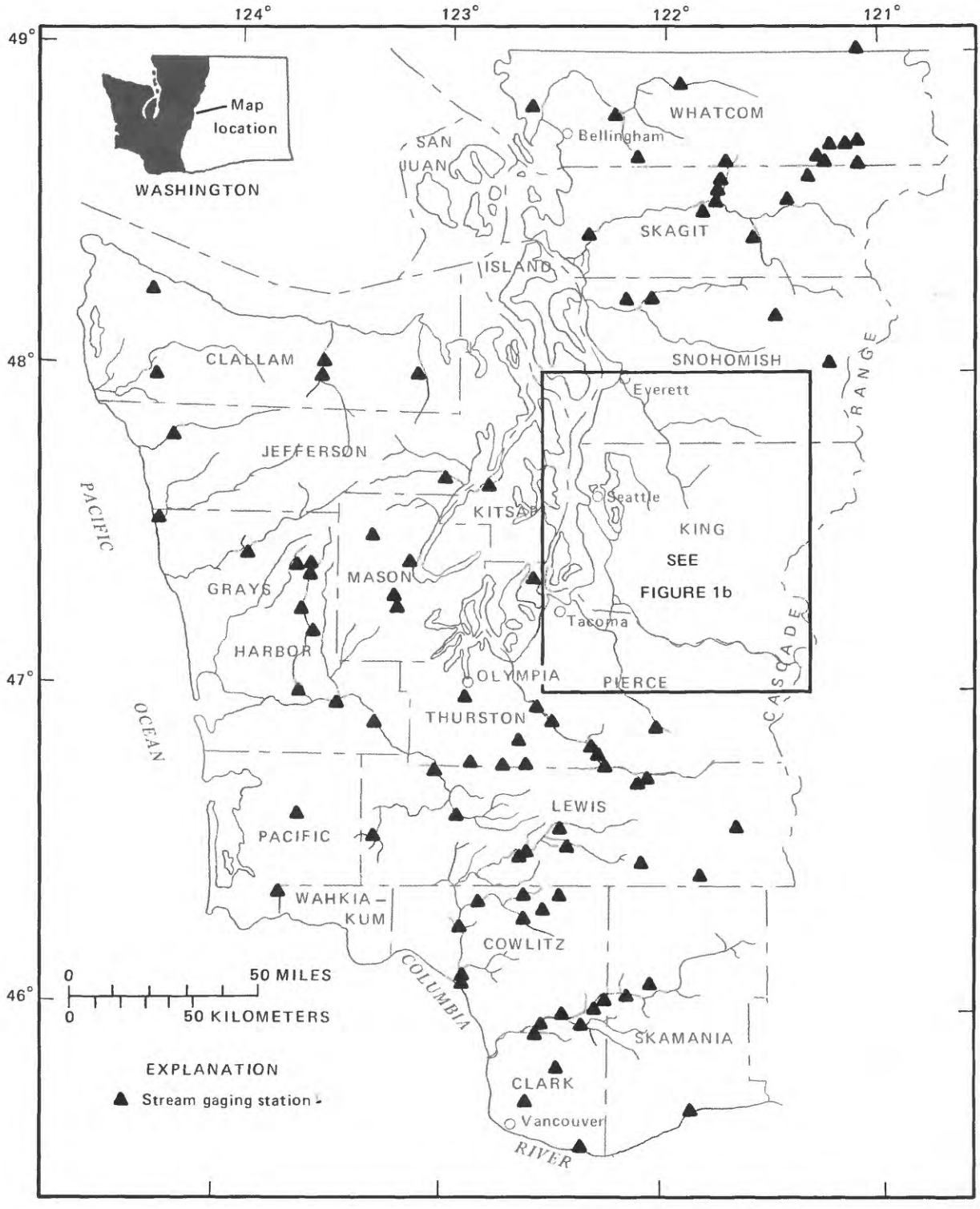



Figure 1a.–Locations of stream gaging stations in Western Washington.

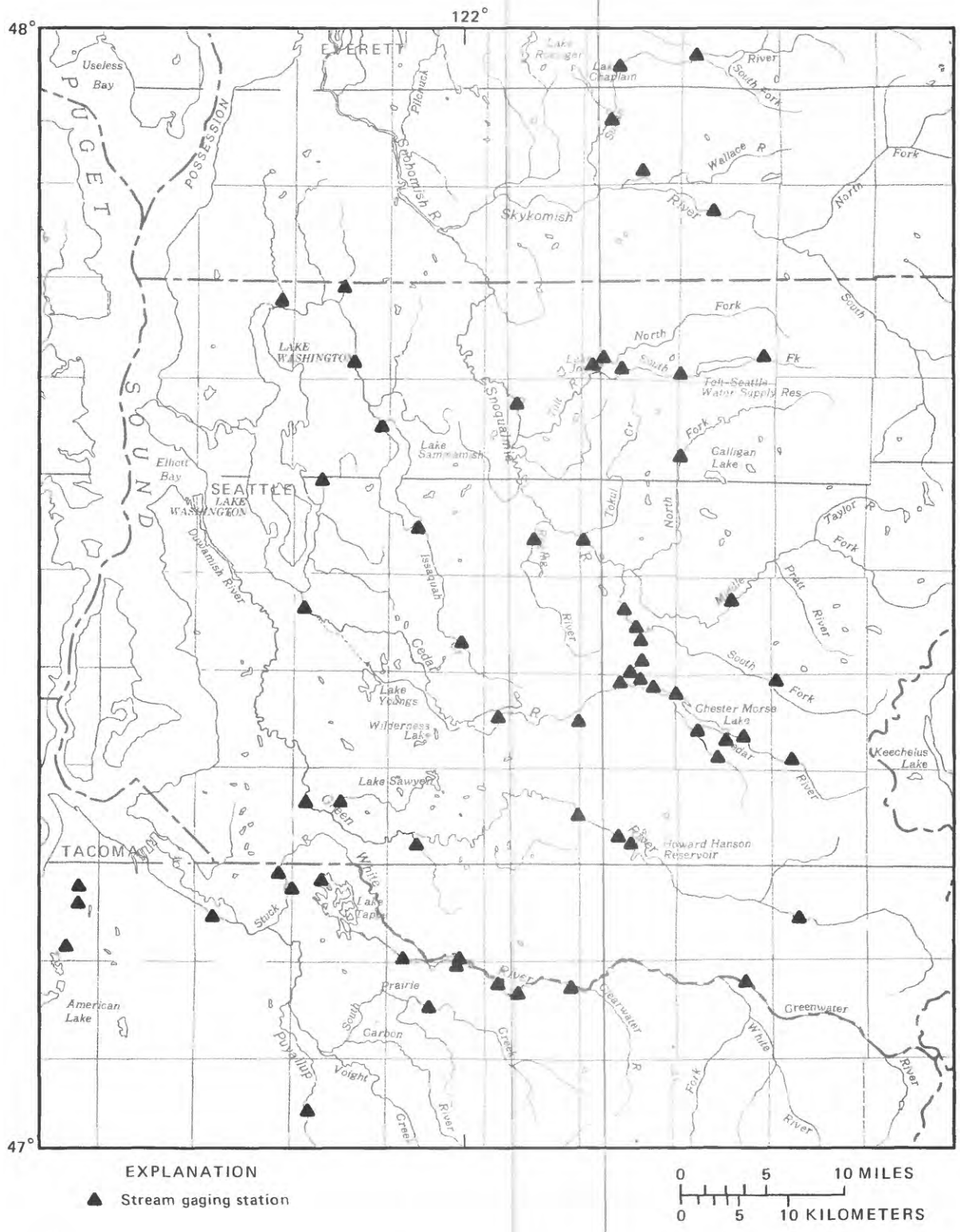



Figure 1b.–Locations of stream gaging stations in Western Washington, insert map.

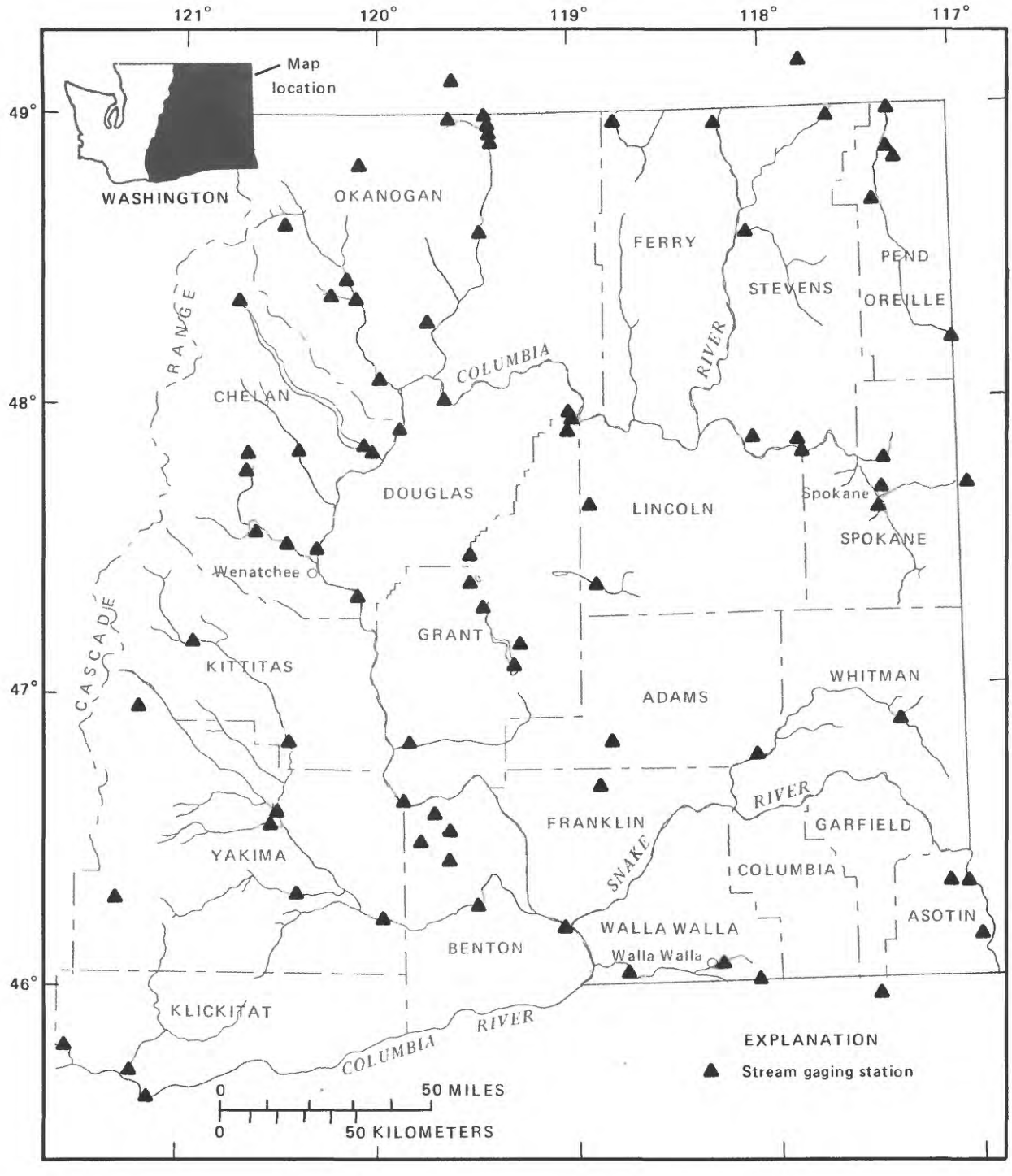



Figure 1c.–Locations of stream gaging stations in Eastern Washington.

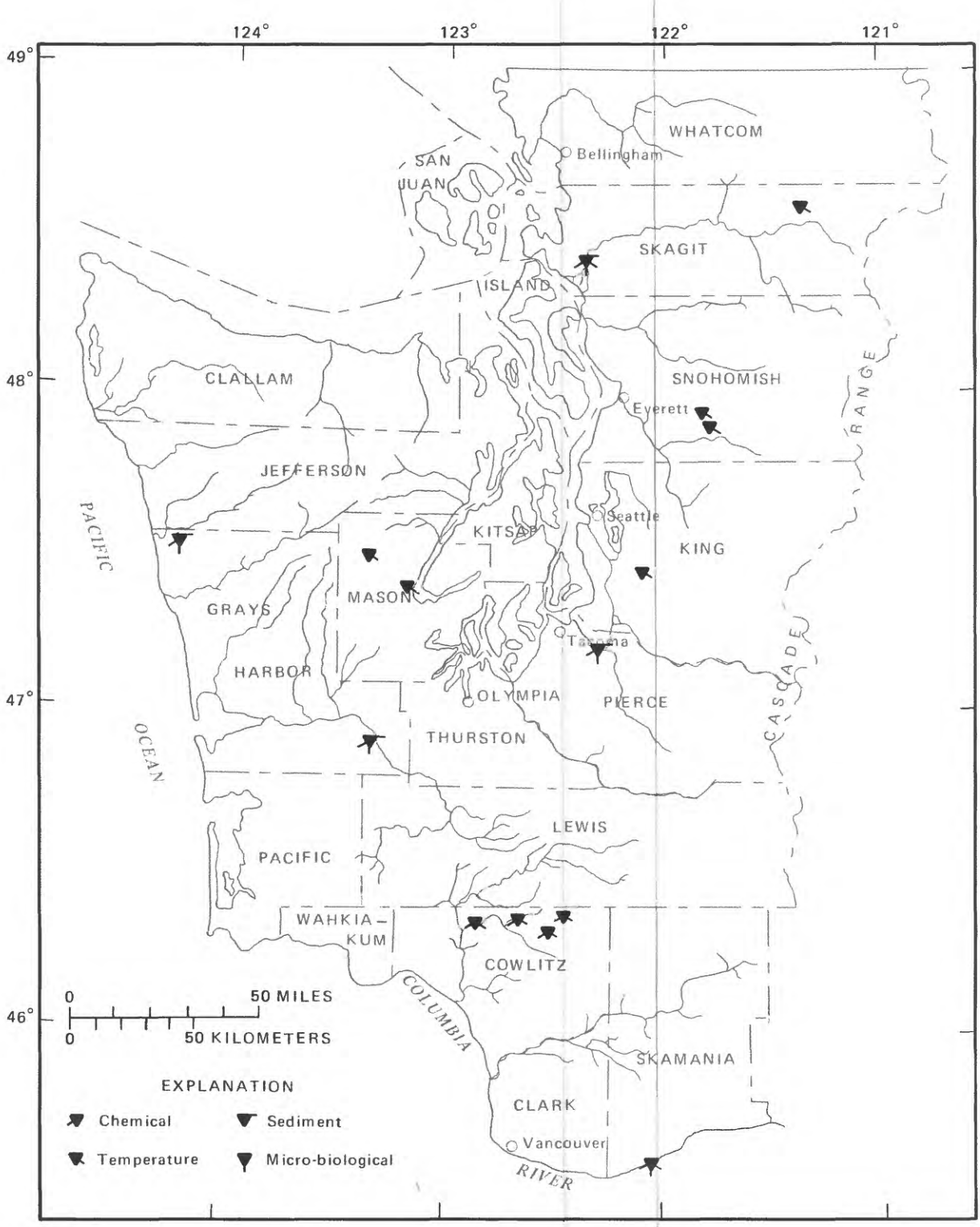



Figure 2a.–Locations of surface-water-quality sampling stations in Western Washington.

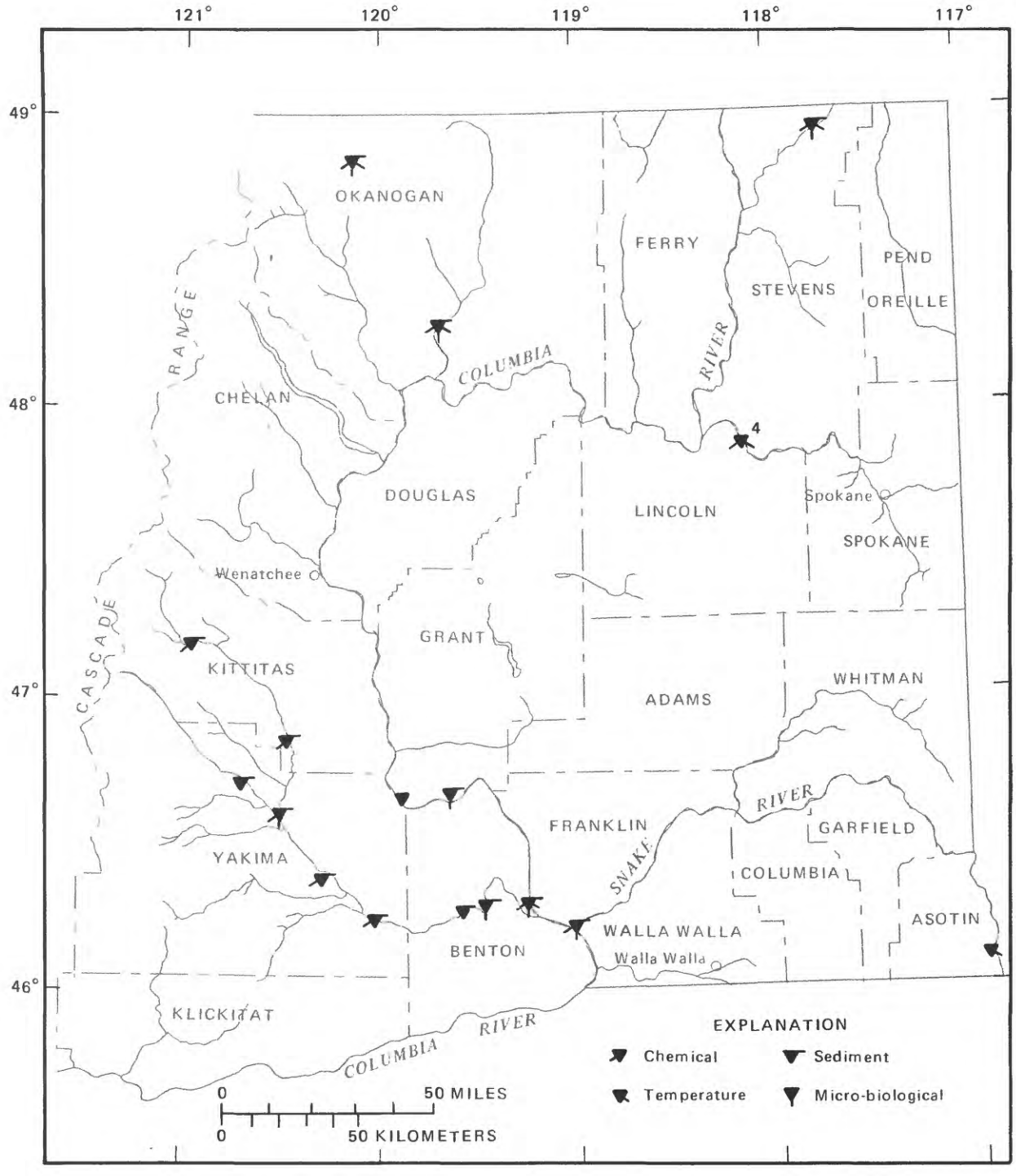



Figure 2b.–Locations of surface-water-quality sampling stations in Eastern Washington.

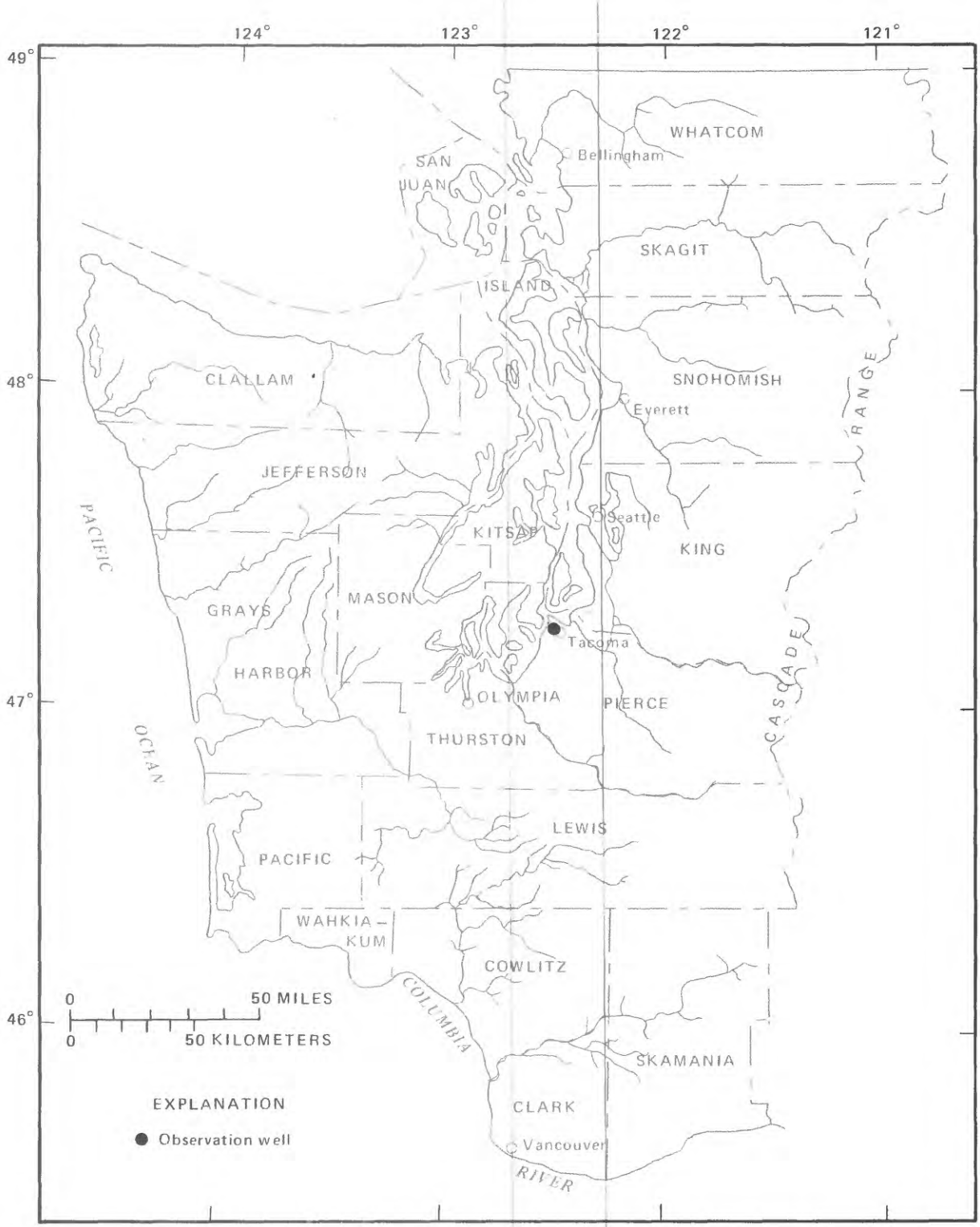



Figure 3a.–Locations of ground-water level observations in Western Washington.

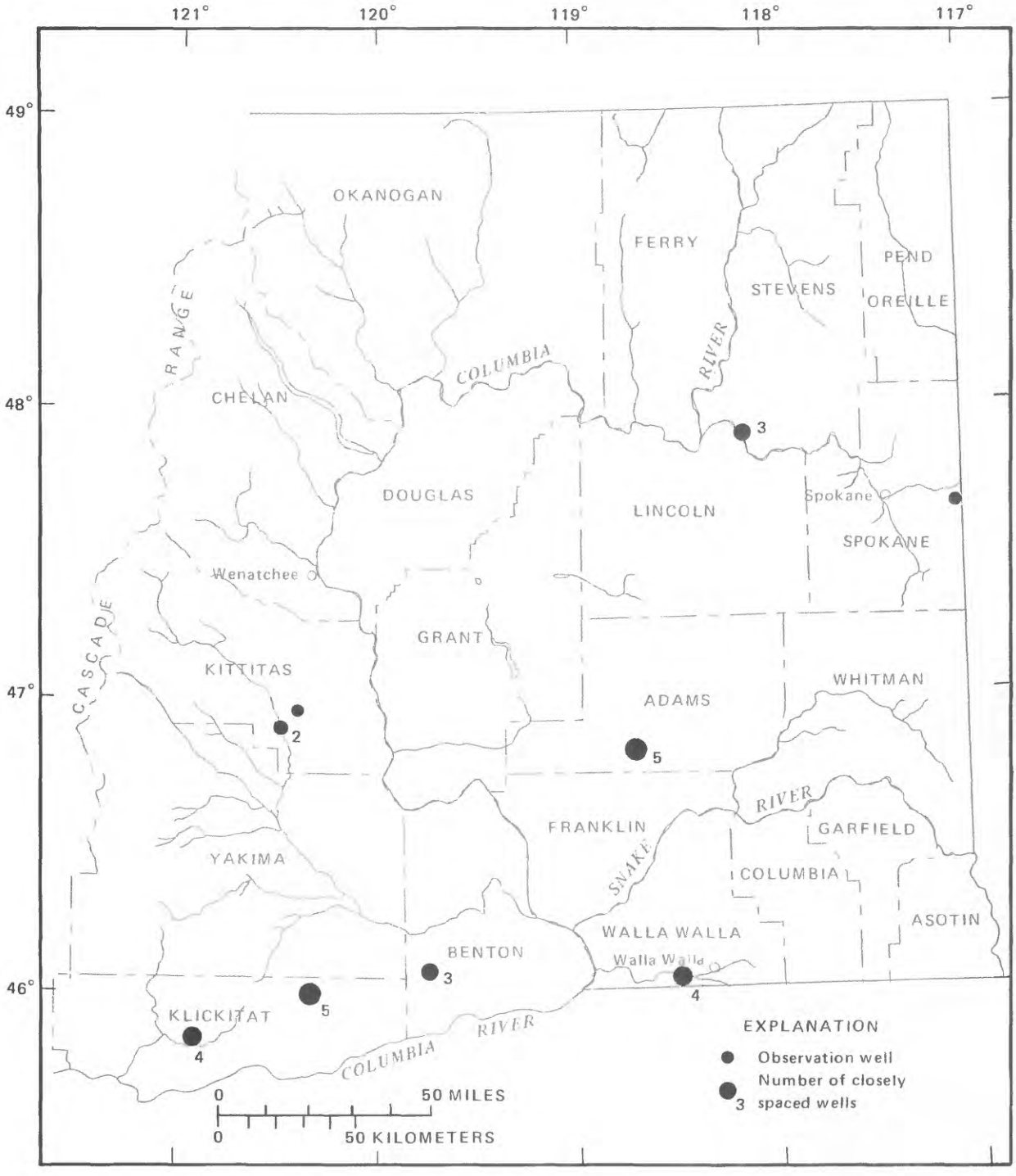



Figure 3b.–Locations of ground-water level observations in Eastern Washington.

*Table 1.--Water-resources data-collection stations in operation during fiscal year 1991, by station classification*

| Station classification | Number of stations |
|---|---|
| **SURFACE WATER** | |
| Streamflow: | |
| Discharge: Continuous record | 202 |
| Partial record | 41 |
| Stage only: Continuous record | 15 |
| Partial record | 2 |
| Real-time stage and discharge (data collection platforms) | 119 |
| Lakes and reservoirs: | |
| Stage and content | 51 |
| Water quality: | |
| Periodic chemical quality | 28 |
| Continuous or daily quality monitoring | 11 |
| Temperature | 19 |
| Specific conductance | 9 |
| pH | 4 |
| Suspended sediment: | |
| Daily or more often than weekly | 5 |
| Periodic | 12 |
| **GROUND WATER** | |
| Water level: | |
| Continuous | 6 |
| Long term | 2 |
| Short term | 337 |
| Water quality: | |
| Periodic chemical--monthly or more frequent | 1 |
| Periodic chemical--less than monthly | 326 |
| **METEOROLOGICAL** | |
| Precipitation | |
| Quantity, weekly | 60 |
| Quantity, real time | 21 |
| Quality, weekly | 1 |
| Wind speed | 7 |
| Relative Humidity | 4 |
| Air temperature | 18 |
| Solar radiation | 4 |
| Net radiation | 4 |
| Snow pillows | 2 |

## Ground-Water Data

Data on ground-water levels, well and spring discharge, and ground-water quality are collected at a network of observation wells established throughout the State. The data are used to study the behavior of the major aquifer systems and to provide information to water users and managers to make decisions about the management of their ground-water resources. Water levels are measured continuously at 6 wells, on a long-term basis at 2 wells, and on a short-term basis at 337 wells. Periodic water-quality samples were taken monthly at 1 well and less frequently at 326 wells.

## Meteorological Data

One meteorological station in Washington is part of the nationwide National Trends Network program to monitor long-term precipitation quality and its changes. Composite samples are collected weekly by an observer who records precipitation quantities, measures pH and specific conductance of the composite sample, and submits the sample to the laboratory for chemical analysis.

Hourly quantity data are collected at 5 sites for rainfall-runoff investigations in one county, and at 27 sites in conjunction with the collection of flow data at stream-gaging stations.

As part of an evapotranspiration study, data are collected at four sites in Washington. At three of these sites, in eastern Washington, wind speed, relative humidity, air temperature, solar radiation, net radiation, and precipitation are measured. Data are collected at 20-minute intervals in the spring and summer and at 60-minute intervals in the autumn and winter. At the fourth site, in western Washington, data are collected to compute evapotranspiration for the Puget-Willamette Lowland Regional Aquifer-System Analysis (RASA). Data collected here are the same as for the eastern Washington evapotranspiration sites but at 60-minute intervals year-round. An identical site is located in western Oregon as part of this RASA.

# INTERPRETIVE HYDROLOGIC INVESTIGATIONS

Forty interpretive hydrologic investigations were conducted during fiscal year 1991, in cooperation with 28 Federal, State, and local agencies. The hydrologic investigations provide information to answer questions specific to hydrologic processes and the State's needs, as well as questions addressing statewide, multistate, and nationwide hydrologic problems. A brief summary of each investigation follows.

PROJECT TITLE: Washington Water-Use Program

PROJECT NUMBER: WA-007

STUDY LOCATION: Statewide

COOPERATING AGENCIES: Washington Department of Ecology and Washington Department of Health

PROJECT CHIEF: Ronald C. Lane

PROJECT DURATION: Ongoing, beginning in 1978

PROBLEM: Water use in Washington has evolved over the past century from meager domestic and stock-water requirements to the present complex and often conflicting requirements of large irrigation projects, municipalities, industrial plants, and power-generation facilities. Unfortunately, little attention has been paid to keeping accurate accounts of the actual quantities of water used. The increasing demands and competition for water (especially during droughts) makes accurate water-use information extremely valuable in determining future water availability and in making sound resource-management decisions.

OBJECTIVES: The objectives of this project are to (1) assist and encourage Washington Department of Ecology (WDOE), Washington Department of Health (WDOH), and USGS efforts in the establishment, maintenance, and expansion of a water-use data-collection program appropriate for Washington; (2) establish and maintain a centralized and computerized water-use data storage and retrieval system to provide adequate, timely access to all users in the Federal and State sectors; and (3) relate all withdrawals and diversions to their specific source (aquifer, stream reach, or other location).

APPROACH: The approach for this project is to (1) work with, support, and encourage WDOE and WDOH efforts to implement and expand their "Water-Use Reporting System;" (2) render assistance and encouragement to other USGS water-resource investigations in the collection, storage, and interpretation of water-use data within their area of interest; (3) convert from the current local site-specific water-use data base to the NWIS-based site-specific water-use data system (SSWUDS); and (4) continue to develop, maintain, and expand the site-specific and aggregated water-use data bases.

PROGRESS: The local site-specific water-use data base was developed in 1988 and used to provide storage and retrieval services from that time forward. Data from the 1988 and 1990 WDOH Public Water Supply Facilities Reports and selected 1990 power-generation and reservoir-evaporation data were entered into the local site-specific water-use data base. The Washington State contribution to the 1990 National Water-Use compilation was completed in September 1990, and the data entered into the NWIS aggregated water-use data system (AWUDS), where they are available in a variety of graphical and report formats.

PLANS FOR FY 1992: Plans for the next fiscal year are to (1) convert from the local site-specific water-use data base to the NWIS-based SSWUDS data base; (2) render support and assistance to USGS water-resources investigations as requested; (3) coordinate and work with WDOE and WDOH to develop, implement, and expand their water-use reporting programs, to ensure complete and compatible data-collection efforts; and (4) provide a centralized and computerized water-use storage and retrieval system.

PROJECT TITLE: Ground-Water Availability and Predicted Water-Level Declines Within the Basalt Aquifers of the Horse Heaven Hills, South-Central Washington

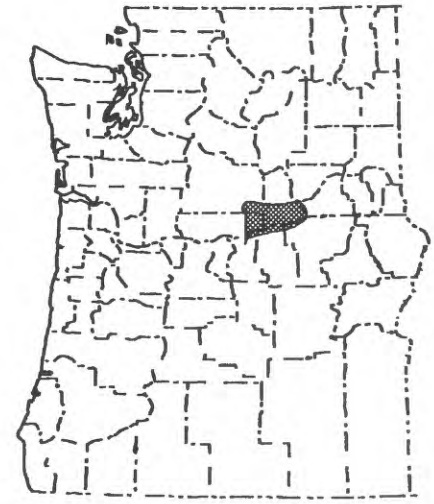
PROJECT NUMBER: WA-232

STUDY LOCATION: South-central Washington

COOPERATING AGENCY: Washington Department of Ecology

PROJECT CHIEF: Frank A. Packard

PROJECT DURATION: Complete, except for report



PROBLEM: The Horse Heaven Hills area of south-central Washington contains about 10 percent of the potentially irrigable land of the State. Since 1970, surface water has been imported from the Columbia River to irrigate the southeastern parts of the area; a smaller quantity of irrigation water is pumped from deep wells in the central part of the area. Recently, deep wells were drilled in order to develop the remaining irrigable land. However, WDOE was concerned about the stresses placed on these aquifers and the possibility that pumpage rates could exceed water availability immediately or in the near future.

OBJECTIVES: The objectives of this project were to (1) determine the availability of ground water in the Horse Heaven Hills area, and (2) develop a numerical model to simulate ground-water movement.

APPROACH: Data collected during a 1977 study and data generated by subsequent development were used to determine the extent to which the geohydrologic setting of the study area could be described. The study was conducted in two phases. Phase I included (1) defining the ground-water flow system from available and field-reconnaissance data; (2) constructing a preliminary numerical model to assist in determining the data-collection scheme; and (3) determining the time and cost needed to collect the remaining information and construct a final model. Phase II was collecting the data identified during phase I and refining and calibrating the numerical model.

PROGRESS: The report was revised in response to technical review.

PLANS FOR FY 1992: The report will be approved for publication and printed.

PROJECT TITLE: Real-Time Hydrologic Data in the Pacific Northwest Area and Alaska by GOES Satellite Telemetry

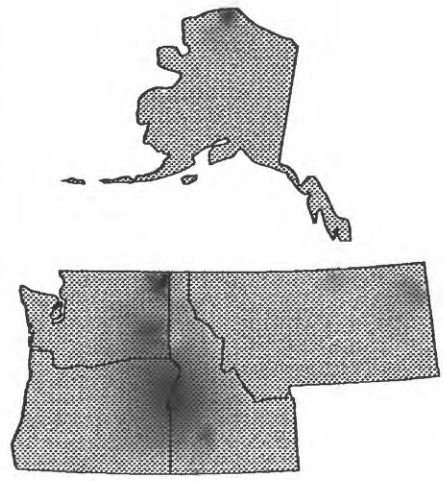
PROJECT NUMBER: WA-241

STUDY LOCATION: Washington, Oregon, Idaho, Montana, and Alaska

COOPERATING AGENCIES: All agencies, local governments, and entities that access real-time GOES data

PROJECT CHIEF: Scott M. Knowles

PROJECT DURATION: Ongoing, beginning in June 1980



PROBLEM: The use of telemetry from the U.S. National Oceanographic and Atmospheric Administration's (NOAA) Geostationary Orbiting Environmental Satellite (GOES) to relay remotely collected hydrologic data is now well established. Use of the data has increased over the last few years to include volcanic hazard warning; flood warning; and real-time streamflow regulation, monitoring, and management. Cooperating agencies and Water Resources Division districts want a reliable real-time data-collection, processing, and dissemination system that includes redundant communication pathways and equipment for added security.

OBJECTIVES: The objectives of this project are to (1) operate a reliable, redundant GOES telemetry data-collection system and improve its effectiveness, efficiency, and usefulness; (2) operate a data processing, display, and dissemination system to meet the real-time needs of the cooperators and districts; and (3) investigate ways to provide effective and efficient surface-water-data management for the future needs of the Washington District and the Pacific Northwest Area.

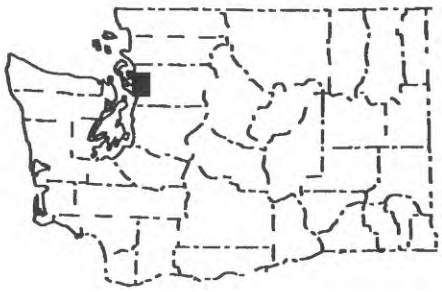
APPROACH: Two Direct Readout Ground Stations (DRGS) are operated by the Washington District. The surface-water data collection, processing, and dissemination software (ADAPS and REALTIME), part of the NWIS, are used to process the real-time data from the DRGS's and to distribute the data to cooperators by way of the data-relay system. Additional software was developed to provide users and cooperators with easy data retrieval and plot commands to display real-time data.

PROGRESS: The Washington DRGS's collected data from 253 DCP's--222 in the Pacific Northwest Area. Of the Washington DCP's, 114 are in western Washington for Mount St. Helens hazard warning, flood monitoring, and river operations in support of district and cooperator data needs. Forty-one new USGS DCP's were added during the year and 18 non-USGS DCP's were discontinued, increasing the total number of DCP's by 23. One DRGS was replaced with a new-technology domestic satellite (DOMSAT) Receive Station (DRS), or Local Readout Ground Station (LRGS), that will begin operation in fall 1991.

Operation and management of the Data-Relay system was linked with existing surface-water-management systems such as ADAPS and WATSTORE to improve data processing within the district. Major reviews were completed of several data bases: the DRGS Emulator files for backup of real-time data through a computer in Reston, Virg.; Platform Assignment Subsystem (PASS) files for DCP assignments; ADAPS Daily Values discharge data; and Surface-Water Index for historical and published discharge data.

PLANS FOR FY 1992: Plans for the next fiscal year are to (1) link the DRS to the Prime computer and ADAPS software to support real-time data-collection activities; (2) purchase a second DRS to support the operating DRGS; (3) install the new revision of ADAPS with the new Device Conversion and Delivery System (DECODES), Satellite Input (SATIN), and Standard Entry (SENTRY) programs, and revise the REALTIME data-relay programs to be compatible with ADAPS; (4) revise the existing real-time data retrieval and plot programs to be compatible with NWIS 91.1 and future revisions of NWIS; (5) complete additional reviews, such as the NWIS Sitefile for surface-water sites, ADAPS Daily Values data base for nondischarge data, and district surface-water informational data bases; and (6) maintain a high level of communication with cooperators who depend on real-time data transmissions in order to anticipate and adequately respond to their needs.

PROJECT TITLE: Quantitative Evaluation of the Water Resources of the Tulalip Indian Reservation and Surrounding Areas, Snohomish County, Washington



PROJECT NUMBER: WA-244

STUDY LOCATION: Northwestern Washington

COOPERATING AGENCY: Tulalip Tribal Board of Directors

PROJECT CHIEF: William E. Lum II

PROJECT DURATION: Complete, except for report

PROBLEM: The population of the Tulalip Reservation doubled between 1960 and 1975, and growth has continued since 1975 with an additional influx of about 1,600 summer-only residents. The well field, established in 1975, had water-level declines of about 1.5 feet per year in the 1980's, and was estimated to have a remaining useful life of perhaps 15 to 20 years under those conditions. Moreover, there was potential for industrial development that would require additional water supply. Seawater intrusion occurred locally on the reservation, but was not yet a serious problem. Data from the ground-water phase of a 1975 study by the USGS were not sufficient to answer these new concerns because the study was limited to interpretation of data available from existing wells and two test holes drilled on the reservation.

OBJECTIVE: The objective of this comprehensive study was to determine, in terms of areal distribution and quantity, the availability of ground water on the reservation from aquifers generally above sea level.

APPROACH: Quantification of the ground-water resources of the reservation required mapping of aquifers in the unconsolidated deposits underlying the reservation, determining aquifer characteristics, and determining the hydraulic relations between the ground-water system and streams. The study included modeling of ground-water flow in aquifers at and above sea level to quantify the available supply and ascertain the effects of future development.

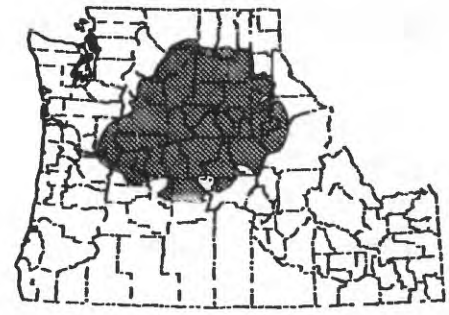
PROGRESS: The report has been revised in response to technical review.

PLANS FOR FY 1992: The report will be approved for publication and printed.

PROJECT TITLE: Columbia Plateau Regional Aquifer-System Analysis

PROJECT NUMBER: WA-260

STUDY LOCATION: Southeastern and south-central Washington, north-eastern Oregon, and northwestern Idaho



COOPERATING AGENCY: None, U.S. Geological Survey funds only

PROJECT CHIEF: John J. Vaccaro

PROJECT DURATION: Complete, except for reports

PROBLEM: The RASA program of the USGS began in the 1978 fiscal year, to provide information, on a regional scale, about the major ground-water systems in the Nation. This information includes the aquifer boundaries, description of the flow system, geohydrologic and hydraulic characteristics, and water quality. Flow models are constructed in the RASA studies to improve understanding of the ground-water flow systems and to analyze the effects of stresses that have led to changes. The flow models also provide a means of assessing the effects of future development of the systems. The Columbia River Basalt Group (CRBG) in the Columbia basin was selected as a RASA study subject and the investigation began in the 1983 fiscal year.

OBJECTIVES: The objective of this project was to obtain a better understanding of the regional ground-water system of the CRBG aquifer by (1) describing the geologic framework; (2) describing the geohydrologic characteristics of the system; (3) determining the water budget of the system; (4) determining water quality, flow paths, residence time, and chemical interactions between water and rock; (5) developing a data-base management and application system for water-use, water-quantity, and water-quality data; and (6) developing a regional ground-water flow model to improve understanding of the aquifer system, including the sensitivity of the hydraulic parameters, components of the water budget, geologic framework, and the hydrologic effects of proposed future development.

APPROACH: Data from drillers' logs, geophysical logs, and mass water-level measurements were stored in the Ground Water Site Inventory (GWSI) data base. They were used, along with pumpage data for crops, irrigated land, and pump efficiencies, in a recharge estimation model that calculates daily water budgets. A steady-state ground-water model for predevelopment and time-averaged 1983-85 conditions was conceptualized and calibrated. The model was operated to evaluate the effects of various hypothetical ground-water development scenarios. In addition, water-quality characteristics of the major formations in the CRBG were described, and a geochemical model was developed.

PROGRESS: The last four scheduled reports were written and submitted for technical review.

PLANS FOR FY 1992: The four reports will be approved for publication and printed.

PROJECT TITLE: Water Resources of the Lower Puyallup River Basin

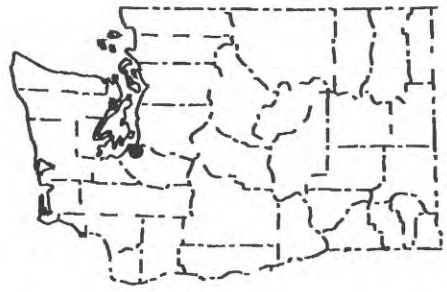
PROJECT NUMBER: WA-279

STUDY LOCATION: Western Washington

COOPERATING AGENCY: Puyallup Tribe of Indians

PROJECT CHIEF: Ronald C. Lane

PROJECT DURATION: Complete, except for report



PROBLEM: The water resources in and adjacent to the lower Puyallup River valley are of vital interest to the Puyallup Tribe of Indians. The Puyallup River and the numerous streams that cross present and historical tribal lands are spawning areas or migration routes for salmon and steelhead trout; these fish are a major part of the tribe's economy and culture. Ground water provides the base streamflows necessary for instream fisheries activity and also is used at the tribe's Diru Creek fish hatchery. The tribe planned to increase ground-water use at the Diru Creek hatchery and to use ground water to supplement the surface-water supply at a proposed hatchery on Clark's Creek. Most of the land within and adjacent to the original tribal reservation has been developed for residential, commercial, industrial, and agricultural uses. The tribe was concerned that the quality and quantity of surface and ground waters may have become impared to the extent that fish propagation, human health, and esthetics were being adversely affected. This concern was intensified in 1981 when the U.S. Environmental Protection Agency (EPA) designated the nearshore and tideflats areas of Commencement Bay top-priority hazardous-waste sites and targeted them for remedial action.

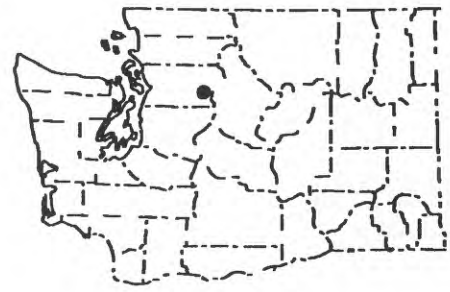
OBJECTIVES: The objectives of this project were to (1) describe the geohydrology of the lower Puyallup Valley and adjacent uplands; and (2) estimate the regional hydrologic effects of pumping ground water for use at the proposed Clarks Creek fish hatchery site.

APPROACH: The geologic framework was defined by reviewing published reports and by compiling and interpreting well logs from drillers' reports. The ground-water flow system was defined by collecting and interpreting data on ground-water elevations and discharges in small streams. The data were used to construct and calibrate a numerical ground-water flow model based on a generalized model developed previously to simulate steady-state, multilayer ground-water flow systems and seawater intrusion. The resulting model was used to simulate changes in ground-water levels and to test for saltwater intrusion caused by the continuous pumping of as much as 13 cubic feet per second from a well at the proposed hatchery site. Whether wells can be constructed to obtain this quantity of water at the proposed hatchery site was beyond the scope of this investigation. Answering this question would require a site-specific study that includes drilling and aquifer testing.

PROGRESS: The report was submitted for Director's approval.

PLANS FOR FY 1992: The report will be approved for publication and printed.

PROJECT TITLE: Hydrology of the Goat Lake Watershed, Snohomish County, Washington



PROJECT NUMBER: WA-290

STUDY LOCATION: Southeastern Snohomish County, Washington

COOPERATING AGENCY: None, U.S. Geological Survey funds only

PROJECT CHIEF: Norman P. Dion

PROJECT DURATION: Ongoing, beginning in 1982

PROBLEM: In 1982, the Goat Lake watershed was selected by the USGS as an "experimental watershed" to function as the focus for long-term studies on the effects of acidic precipitation on water resources. The reasons for selecting Goat Lake were as follows: (1) The lake contains dilute water and is highly sensitive to acidic inputs from atmospheric deposition and streamflow; (2) during the rainy (winter) season, the lake is downwind of the Tacoma-Seattle-Everett industrial and urban area that emits sulfurous and nitrous oxides that combine with atmospheric moisture to produce acidic precipitation; (3) the lake is situated at high altitude and receives more than 150 inches of precipitation per year; (4) the lake is in a wilderness area, where land-use changes are unlikely; (5) the lake is relatively inaccessible and is unlikely to be substantially affected by man; and (6) the lake is typical of numerous lakes in the Cascade Range.

OBJECTIVE: The objective of this project is to collect sufficient discharge and water-quality data for the inflow and outflow to enable a general assessment of the water-quality characteristics of the streams, especially with respect to those constituents that are sensitive to, or indicative of, acidic precipitation.

APPROACH: Samples from the outflow and principal inflow are being collected monthly. Specific conductance and pH are measured in the field. The samples then are processed and prepared for USGS Central Laboratory analysis for concentrations of calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, phosphate, fluoride, alkalinity, pH, specific conductance, iron, manganese, and aluminum. Samples for the determination of concentrations of iron, manganese, and aluminum are filtered through a 0.10-micron filter and acidified with ultra-pure nitric acid. A non-recording gage that monitors precipitation quantity is maintained just downstream of the lake outlet.

PROGRESS: Monitoring of the quantity and quality of the lake inflow and outflow continued as scheduled. The mean annual discharge of the Goat Lake outflow was about 35 cubic feet per second; precipitation on the watershed was estimated to be about 170 inches per year. A short progress report (Water Resources Investigations Report 88-4235) published in 1989 indicated that the water in Goat Lake and in the inlet and outlet is of low ionic strength and of calcium-bicarbonate type. Limited sampling of the lake biota indicated that the phytoplankton and zooplankton populations are dominated by diatoms and rotifers, respectively. The pH of water in the lake has ranged consistently from 6.1 to 7.2, indicating that the lake is not acidified.

PLANS FOR FY 1992: Monitoring will continue at a reduced frequency. The mercury manometer currently used to monitor the stage of the lake outlet stream will be replaced with a pressure transducer. The Tacoma Field Office will assume full responsibility for the maintenance and operation of the continuous stream gage at the lake outlet and for the compilation and interpretation of the resulting data.

PROJECT TITLE: Hazardous-Waste Assessment in the State of Washington

PROJECT NUMBER: WA-297

STUDY LOCATION: Statewide

COOPERATING AGENCY: Washington Department of Ecology

PROJECT CHIEF: Edmund A. Prych

PROJECT DURATION: Ongoing, beginning in October 1983

PROBLEM: The impact of hazardous-waste disposal is one of the most significant problems that affects our water resources. Public Law 94-580 provides that the Federal government promote the protection of health and environment through technical assistance to State agencies in the development of solid- and hazardous-waste management laws. Numerous sites identified under the "Superfund Program" are located in Washington. In addition, nearly 200 other sites have been identified where less severe hazardous-waste problems exist. Leachate from almost all of these sites affects ground or surface waters. The State of Washington is now developing a major program to deal with this problem.

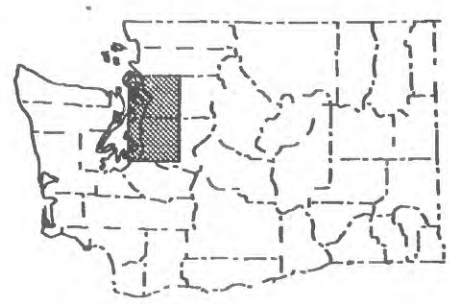
OBJECTIVES: The objectives of this project are to (1) carry out a four-phase cooperative program to determine the present and future effects of hazardous waste on the water resources of Washington; (2) improve knowledge of the processes and technology that will apply to the study area and other areas; and (3) develop a framework for hazardous-waste assessments that will provide a more consistent approach to the analysis of geohydrologic aspects.

APPROACH: The four phases of the program are (1) characterization of hazardous-waste disposal sites; (2) research on processes; (3) characterization of areas for hazardous-waste disposal; and (4) technical support. Where site characterization is undertaken, a wide array of analytic tools is used, including (1) definition and modeling of the ground-water system; (2) electric resistivity and other geophysical surveys; (3) use of a USGS auger to obtain drill and (or) core samples; and (4) determination of ground-water flow directions from water-level data. Research proposals are generated from each study undertaken in the first phase. Characterization of areas includes assessing such factors as thickness and permeability of soil; type, age, and permeability of indurated rock; depth to zone of saturation; lithology; rainfall and natural recharge; and physiographic measurements.

PROGRESS: During the past 2 years, work was done on five subprojects: (1) a compilation and interpretation of data on hydrocarbon compounds in ground water at the site of a gasoline and diesel-fuel leak in the city of Yakima; (2) an inventory of geohydrologic data in the South Tacoma Channel, an urban area where there are two "Superfund" sites, a large solid-waste landfill, and a well field for a municipal water utility; (3) a statewide reconnaissance of ambient concentrations of metals in soils; and (4) and (5) detailed studies of metals concentrations in soils in southern Clark County and the Yakima River basin.

PLANS FOR FY 1992: Soil samples will be collected to determine background concentrations of metals in soils in the Spokane River basin. The data from the statewide reconnaissance of soils metals will be analyzed and summarized in a report. Additional ground-water samples from the gasoline and diesel-fuel leak site in Yakima will be collected from selected wells to continue monitoring the concentrations of these organic compounds and determine if concentrations vary seasonally.

PROJECT TITLE: Rainfall-Runoff Models for Small Basins in Metropolitan Areas of Western Washington



PROJECT NUMBER: WA-303

STUDY LOCATION: Northwestern Washington

COOPERATING AGENCIES: King County, Snohomish County, and the Municipality of Metropolitan Seattle

PROJECT CHIEF: Richard S. Dinicola

PROJECT DURATION: Complete, except for report

PROBLEM: Most new population growth in King and Snohomish Counties is in the mid- and upstream parts of small drainage basins. Land-use changes in upland areas and encroachment of development on natural marshes and wetlands have caused floods in the small basins that are more frequent, more severe, and, as a result, more costly. These changes also have a negative effect on the anadromous fish resources as accelerated bank erosion and the increase in fine-sediment load reduce the quantity of good spawning habitat. There is a rapidly growing need to understand and describe the effects of urbanization on runoff in these small basins of largely unincorporated residences, so that local agencies can mitigate undesirable effects in an informed way.

OBJECTIVE: The objective of this project was to characterize and simulate rainfall-runoff relations in five headwater drainage basins in western King and Snohomish Counties.

APPROACH: The characteristics of rainfall-runoff for the study area were conceptualized as follows. In undisturbed areas, Horton overland flow--runoff generated from rain falling at a greater rate than the infiltration rate of the unsaturated soil--is not a significant mechanism. Instead, the significant runoff mechanisms are shallow-subsurface flow from hillslopes mantled with glacial till, ground-water flow from glacial outwash deposits, and overland flow from saturated depressions, stream bottoms, and till-capped hilltops. Only in disturbed, primarily urbanized areas is Horton overland flow a significant mechanism. Overland flow from impervious surfaces is also important in these areas.

PROGRESS: These conceptualized characteristics were incorporated into the Hydrologic Simulation Program-FORTRAN (HSPF) model, and the model was calibrated concurrently with hydrologic data for the 1985-86 water years from 21 stream-gage sites in the study area. The calibration resulted in 12 sets of generalized HSPF parameters, one set for each land-segment type defined to have a unique hydrologic response. The generalized parameters can be used with HSPF to simulate runoff from most headwater basins within the study area. The average standard errors of estimate for calibrated streamflow simulation at all 21 sites were 8 percent for annual runoff, 11 percent for winter runoff, 13 percent for spring runoff, 40 percent for summer runoff, 21 percent for storm peak discharge, 21 percent for storm runoff volume, and 42 percent for all daily mean discharges. For the most part, high flows were simulated more accurately than were low flows. The generalized parameters were verified in 12 additional King County drainage basins using data from the 1987-88 water year. However, the application of the generalized parameters to ungaged basins potentially could result in serious simulation errors without additional considerations. A report describing the model calibration effort was published. Model input for basins to be used for the model verification was prepared, and the 1987 streamflow, rainfall, and potential evaporation data were readied for use.

PLANS FOR FY 1992: The results of the verification effort will be incorporated into the final project report.

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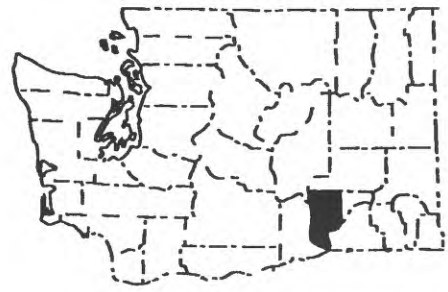
| PROJECT TITLE: | Ground-Water Study for Benton and Franklin Counties |
| PROJECT NUMBER: | WA-315 |
| STUDY LOCATION: | Pasco basin, Washington |
| COOPERATING AGENCY: | Washington Department of Ecology |
| PROJECT CHIEF: | Brian W. Drost |
| PROJECT DURATION: | October 1985 to November 1990 |



PROBLEM: The area surrounding the Tri-Cities of Kennewick, Pasco, and Richland has been changing from rangeland and dryland farming to one of the major irrigated-agriculture areas of the Northwest. With the introduction of imported irrigation water, there is new concern about ground water: no longer is there not enough, but rather, there is too much. There are problems of rising water tables, canal seepage, and ponding throughout the region; the relative importance of individual causes of these water-level changes (applied irrigation, canal seepage, and base-level changes) has been difficult to ascertain. Water quality is also a major problem. Various agencies have documented an increase in concentrations of nitrate and other contaminants in local ground water, but the source and patterns of contaminant movement and migration can be identified only after the hydrology of the area is determined.

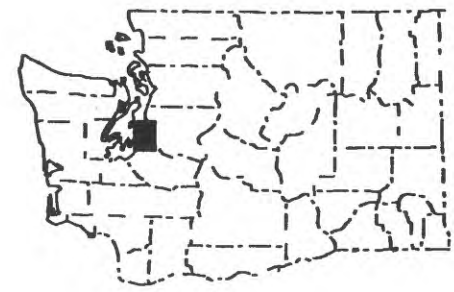
OBJECTIVES: The objectives of this project were to (1) determine flow directions and quantities of the ground-water system so that the effects of stresses on the system caused by artificial recharge and ground-water withdrawals could be documented; (2) determine the effects of possible mitigation measures; (3) determine the effects of various land uses and rising water levels on the quality of water; (4) determine if pesticides are present in ground water in and downgradient of areas of high pesticide usage; and (5) determine the movement of selected chemicals under the present system and under suggested mitigation procedures.

APPROACH: The nature of the present ground-water flow system was determined. This required mapping the lithologic units that make up the unconsolidated deposits, and making mass water-level measurements before, during, and after irrigation. The individual elements of recharge to the ground-water system were determined. Present and pre-development water budgets were calculated, and long-term changes in ground-water storage were determined. Concurrent with this effort was a program to identify the nature, magnitude, and sources of water-quality problems.

PROGRESS: Two basic-data reports were approved and published. Mass ground-water samplings were conducted during February and September 1988; approximately 150 wells were sampled during each mass sampling. Soil samples were collected from eight unfarmed sites and tested for nitrogen content to determine if natural soils and conditions may be contributing nitrates to the ground water. The potential effects of lining irrigation canals on ground-water quality were presented at a conference and published in the proceedings.

PLANS FOR FY 1992: The final ground-water and water-quality reports will be completed. A presentation of project results will be made at the annual conference of the American Institute of Hydrology.

PROJECT TITLE: Evaluation of the Ground-Water Resources of Southwestern King County



PROJECT NUMBER: WA-318

STUDY LOCATION: Western Washington

COOPERATING AGENCIES: Washington Department of Ecology, Regional Water Association of South King County, and Seattle-King County Health Department

PROJECT CHIEF: Dennis G. Woodward

PROJECT DURATION: October 1985 to March 1992

PROBLEM: Southwest King County is one of several areas in the Puget Sound region where population and urban development are growing rapidly; this growth has increased demands for water for public-supply, domestic, commercial, and industrial uses. Several municipalities are drilling additional public-supply wells in order to satisfy both normal and peaking water demands. The availability of ground water and the effects of well pumpage on lakes, springs, wetlands, and instream flows are important issues that need to be reconciled. Several serious water-quality problems related to industrial and waste-disposal practices have been recognized at sites in the study area. Contamination and the potential for seawater intrusion can limit the ability of the aquifer system to provide water of adequate quality for the needed uses.

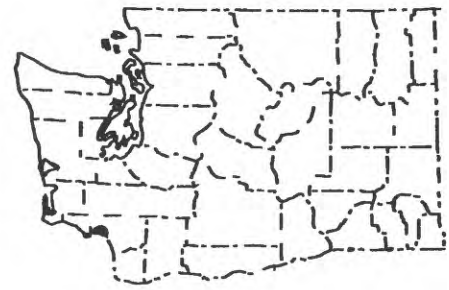
OBJECTIVES: The objectives of this project are to (1) define and quantify the ground-water system using available or readily collectable data; (2) determine the general water chemistry for the major aquifers from which water is being withdrawn; and (3) determine what additional data, if any, are required to sufficiently characterize the ground-water system in order to allow management decisions for developing further supplies.

APPROACH: The approach for this project is to (1) map the Pleistocene and Holocene sediments; (2) inventory and measure water levels in about 1,000 wells; (3) correlate drillers' and geophysical logs to define aquifer and confining units, and draw structure and thickness maps; (4) make mass water-level measurements of 300 to 500 wells to map the flow system within each major aquifer; (5) estimate recharge to the ground-water system; (6) estimate major components of discharge from the ground-water system; (7) estimate the annual water budget for the Big Soos Creek basin; (8) estimate the major pumpage and domestic well use; (9) determine water chemistry of the major aquifers; (10) design an observation-well network to monitor water-level and water-quality changes; and (11) describe additional data and analyses needed to determine ground-water availability and ground water-surface water interaction.

PROGRESS: The project has been completed, and a report describing the results is in technical review.

PLANS FOR FY 1992: The report will be approved for publication and printed.

PROJECT TITLE: Influence of Sediment From the 1980 Mount St. Helens Mudflows on the Ground-Water System in the Lower Cowlitz River Valley, Washington



PROJECT NUMBER: WA-319

STUDY LOCATION: Southwestern Washington

COOPERATING AGENCIES: Cowlitz County, and the Cities of Castle Rock, Kelso, and Longview, Washington

PROJECT CHIEF: Frank A. Packard

PROJECT DURATION: Complete, except for report

PROBLEM: Since the eruption of Mount St. Helens on May 18, 1980, ground-water levels in the Cowlitz River valley have risen, probably because the Cowlitz River streambed and stage rose after mudflow deposition. The sewer systems of the area were old, and apparently the rising ground water destabilized the foundations of sanitary sewer and storm drain lines and caused pipes to crack and joints to pull apart. During an unusually large storm in February 1986 (with a 75-year recurrence interval), the pipes acted as ground-water drains as water levels rose above the pipes, possibly to historically high levels. Sediment around the broken sewers was carried into the pipes, and the displacement caused more than 34 collapse holes above sewer lines in the towns of Kelso and Longview alone. At some locations, collapse holes undermined roadways, resulting in substantial damage. Costs associated with repairing roadway damage from one collapse hole alone exceeded $300,000. In all, the February storm resulted in more than $1.8 million in damage.

OBJECTIVES: The objectives of this project were to (1) determine the relation between the river and the adjacent ground-water system; (2) determine if ground-water levels have risen steadily in the Cowlitz River since 1980; (3) if they have risen, determine the cause or causes; and (4) document the relation between ground-water levels and collapse holes above the sewer lines.

APPROACH: Information on pre-eruption ground-water levels and seasonal fluctuations was available. A piezometer network was installed in the valley immediately after the eruption, and was measured for 1 1/2 years thereafter; however, a survey indicated that many of those wells had since been lost or destroyed. The existing network was expanded in order to determine the present relation between the river and ground-water system. Water-borne seismic instruments were used to determine if the mudflow deposits still existed in the Cowlitz River streambed. A longitudinal profile of the Cowlitz River streambed and stage was compared with pre- and post-eruption information to determine if changes had occurred since the U.S. Army Corps of Engineers had dredged the river. The location and extent of dredged materials were mapped, and the position of the water table relative to these deposits was determined. Precipitation records were reviewed to determine if there had been an increase since 1980.

PROGRESS: The report was revised in response to technical review.

PLANS FOR FY 1992: The report will be approved for publication and printed.

PROJECT TITLE: Yakima National Water-Quality Assessment

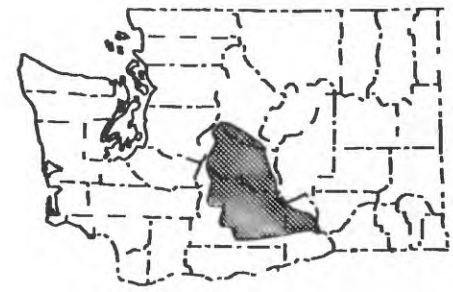
PROJECT NUMBER: WA-321

STUDY LOCATION: Southcentral Washington

COOPERATING AGENCY: None, U.S. Geological Survey funds only

PROJECT CHIEF: Stuart W. McKenzie

PROJECT DURATION: 1986 - ongoing



PROBLEM: The National Water-Quality Assessment (NAWQA) program is intended to integrate investigations of surface water, ground water, and precipitation with special emphasis on drinking-water sources; the program calls for a national perspective on surface water and ground water by studying hydrologic units scattered around the Nation, which in aggregate account for a large percentage of the Nation's water use. In order to address these complex concerns and related issues, the NAWQA program proposes to (1) provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources; (2) define long-term trends (or lack of trends) in water quality; and (3) identify, describe, and explain, to the extent possible, the major natural and human factors that affect observed water-quality conditions and trends. This pilot study on the surface-water phase of NAWQA is centered on the Yakima River basin, which has a drainage area of 6,200 square miles and about 1,900 miles of perennial streams. Land use is dominated by forest and grazing lands near the headwaters and by 500,000 acres of irrigated agriculture in the Yakima and Kittitas Valleys. The average annual diversion for irrigation is about 80 percent of total runoff; at times, however, up to 99 percent of the flow is diverted, leaving little water in some reaches.

OBJECTIVE: The objective of this project is to implement the National Water-Quality Assessment (NAWQA) program in a test area. This requires the specific details of program implementation regarding site selection, data collection and analysis, and interpretation of results be analyzed and reported on. The purpose of this study is to provide the USGS Water Resources Division headquarters with timely results on the identifying methodology used so that guidelines may be established for expanding the NAWQA program to 60 basins.

APPROACH: The study includes two basic approaches: (1) fixed-frequency data collection at seven sites with additional sampling to cover high flows and (2) synoptic sampling of 8 to 400 sites during steady-state conditions. The fixed stations provide seasonal variability, sufficient data to estimate annual loads, and eventually long-term trends. The synoptic sampling provides spatial variability and the calculation of source and transport of contaminants. Issues of interest include eutrophication (nutrients), toxics (trace elements, synthetic organic compounds, and radiochemicals), salinity (major ions), erosion of soil and deposition of sediment, water temperature, dissolved oxygen, sanitary health (indicator bacteria), aquatic biota (algae, benthic invertebrates, and fish), and acid precipitation (pH of rainfall and runoff). Early results have been shared with the Yakima NAWQA Liaison Committee. The liaison committee includes managers, researchers, and citizens interested in water quality in the Yakima Valley.

PROGRESS: Intensive data collection occurred from 1987 to 1990. The NAWQA team members have made several presentations at local and national meetings describing results of the study. The team is currently interpreting the data. Below are reports that have been completed or will be completed in the future.

PLANS FOR FY 1992 to 1994: Plans for the next fiscal year are to complete all reports.

PROJECT TITLE: Pesticide Applications Data-Base Management System

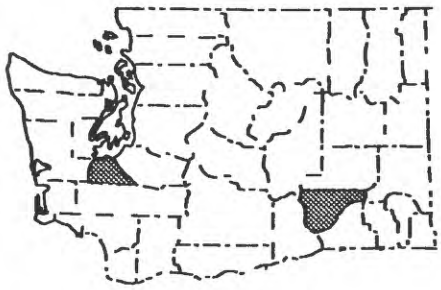
PROJECT NUMBER: WA-323

STUDY LOCATION: Franklin and Thurston Counties, Washington

COOPERATING AGENCY: U.S. Environmental Protection Agency

PROJECT CHIEF: Karen M. Schurr

PROJECT DURATION: October 1989 to October 1991



PROBLEM: Since 1989, pesticide applicators in Washington have been required by legislation to maintain records of their applications. The Washington State Department of Agriculture (WSDA) can require submission of copies of these records for areas where the potential effects of pesticide application are a concern. These records could provide a valuable source of pesticide-loading data for water-resource evaluation and protection studies. The records could be even more valuable if they could be located in a computer data base linked to a geographical information system (GIS).

OBJECTIVE: The objective of this project was to design a data-base management system that would store and spatially display pesticide-application data that were collected by the WSDA. The system would have the capability to handle both statewide and local data, and would be designed to accommodate all the data on the WSDA field sheets. Ideally, users of the system would need little or no GIS experience in order to use the system.

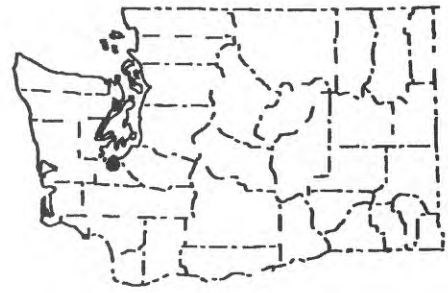
APPROACH: To accomplish the stated objectives, various options were considered for representing and geographically locating the pesticide application data. The WSDA provided information on which data would be required on the new field sheets and the types of retrievals most likely to be used by their agency and by other State and Federal agencies. The data files were first populated with hypothetical data; when actual field data became available, they were loaded onto the system and tested.

PROGRESS: The spatial framework for the pesticide-application data was the Public Land Survey System grid, and the data were located to the nearest quarter-quarter section. Data files based on GIS data base ARC/INFO were designed for the data fields (items) on the field sheets. A menu-driven retrieval system was designed to provide both data listings and ARC/INFO plots. Programs were written to question the user interactively for some of the parameters required for the retrieval, and then to display plots automatically on the screen for the viewer.

The system was tested with hypothetical data and with field data from Franklin County, and was found to be accurate. A USGS Open-File Report was written and is in technical review. The Pesticide-Application Data-Base Management System was installed and is in use at the EPA. Field data from Thurston County will be entered and tested on the Prime computer by the EPA.

PLANS FOR FY 1992: The report will be approved for publication and printed.

PROJECT TITLE: Streamflow Simulation Models for Small Urban Drainage Basins in Thurston County



PROJECT NUMBER: WA-327

STUDY LOCATION: Southern Puget Sound Lowland, Washington

COOPERATING AGENCY: Thurston County Department of Public Works

PROJECT CHIEF: Steven N. Berris

PROJECT DURATION: January 1988 to February 1992

PROBLEM: Population in the north-central part of Thurston County is growing rapidly, and large areas of agricultural and forested lands are being developed for residential and commercial use. Thurston County planning agencies need a method for estimating the effects of different zoning and land-use practices on streamflow.

OBJECTIVES: The objectives of this project are to (1) develop simulation models to estimate runoff in small, ungaged basins in north-central Thurston County; and (2) expand existing knowledge of the influence of physical characteristics of stream basins on runoff in the Puget Sound Lowland.

APPROACH: The USGS will develop numerical rainfall-runoff models using the Hydrologic Simulation Program-FORTRAN (HSPF) package of computer programs to estimate runoff on three small drainage basins in north-central Thurston County. The models will be based on the influence of physical basin characteristics on runoff so that changes in those characteristics can be used to estimate the effects of land development. Those characteristics unique to Thurston County will be added to a base of characteristics determined from prior studies in two other counties. The models will be tested by comparing model-simulated runoff with runoff observed continuously over a 2-year period at recording gaging stations, and intermittently at crest-stage gages in the three basins. The USGS will transfer use of these hydrologic models to county personnel.

PROGRESS: Final calibration of HSPF rainfall-runoff models was completed. Simulated runoff was calibrated to observed runoff for the period March 1, 1988, through March 15, 1990, at gages in the three study basins. Most of the final HSPF parameter values, which represent the runoff characteristics of soil-land cover-slope complexes throughout the county, were based on previously calibrated models in King and Snohomish County basins (Water Resources Investigations Report 89-4052). Parameter values were determined for seven soil-land cover-slope complexes not present in those basins. Model calibrations indicated that hydraulic linkages (connections) from the soil-land cover-slope complexes to streams varied throughout the basins. A report documenting the construction and calibration of the HSPF models was written.

PLANS FOR FY 1992: The report will be submitted for technical review.

PROJECT TITLE: Ground-Water Hydrology of Northern Thurston County, Washington

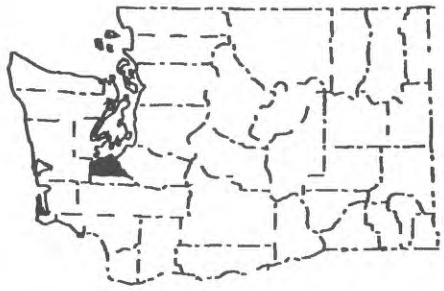
PROJECT NUMBER: WA-332

STUDY LOCATION: Thurston County, southwestern Washington

COOPERATING AGENCY: Thurston County Health Department

PROJECT CHIEF: Norman P. Dion

PROJECT DURATION: April 1988 to September 1991



PROBLEM: Thurston County is undergoing rapid population growth, and the study area is served almost entirely by ground water for public supply, domestic use, industrial use, and irrigated agriculture. The city of Olympia obtains most of its water from McAllister Springs, which discharges about 15 cubic feet per second of water from glacial deposits. Although at present there are no significant, identifiable problems with ground-water quantity or quality, county and State officials are concerned about the potential for such problems in the future. Concerns about the availability of additional ground-water supplies stem from the recognition that ground-water withdrawals are increasing rapidly, little is known about the productivity of the deeper aquifers, and increased development eventually could affect the discharge and quality of McAllister Springs.

OBJECTIVES: The objectives of this study were to (1) describe and quantify the ground-water system to the extent that existing or readily collectable data allow; (2) describe the general water chemistry of the major aquifers and the regional patterns of pollution from septic tanks, agriculture, and other sources; (3) examine the feasibility of constructing a three-dimensional ground-water flow model for the area; and (4) propose monitoring networks for ground-water quantity and ground-water quality.

APPROACH: All existing ground-water data files (about 3,000) were assembled, and 1,000 to 2,000 were selected for field inventory and water-level measurement. The aquifer geometry was mapped. Specific-capacity data were used to calculate hydraulic conductivities. A water budget was developed. Existing water-quality data were assembled and reviewed along with land-use maps and other pertinent information available from the Thurston County Health Department. The feasibility of building a three-dimensional ground-water flow model was based on how adequately the data could define the geometry and hydraulic characteristics of the aquifers.

PROGRESS: Approximately 1,300 wells were visited in the field, well schedules were prepared, and water levels were measured. All resulting data were entered into the GWSI data base. ARC/INFO files were created for topography, land net, drainage, land use, soils, housing density, and areas of central water and sewer service. Geologic sections were prepared by correlating drillers' lithologic logs. Maps of the top and thickness of each major geohydrologic unit and of water levels in the principal aquifer units were prepared. Approximately 360 wells were selected for sampling, and the waters analyzed for several chemical characteristics and possible water-quality degradation. Water levels were measured in 35 project observation wells on a monthly basis for 18 months. The major springs in the study area were inventoried and an estimate made of their discharges. An inventory of the quantities of water used for public-supply, domestic, industrial, and irrigation purposes was made for calendar year 1988 and the results tabulated by aquifer. Two independent estimates of recharge by precipitation were made. The results of the recharge estimates and of the water-use survey were incorporated into a water budget of the study area. A report was completed and submitted for technical and regional review.

PLANS FOR FY 1992: The project is formally completed; the report will be approved for publication and printed.

PROJECT TITLE: Quality of Ground Water in the Toppenish Basin, Yakima Indian Reservation

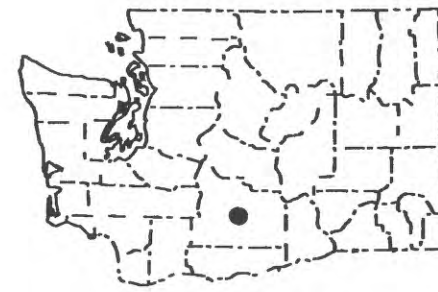
PROJECT NUMBER: WA-335

STUDY LOCATION: Toppenish Creek basin

COOPERATING AGENCY: Yakima Tribal Council

PROJECT CHIEF: Steven S. Sumioka

PROJECT DURATION: February 1989 to September 1992



PROBLEM: Domestic water supplies, taken from two shallow aquifers, may contain large concentrations of nitrate. There is also concern that pesticides may contaminate these supplies.

OBJECTIVES: The objectives of the project are to (1) define ground-water quality in the eastern part of the basin; (2) relate ground-water quality to geohydrology; and (3) attempt to identify source areas and flow paths of any contaminants.

APPROACH: The approach for this project is to sample about 500 wells and 50 surface-water sites in order to obtain an areal distribution of nitrate concentration (about 20 wells will be sampled every 6 weeks to obtain a seasonal distribution) and to sample about 60 wells to determine pesticide concentrations.

PROGRESS: A total of 487 wells and 50 surface-water sites were sampled for nitrate concentration and 20 wells were sampled 5 times for seasonal distribution; 15 of 60 wells were sampled for the presence of pesticides. A report describing the areal distribution of nitrate concentrations has been drafted.

PLANS FOR FY 1992: The report will be submitted for technical review. Sampling will continue at the 20 "seasonal" wells approximately every 6 weeks; and the first 15 wells will be resampled for pesticides, along with 45 additional wells.

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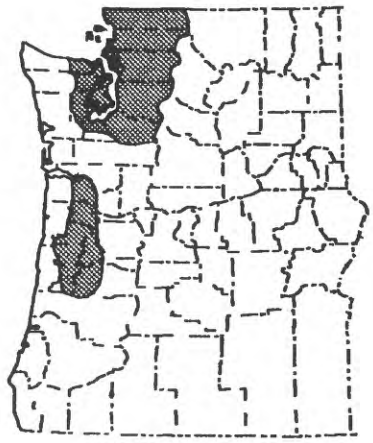
| PROJECT TITLE: | Puget-Willamette Lowland Regional Aquifer-System Analysis |
| PROJECT NUMBER: | WA-336 |
| STUDY LOCATION: | Western Washington and northwestern Oregon |
| COOPERATING AGENCY: | None, U.S. Geological Survey funds only |
| PROJECT CHIEF: | John J. Vaccaro |
| PROJECT DURATION: | October 1988 to September 1994 |



PROBLEM: The Puget-Willamette Lowland regional aquifer system is one of the 28 regional aquifers chosen for study under the USGS RASA program. The States of Washington and Oregon are interested in this study because more than 70 percent of their population resides within the study-area boundaries. In the study area, such information as quantity and direction of ground-water flow, lengths of flow paths, locations of ground-water discharges, stream-aquifer interaction, relations of ground water with older rock materials, and hydraulic continuity between aquifer units is largely unknown. All of these topics require better definition; lack of that information impairs the ability of managers to make knowledgeable decisions.

OBJECTIVES: The primary goal of this project is to obtain a better understanding of the regional ground-water system. To achieve this goal, the following objectives have been defined: (1) Describe the geologic framework of the regional aquifer system; (2) describe the geohydrologic characteristics of the regional aquifer system; (3) describe the regional flow system; (4) estimate water budgets for selected areas of the aquifer system and combine this information to describe the regional water budget; (5) determine the present water quality and its variations, and water-rock chemical interactions along selected ground-water flow paths; and (6) use ground-water flow models to synthesize the geohydrologic data and concepts on how the regional flow system operates.

APPROACH: Available information will be gathered, compiled, and analyzed, and will be used to develop a plan of study. New information will be collected for selected work items in selected areas. Hydrogeologic units will be defined and mapped, to the extent possible. Ground-water-use data will be compiled. Numerical cross-sectional models will be constructed for several locations. Regional water-budget components will be estimated on the basis of detailed local studies. Water-level maps will be constructed in order to describe the ground-water flow. All items will then be synthesized for a description of the aquifers on a regional basis.

PROGRESS: Historical data were analyzed. Two bibliographies (for the Puget Sound Lowland and for the Willamette Valley) were compiled and published. The plan of study was written and submitted for approval. Surficial geologic unit maps were constructed. Five cross-sectional models were constructed and used to analyze the flow system. Various hydrogeologic sections were constructed. A preliminary water-level map of the Puget Sound Lowland was constructed in order to help define hydrogeolgic units. Work began on constructing the geologic framework maps. Tritium samples were collected to check conceptual models of ground-water flow. Collection of Penman and time-domain reflectometry (TDR) data began in a basin, to determine evapotranspiration.

PLANS FOR FY 1992: Plans for fiscal year 1992 are to (1) publish the plan of study; (2) estimate regional recharge; (3) submit for technical review the Professional Papers on the geologic framework; (4) construct more cross-section flow models; and (5) develop conceptual models of ground-water flow.

PROJECT TITLE: Hazardous Waste at the Hanford Nuclear Reservation

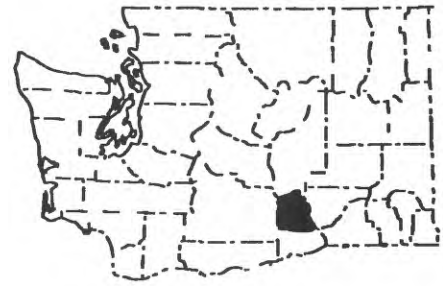
PROJECT NUMBER: WA-338

STUDY LOCATION: South-central Washington

COOPERATING AGENCY: U.S. Environmental Protection Agency

PROJECT CHIEF: Ward W. Staubitz

PROJECT DURATION: February 1989 to September 1993



PROBLEM: The U.S. Department of Energy's (USDOE) Hanford Nuclear Reservation was designed and operated to produce plutonium for nuclear weapons. As a result of plutonium processing and operation of nine nuclear reactors, large volumes of liquid wastes were generated and discharged to the ground. These wastes include a wide variety of radionuclides and organic and inorganic chemicals contained in more than 1,400 waste storage, disposal, or spill sites. The degree of contamination is largely unknown. Although the USDOE has operated a long-term ground-water-monitoring program for selected radionuclides and inorganic constituents, sampling for a wider range of constituents has been limited; in recent sampling, several hazardous constituents were detected in excess of EPA maximum contamination levels. The Hanford site has been organized into 78 operable units, and the clean-up of each unit will entail a detailed site-characterization study to determine the nature and extent of contamination. EPA has oversight responsibility for the remediation, and the USGS is providing technical assistance.

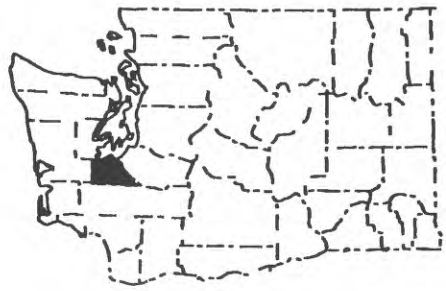
OBJECTIVE: The objective of the study is to review data-collection activities and evaluate all hydrologic and geologic data collected at Hanford Comprehensive Environmental Response Compensation and Liability Act (CERCLA) sites, and to use these data and additional information supplied by the EPA and the USDOE to assess the hydrology and geology of the CERCLA sites.

APPROACH: The USGS reviews and comments on each operable unit Remedial Investigation/Feasibility Study (RI/FS) work plan, concentrating on sections pertaining to geologic and hydrologic site characterization. The USGS periodically reviews field data-collection activities and meets with representatives of the EPA, USDOE, and their contractors to discuss and resolve disagreements on the technical approach and execution of the hydrologic investigations. The USGS evaluates data generated from the RI/FS and incorporates existing information to assess the geology and hydrology of each operable unit and define the extent of contamination and its potential for migration.

PROGRESS: Since the beginning of the project in February 1989, the USGS has reviewed RI/FS work plans for 15 operable units and commented on drilling and geophysical techniques, documentation of data-collection methods, quality-assurance and quality-control procedures, and the development of site-wide ground-water flow models. Project personnel completed radiation and hazardous-waste health and safety training and conducted field oversight visits at several hazardous waste sites.

PLANS FOR FY 1992: It is anticipated that 1 new and 10 revised work plans will be reviewed in the next year. Oversight visits to field sites and reviews of available data will increase as more remedial investigations get underway. In addition, the USGS will provide guidance on the development, calibration, and verification of ground-water flow and solute transport models.

PROJECT TITLE: A Numerical Model Analysis of the Ground-Water Flow System in Northern Thurston County, Washington



PROJECT NUMBER: WA-339

STUDY LOCATION: Western Washington

COOPERATING AGENCY: Thurston County Health Department

PROJECT CHIEF: William E. Lum II

PROJECT DURATION: February 1989 to September 1992

PROBLEM: The metropolitan area of Olympia-Lacey-Tumwater, in Thurston County at the southern end of Puget Sound, is the fastest growing area in the State. The area is served almost entirely by ground water for public supply, industrial use, and irrigated agriculture. Recent State legislation requires local management of water resources. Ongoing USGS cooperative studies in Thurston County provide information on rainfall-runoff relations under various land usages and soil types, the geohydrologic framework of the area, current ground-water usage, and quality of water. The results of these studies will be used to construct a ground-water flow model that will provide a quantitative tool for managing the ground-water resources of the area. The model will help define ground-water recharge and discharge areas, potential pathways for movement of contaminants in ground water, and effects of land-use changes on the natural ground-water flow system.

OBJECTIVES: The objectives of this project are to (1) gain a greater understanding of the ground-water flow system of the area, and quantify the flow components, by constructing, calibrating, and operating a three-dimensional ground-water flow model; and (2) estimate possible areas of recharge, discharge, and ground-water flow paths by constructing and operating a particle-tracking post processor within the flow model. Meeting these objectives helps meet the following water-management goals: (1) Quantitatively assessing how the installation of sanitary sewers in specific areas would affect ground-water quality, wetlands, and water-budget items; (2) assessing the effects of various farming practices on ground-water quality; (3) determining areas where degradation of ground-water quality would have a long-term effect on major sources of public or municipal water supply; and (4) estimating the effects of large increases in pumpage on ground-water quality and water levels in all known aquifers in the study area.

APPROACH: To accomplish the stated objectives, a ground-water flow model will be constructed and calibrated with the observed data. The model will provide information about the quantity of water moving through the ground-water system under the study area. A particle-tracking post processor will allow definition of flow paths in the ground-water system. The definition of specific groups of flow paths will allow (1) the mapping of recharge areas for specific discharge points of the ground-water system; (2) the mapping of probable pathways of contaminants from their source to points of discharge from the ground-water system; and (3) an estimate of the time-of-travel for a conservative-type contaminant through the ground-water system.

PROGRESS: The ground-water flow model has been constructed. It has eight active layers representing geohydrologic units made up of unconsolidated glacial and nonglacial deposits of Quaternary age. Model cells are 3,000 feet on a side, and there are 53 rows and 66 columns of cells. This regional-scale model simulates recharge derived from incident precipitation, leakage to and from rivers, springflow, and pumpage of ground water from wells. A report has been outlined and partly written.

PLANS FOR FY 1992: The modeling will be finished, the results interpreted, and a report completed and reviewed.

PROJECT TITLE: Hydrologic Investigations at Hanford Nuclear Reservation

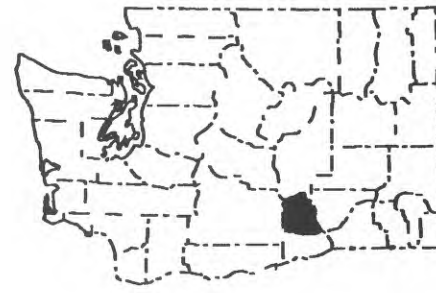
PROJECT NUMBER: WA-340

STUDY LOCATION: South-central Washington

COOPERATING AGENCY: U.S. Department of Energy

PROJECT CHIEF: Richard S. Dinicola

PROJECT DURATION: July 1989 to September 1994



PROBLEM: The U.S. Department of Energy's (USDOE) Hanford Nuclear Reservation was designed and operated to produce plutonium for nuclear weapons. As a result of plutonium processing and operation of nine nuclear reactors, large volumes of liquid wastes were generated and discharged to the ground. These wastes include a wide variety of radionuclides and organic and inorganic chemicals. The degree of contamination is largely unknown. Although the USDOE has operated a long-term ground-water-monitoring program for selected radionuclide and inorganic constituents, sampling for a wider range of constituents has been limited; several hazardous constituents were detected in recent samples in excess of EPA maximum contamination levels.

Despite extensive studies of the hydrology of the Hanford Reservation over the past 40 years, several processes important to site characterization and the development and implementation of remediation strategies are not well understood: (1) The quantity of natural recharge from precipitation and its effect on migration of contaminants in the unsaturated zone; (2) the quantity of natural recharge from infiltration of surface-water runoff originating in the Cold and Dry Creek watersheds and its influence on the rate and direction of ground-water flow; and (3) the potential flooding of existing waste sites by runoff from Cold and Dry Creeks during extreme floods.

OBJECTIVE: The objective of this project is to provide site-wide hydrologic information and technical support to the USDOE for accurate characterization of the ground-water flow system and effective development and implementation of remediation strategies at Hanford.

APPROACH: The USGS will interpret existing information and conduct hydrologic investigations to develop a refined understanding of the hydrology of the Hanford site. The USGS will participate in third-party technical review panels to evaluate ongoing sitewide hydrologic characterization and solute-transport and ground-water flow model development being conducted under the performance-assessment program. The USGS also will provide project proposals and conduct investigations to address specific hydrologic issues mutually agreed to by the two agencies. Current projects include development of a rainfall-runoff model of the Cold and Dry Creek watersheds to estimate long-term discharge from these ephemeral streams and recharge to the unconfined aquifer underlying the Hanford Reservation, as well as a feasibility study for a paleoflood investigation of the Cold and Dry Creek basins.

PROGRESS: For the rainfall-runoff study, climate, runoff, and recharge data were collected in the Cold and Dry Creek drainage basins. Additional soil-moisture measurement sites and snow-survey sites were added to the existing data-collection network. Five minor floods were monitored in the two basins. Drainage-basin characteristics also were entered into a GIS data base, and digitized soils, land-use, and topographic data were assembled to enter into GIS. The paleoflood feasibility study of Cold and Dry Creeks was completed, and the results were accepted by the USDOE.

PLANS FOR FY 1992: Field data collection will continue in both basins for the rainfall-runoff study. Calibration curves for the neutron soil-moisture probe will be developed. Hydraulic characteristics of the drainage network will be measured. The GIS data base will be completed, and the watersheds will be "partitioned" for input into the Precipitation Runoff Modelling System (PRMS) runoff model. Initial model simulations will be performed using climate and runoff data collected to date, and some plot-scale lysimeter and runoff data.

PROJECT TITLE: Pierce County Rainfall-Runoff Investigation

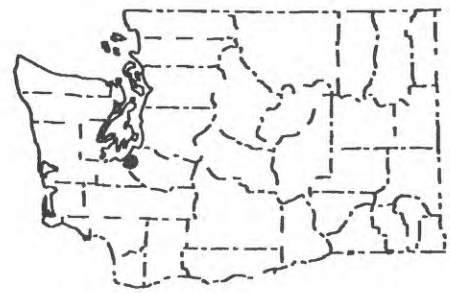
PROJECT NUMBER: WA-341

STUDY LOCATION: Western Washington

COOPERATING AGENCY: Pierce County Surface Water Management Utility

PROJECT CHIEF: Mark C. Mastin

PROJECT DURATION: June 1989 to September 1990



PROBLEM: Pierce County is in the Puget Sound region of western Washington. The USGS recently calibrated the Hydrologic Simulation Program-FORTRAN (HSPF) rainfall-runoff program for several small upland drainage basins adjacent to Pierce County. The newly formed Pierce County Surface Water Management Utility is developing a comprehensive surface-water management plan for unincorporated areas of the county, and needed to determine the current and future runoff and streamflow characteristics of many upland drainage basins in the county as foundation for the plan.

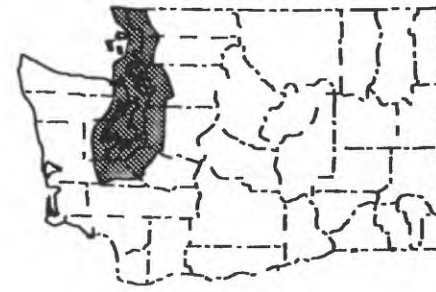
The HSPF program could be the tool of choice for such determinations by Pierce County, because the hydrologic and physical properties of upland basins in Pierce County are similar to those represented in the model calibrated for nearby basins. The calibration was not made specific to the basins of Pierce County, and tests of simulation accuracy in those basins were not made.

OBJECTIVE: This study was a preliminary application of the HSPF program for two small drainage basins in Pierce County to determine its accuracy in simulating streamflow that will be measured and recorded for 12 months at 12 sites in the 2 basins. If this modelling approach is accepted, a second-phase study will begin that will include at least a second year of data collection and calibration to refine the regional parameters used in the model.

APPROACH: The applicability of the model was tested on the Clear Creek and Clarks Creek basins, which are tributaries to the Puyallup River in Pierce County. These two basins typify the topographic, geologic, soil, and land-use characteristics found in many upland basins in the county, and they are also physiographically similar to nearby basins for which the HSPF model was calibrated. Three primary tasks were done for this study. First, a streamflow and rainfall data-collection network was installed in the two basins and operated to obtain one complete year of record. Next, the topographic, geologic, soil, land-use, and hydraulic characteristics of the basins were inventoried. Finally, the hydrologic data and basin characteristics were incorporated into the regional HSPF model framework and the model was run to simulate the hydrology of the basins for the 1-year period of data collection.

PROGRESS: Five calibrated models based on the HSPF program were constructed for five streams within the Clear Creek and Clarks Creek drainage basins. The models were run for the period from October 1, 1989, through May 31, 1990, using the available climate data. Results were compared with observed data collected at streamflow gaging sites within the study area. A letter report outlining the framework that was used in each of the models and tabulating the results comparing observed data with simulated data was given to the Pierce County Surface Water Management Utility. The project was completed.

PROJECT TITLE: A Demonstration of Ground Water-Surface Water Interactions Typical of the Glaciated Puget Sound Lowland of Western Washington



PROJECT NUMBER: WA-342

STUDY LOCATION: Puget Sound Lowland, western Washington

COOPERATING AGENCY: Washington Department of Ecology

PROJECT CHIEF: Joseph L. Jones

PROJECT DURATION: October 1990 to September 1992

PROBLEM: Streamflows in the Puget Sound Lowland of western Washington are not sufficient to meet projected, and in some cases, current demands; as the logical alternative, ground-water sources are being developed. The WDOE is charged with regulating both ground-water and surface-water withdrawals, and is concerned because of the difficulty it is having in finding an adequate means of estimating the effects of ground-water withdrawals on stream baseflows.

OBJECTIVE: The objective of this project is to explore and demonstrate the relations between ground-water and surface-water systems in the Pleistocene deposits of the Puget Sound Lowland. The effects of water well location, depth, and timing of withdrawal on baseflows will be studied in a hypothetical stream-aquifer system of Pleistocene glacial deposits. The assumed hydrogeologic conditions will be based on data and findings gathered in previous studies.

APPROACH: A modular ground-water flow model (MODFLOW) will be applied to the hypothetical system. Steady-state three-dimensional simulations will be run in conjunction with a flow path module (MODPATH) and the Streamflow Routing Package to document the steady-state responses. The model will be calibrated to reasonable values of static ground-water levels and streamflows. Sensitivity checks will be conducted to determine which physical parameters are most influential, and to provide some estimate of the credibility of the predictions. Changes in baseflows in response to variations in the depth, location, and timing of ground-water withdrawals will be documented, as will changes in zones of contribution, zones of discharge, and flow patterns.

PROGRESS: During the 1991 fiscal year, various reports describing the glacial deposits of the Puget Sound Lowland were studied in sufficient detail to develop a generalized conceptual model of a small (less than 300 square miles), typical basin. A numerical (computer) description of the model was begun, as were studies of the sensitivity of heads and baseflow to model parameters.

PLANS FOR FY 1992: Sensitivity studies will be completed and the investigation of the response of heads and baseflows to ground-water withdrawals will be made. A report describing the results of the investigation will be written.

PROJECT TITLE: Long-Term Evapotranspiration Network

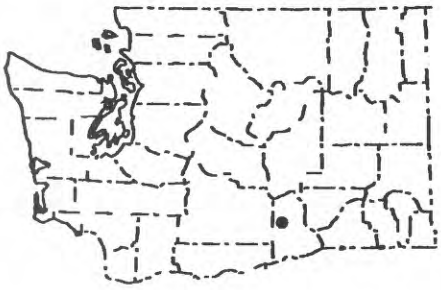
PROJECT NUMBER: WA-343

STUDY LOCATION: South-central Washington

COOPERATING AGENCY: Washington Department of Ecology

PROJECT CHIEF: Stewart A. Tomlinson

PROJECT DURATION: July 1989 to September 1991



PROBLEM: Estimates of evapotranspiration (ET) are important for determining components of a water budget. Accurate estimates of water-budget components are, in turn, important for quantifying ground-water availability. However, both short-term and long-term ET estimates for Washington are lacking, and the few available estimates are for short periods of time.

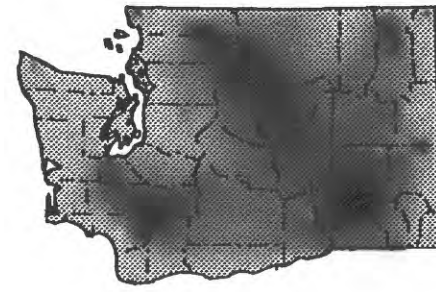
OBJECTIVES: The objectives of this project were to (1) establish long-term ET sites in Washington; (2) quantify ET for those sites; and (3) investigate methods to determine actual ET using reliable, trouble-free instrumentation.

APPROACH: The USGS established two data-collection sites in a single basin; this basin also was monitored for other hydrologic variables. The sites were a Bowen-ratio site, to provide data for calculating actual ET, and a Penman site, to provide data for calculating potential ET. The Bowen-ratio method was used to calibrate the Penman data for the stomatal resistance factor of plants, so that actual ET could be computed with the Penman data; thus future sites could consist of the more trouble-free Penman instrumentation.

PROGRESS: Data were collected from one Bowen-ratio and one Penman site for a grassland in the Snively basin of the Arid Lands Ecology Reserve in eastern Washington. Collected data were downloaded to a personal computer where ET calculations, energy-budget computations, and resultant plots were made. The first draft of the summary report was completed.

PLANS FOR FY 1992: The report will be submitted for technical review and for approval to publish.

PROJECT TITLE: Evaluation of Hydrologic Variable Trends in Washington --Phase I



PROJECT NUMBER: WA-345

STUDY LOCATION: Statewide

COOPERATING AGENCY: Washington Department of Ecology

PROJECT CHIEF: David L. Kresch

PROJECT DURATION: October 1989 to June 1992

PROBLEM: How successfully water suppliers and managers are able to satisfy the current demands for water and prevent future development from over-tapping the available water resources depends on knowledge of how present streamflow and precipitation rates relate to their historical rates. Historical data allow an evaluation of whether current conditions correspond to a dry, normal, or wet period. Furthermore, historical data may give an indication of how long current conditions might be expected to last.

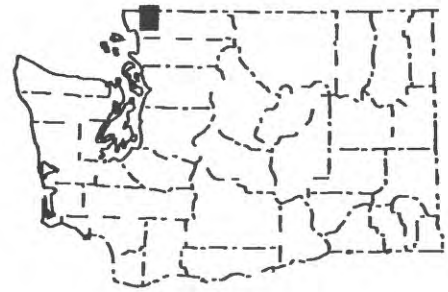
OBJECTIVE: The objective of this project is to develop information for water suppliers and managers about the variability of streamflow and precipitation in Washington by (1) defining geographic regions in which the variations in streamflow and precipitation have similar patterns, and (2) developing a water-resource-availability index that places current conditions of streamflow or precipitation at a particular station in the context of the historical patterns of variation for that station.

APPROACH: Cumulative departures from normal will be used to define the patterns of variation of streamflow and precipitation stations. The departures will be rescaled (normalized) by dividing them by the standard deviation of the cumulative annual values. Regions of similarity will be defined by the use of cluster analysis. A water-resource-availability index will be defined as the weighted sum of rescaled departures during the preceding 3-year period.

PROGRESS: Data collection and analysis were completed and first draft of the summary report was written.

PLANS FOR FY 1992: The report will be submitted for technical review and approval to publish.

PROJECT TITLE: Hydrology, Hydrochemistry, and Sources of Nitrate in Lowland Glacial Aquifers of Whatcom County, Washington, and British Columbia, Canada



PROJECT NUMBER: WA-346

STUDY LOCATION: Whatcom County, Washington; British Columbia, Canada

COOPERATING AGENCY: Whatcom County Planning Department

PROJECT CHIEF: Stephen E. Cox

PROJECT DURATION: October 1990 to September 1992

PROBLEM: The lowlands of the Nooksack and Sumas River valleys are farming areas developed on glacial sediments. Shallow ground water currently supplies much of the water needs of the area. Although the supply of shallow ground water is ample and its quality historically has been good, an increasing number of water-quality problems have been identified in the area. Pesticides associated with agricultural practices have been found in some ground-water samples. Ground waters in the region contain large concentrations of nitrate and iron, and there are local areas of salty and corrosive waters. Wells with available historic data show a trend of increasing nitrate concentration with time.

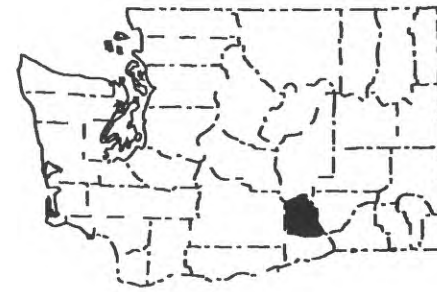
OBJECTIVE: The objective of this study is to conduct an appraisal of the ground-water hydrology and water quality of the area that will provide local water managers sufficient information to make decisions. The focus of this study is to describe the hydrogeologic framework and flow system, document the nature and extent of current water-quality problems, and examine significant potential sources of these problems.

APPROACH: Available data from well files, geologic maps, reports, and drillers' lithologic logs will be used to describe the hydrogeologic framework. Water-level contour maps and specific-capacity data obtained from drillers' logs will be used to define the ground-water flow system. The description of the general ground-water chemistry and the distribution of known inorganic contaminants will be based on historical data and analyses of water-quality samples collected during this project. Baseline information regarding the regional distribution of pesticide and trace metals will be obtained in a similar manner. The examination of probable sources of inorganic contaminants in the ground-water system will be based on the distribution of contaminants in the ground-water system, land-use information, and information on the hydrologic flow system.

PROGRESS: Geologic and hydrologic data were collected from 626 wells. The data were coded and entered in the GWSI data base. GIS coverages of selected hydrologic parameters were prepared. An observation network of 23 water-level sites and 14 water-quality sites was visited monthly for 1 year. Water-quality samples for common ions and septage constituents were collected from 125 wells. Pesticide and trace-metal samples were collected at 20 sites. Historical water-level and water-quality data were obtained from local, State, and Canadian government agencies. Lithologic information from drillers' logs and geologic maps was used to describe hydrogeologic units, and 10 hydrogeologic sections were constructed. Land-use information from air photographs was classified and digitized.

PLANS FOR FY 1992: Water samples will be collected at about 25 sites for analysis of freon concentrations. Water-level maps will be completed and specific-capacity data compiled. Water-level and water-quality data will be analyzed and an interpretive report written.

PROJECT TITLE: Estimation of Natural Recharge at the Hanford Nuclear Reservation Using Techniques of Chloride Mass-Balance and Chlorine-36 Isotopic Tracer



PROJECT NUMBER: WA-348

STUDY LOCATION: Hanford Nuclear Reservation

COOPERATING AGENCY: None, U.S. Geological Survey funds only

PROJECT CHIEF: Edmund A. Prych

PROJECT DURATION: July 1991 to September 1992

PROBLEM: Knowing the quantity of precipitation that flows downward through unsaturated sediments to recharge the ground-water system beneath the Hanford Nuclear Reservation is an important element when assessing the risk posed by contaminated sediments, planning remediation at contaminated areas, and designing buried waste facilities. There is much uncertainty in the present estimates of recharge.

OBJECTIVES: The objective of this study is to examine the applicability of a chloride mass-balance method and a chlorine-36 isotope method for estimating recharge at the Hanford Nuclear Reservation. Applicable methods will be used to estimate recharge at sites with different soil types, topographies, and vegetal covers.

APPROACH: Vertical profiles of chloride concentration in soil water will be obtained by collecting soil samples from trenches or bore holes and analyzing for dissolved chloride, water content, and the ratio of chloride-36 to total chloride. The vertical flow of water per unit area will be computed according to the mass-balance method by dividing the chloride flux by the chloride concentration. The chloride flux is assumed to be uniform with depth and can be estimated from observed ratios of chlorine-36 to total chloride and published values of the ratio of atmospheric fallout of chlorine-36. The chlorine-36 method is based on the fact that nuclear bomb tests conducted in the Pacific Ocean during the 1950's and 1960's produced large quantities of chlorine-36. Peaks in vertical profiles of the ratio of chlorine-36 to total chloride identify the period of bomb testing; water above the peaks was recharged since that time.

PROGRESS: The chloride mass-balance method was used to estimate recharge at a total of 13 sites in 5 areas. Estimated recharge rates at all locations are relatively low, less than 1 millimeter per year. The chlorine-36 method, using preliminary data from two of the above sites in two areas, yielded estimates only slightly higher than those obtained by the chloride mass-balance method.

PLANS FOR FY 1992: The chlorine-36 method will be used to estimate recharge at two more sites in two other areas. A summary report will be written and submitted for technical review.

PROJECT TITLE: Ground-Water Resources of Eastern King County, Washington

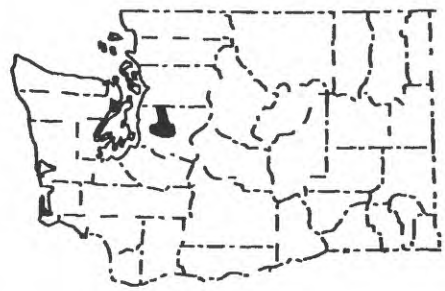
PROJECT NUMBER: WA-352

STUDY LOCATION: Eastern King County

COOPERATING AGENCY: Seattle-King County Health Department

PROJECT CHIEF: Gary L. Turney

PROJECT DURATION: April 1990 to September 1992



PROBLEM: The eastern King County area comprises the Snoqualmie River valley lowlands and adjacent plateaus. This area of about 250 square miles is located east of metropolitan Seattle, and pressure for land development there is increasing rapidly. The last comprehensive study of the ground-water resources in the area was made in 1963. The potential for ground-water development needs to be assessed and documented in time to allow for appropriate planning and zoning. In addition, the shallow alluvial and glacial aquifers are susceptible to contamination by septic tanks and other surficial sources of pollutants. There is also a need to determine what additional data and analyses are required to quantify the ground-water availability in the area.

OBJECTIVES: The objectives of this project are to (1) describe the ground-water system using existing or readily collectable data; (2) determine the general water chemistry of the significant aquifers and describe regional patterns of contamination, if any; (3) examine the general potential for ground-water development in terms of aquifer characteristics, interaction with surface-water bodies, and recharge; and (4) determine what additional data and analyses are needed to quantify ground-water availability in the area.

APPROACH: About 600 to 800 wells will be inventoried to provide data for hydrogeologic sections, head-distribution maps, and hydraulic-conductivity maps. About 150 wells will be sampled and analyzed for concentrations of common constituents, iron, manganese, nitrate, and fecal-coliform bacteria. Selected samples will be analyzed for concentrations of specific organic compounds and trace elements. Data from existing rainfall-runoff models for several small drainages west of the study area will be used to estimate recharge for the part of the study area west of the Snoqualmie River. Seepage runs will be made on selected major streams to evaluate ground water-surface water relations.

PROGRESS: Most of the field work and data collection were completed during fiscal year 1991. More than 600 wells and springs were inventoried and water levels measured. A monthly water-level network of about 40 wells was established. Geologic sections were completed, and selected geographic and geologic features were placed into ARC/INFO coverages. Samples were collected from 124 wells and springs and analyzed for concentrations of the constituents described in the approach. All samples were also analyzed for concentrations of trace elements. About a dozen samples were analyzed for concentrations of volatile organic compounds, and another dozen for concentrations of selected pesticides.

PLANS FOR FY 1992: Work in the next fiscal year will consist largely of data interpretation and report preparation. Geohydrologic unit maps will be completed. Recharge volumes will be calculated, and a simplified water budget will be prepared. Ground-water chemistry will be described. The report will be submitted for technical review.

PROJECT TITLE: Pierce County Watershed Modeling--Phase II

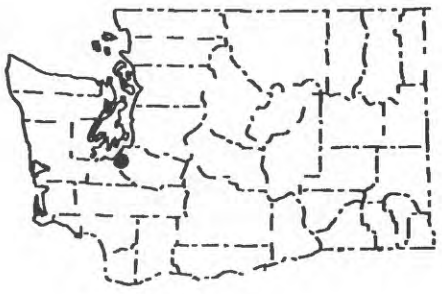
PROJECT NUMBER: WA-353

STUDY LOCATION: Pierce County, Washington

COOPERATING AGENCY: Pierce County Surface Water Management Utility

PROJECT CHIEF: Mark C. Mastin

PROJECT DURATION: June 1990 to September 1993



PROBEM: Pierce County recently formed a Surface Water Management Utility to alleviate the effects of land-use changes on the surface-water resources and storm-water runoff. A rainfall-runoff model, using the Hydrologic Simulation Program-FORTRAN (HSPF), was calibrated recently for the upland basins of nearby King and Snohomish Counties. The hydrologic and physical properties of the upland basins of Pierce County appear to be well suited for application of the HSPF watershed model, but further development is needed to tailor the model and its products for use by land- and water-management agencies. Calibration of the model for specific basins in Pierce County is needed to fine-tune the simulations of actual streamflow. Planners and engineers commonly are confronted with determining the hydrologic effects of development in small (less than 1 square mile) basins. The HSPF model has not been tested at this scale. Application of the HSPF model needs to be simplified for use by planners and engineers to provide them with a convenient tool to more accurately estimate runoff from a subbasin for various scenarios of land use.

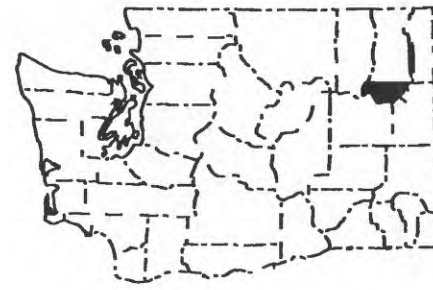
OBJECTIVES: The objectives of this study are to (1) provide thorough calibration and validation procedures for the rainfall-runoff models currently being constructed for the Clear and Clarks Creek basins of Pierce County; (2) model another basin in Pierce County that will contain several individually gaged catchments, to evaluate the sensitivity and applicability of the model at the catchment scale; (3) simplify the use and application of the HSPF watershed model with a user-interactive, preprocessing computer program; and (4) provide a technical transfer of information and training to Pierce County on the operation of the simplified HSPF model and the collection and processing of the necessary hydrologic data.

APPROACH: The streamflow data-collection period for Phase I of the study will be extended 1 water year for Phase II. An additional basin, Clover Creek, will be modeled and calibrated with streamflow data that will be collected for 2 water years. Several catchments representing different land uses will be gaged, and the simulated streamflow will be compared with actual streamflow data. Records of long-term rainfall and potential evapotranspiration will be used to make long-term model runs for each of the land types defined in the model. A user-interactive computer program will be developed that prompts the user to enter the areas of each land type and the drainage network for the specific area or basin of concern.

PROGRESS: Six continuous-record stream-gage sites, ten crest-stage/observer-staff gage sites, and four precipitation gage sites were installed in the Clover Creek study area. Monthly measurements and stage-discharge ratings were made at all the stream-gage sites. Several Pierce County personnel were trained in field techniques of stream gaging. Land-use, soil associations and drainage networks within the study area were digitized into a GIS data base. Channel hydraulics for each of the stream reaches in the Clover Creek basin were computed from map data, cross-sectional information, and field surveys. Flow routing tables were compiled from this information and installed into the flow-routing module of the model. Preliminary rainfall-runoff models were developed for Clear and Clark Creeks, and final calibrations on the first year of precipitation and streamflow data began. The general framework for the user-interactive computer program was developed.

PLANS FOR FY 1992: Stream gaging and data collection will continue throughout the year. Rainfall-runoff models for the Clear, Clark, and Clover Creek basins will be calibrated to the first year of data by comparing simulated discharges with observed discharges. Alan Lumb, WRD, Office of Surface Water, agreed to develop most of the programming of the user-interactive HSPF program through contract with a private programming firm. The Washington District office will provide the runoff files (long-term time series of discharge values for various land types associated with the HSPF model and various local precipitation records), conduct the second-phase testing of the program, and write the user's manual for the program.

PROJECT TITLE: Ground-Water Resources of Selected Areas of the Spokane and Kalispel Indian Reservations, Northeastern Washington



PROJECT NUMBER: WA-355

STUDY LOCATION: Northeastern Washington

COOPERATING AGENCY: U.S. Department of the Interior, Bureau of Indian Affairs

PROJECT CHIEF: Sandra S. Embrey

PROJECT DURATION: May 1990 to September 1991

PROBLEM: The Spokane and Kalispel Indian Reservations are located in northeastern Washington. The primary use of ground water on both reservations is for domestic purposes. Ground water on the Spokane Reservation is obtained from glacial deposits of silt and sand, and from the underlying basalt. Some wells go dry in late summer, and there was concern that cattle feedlot operations and septic tanks might be adversely affecting ground-water quality.

Most domestic wells on the Kalispel Reservation are located on the flood plain of the Pend Oreille River, which is composed primarily of silt. These wells yield only small quantities of water. Concentrations of arsenic, cadmium, and iron are often elevated; at times, the concentration of dissolved arsenic has exceeded drinking-water standards. A few wells were drilled in narrow gravel terraces overlooking the flood plain. These are reported to yield water in sufficient quantity and quality for use as domestic supplies.

The Bureau of Indian Affairs identified two areas within the Spokane Reservation and the terraced areas of the Kalispel Reservations as locations where future ground-water development could occur. A better understanding of the extent and hydraulic characteristics of the aquifers in these two areas was needed.

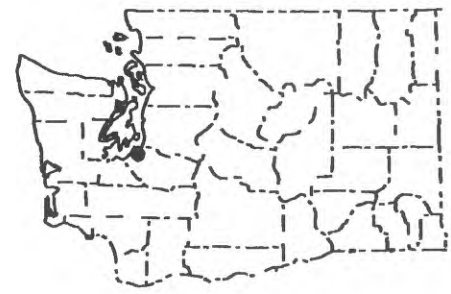
OBJECTIVES: The objectives of this project were to (1) determine the areal extent, lithology, and thickness of the unconsolidated surficial materials and of the underlying basalt on the Spokane Reservation, and of the Pleistocene fluvial and terrace deposits on the Kalispel Reservation; (2) attempt to delineate the water-level surface of individual aquifers on the Spokane Reservation, and describe the magnitude of seasonal water-level changes beneath both reservations; (3) define the regional patterns of water quality in the study areas and determine if any areas of poor ground-water quality exist; (4) estimate the hydraulic characteristics of the principal aquifers; and (5) estimate average annual recharge for aquifers in the study areas.

APPROACH: About 100 to 150 wells were inventoried and the data entered into the NWIS data base. Drillers' logs and available geologic maps were used to define the geometry of the unconsolidated basalt aquifers. Water-level data were plotted on maps of individual aquifers and used to delineate piezometric heads. Water-quality samples were collected to define regional patterns of water quality and to determine if any areas of poor ground-water quality exist. Transmissivity and hydraulic conductivity for wells were estimated and plotted for each aquifer. Average annual recharge was estimated using regression equations developed for the Columbia Plateau RASA project. All data collected were entered into the GIS data base ARC/INFO and provided to the Bureau of Indian Affairs.

PROGRESS: Ground-water data for 180 wells and water-quality data for 64 wells on the Spokane and Kalispel Indian Reservations were collected. The data, geologic maps, and drillers' reports were analyzed to determine the general hydrologic and water-quality characteristics of the ground water. A report was written that describes the results of the study and includes generalized surficial geology maps, maps of the areal distribution of selected water-quality constituents, lithologic sections, and maps depicting the thickness and extent of principal geohydrologic units.

PLANS FOR FY 1992: The report will receive technical review and will be submitted for approval to publish.

PROJECT TITLE: Surface-Water Quality in the Clover Creek Basin, Pierce County, Washington



PROJECT NUMBER: WA-357

STUDY LOCATION: Puget Sound region, Washington

COOPERATING AGENCY: Pierce County

PROJECT CHIEF: James C. Ebbert

PROJECT DURATION: April 1990 to September 1993

PROBLEM: The USGS is conducting a study to construct and calibrate rainfall-runoff models for drainage basins, including the Clover Creek basin in Pierce County. Water quality is a concern in the Clover Creek basin because land use over much of the area is rapidly changing from rural to urban and suburban.

OBJECTIVES: The objectives of this project are to (1) describe spatial and temporal changes in water-quality conditions in Clover Creek and its tributaries; (2) develop a conceptual understanding of the influence of land use and other basin characteristics on the quality of water in Clover Creek and its tributaries; and (3) test the use of a water-quality model to simulate the loading of selected constituents to Clover Creek and the transport of constituents in the stream channel.

APPROACH: Samples will be collected over a 2-year period during baseflows and stormflows to determine spatial and temporal changes in water-quality conditions. These data will also be used to identify the influence of land use and other basin characteristics on water quality. Constituent concentrations in runoff from three sampled catchments, each with different land-use characteristics, will be used to help calibrate the water-quality model.

PROGRESS: During the 1991 fiscal year, approximately 180 stream-water samples were collected and analyzed. Sampling periods included three storms, winter baseflow, and a 24-hour study during summer baseflow. Continuous water-quality monitors were installed at two of the sampling sites. Bottom sediments were collected at selected sampling sites and analyzed for trace metals in order to help determine target metals for future water sampling.

PLANS FOR FY 1992: Approximately 200 stream-water samples will be collected during storms and, to a limited extent, during baseflow. Continuous water-quality monitors will be operated at three sampling sites. Interpretation of data and initial testing of a water-quality model will begin.

PROJECT TITLE: Updated Hydrology of the Swinomish Indian Reservation, Northwestern Washington

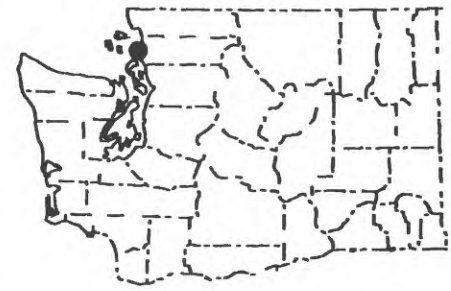
PROJECT NUMBER: WA-358

STUDY LOCATION: Northwestern Washington

COOPERATING AGENCY: Swinomish Tribe

PROJECT CHIEF: Sandra S. Embrey

PROJECT DURATION: May 1990 to September 1991



PROBLEM: A USGS investigation of the ground-water resources of the Swinomish Indian Reservation in 1979 documented the existence of three shallow aquifers within the top 200 to 300 feet of a 900-foot assemblage of unconsolidated sediments beneath the reservation. These three aquifers are an uppermost till unit, a middle unit of stratified drift, and a lower clay unit. At that time, all wells were finished in one of the three aquifer units, and no well completely penetrated the lower clay unit. Since 1979, several wells, including two public-supply wells, have penetrated the clay unit to a deeper aquifer beneath the central part of the reservation. The extent and hydraulic characteristics of this deeper aquifer were unknown. In 1981 an inactive waste-disposal site was discovered about a mile northeast of the tribal well field. The site had been used for the disposal of refinery wastes, and an investigation by a private consultant indicated the presence of substantial amounts of polycyclic aromatic hydrocarbons and aliphatic hydrocarbons, as well as small concentrations of volatile organic compounds. A better understanding of the Swinomish ground-water system and the potential and likelihood of its contamination by wastes from the disposal site were needed.

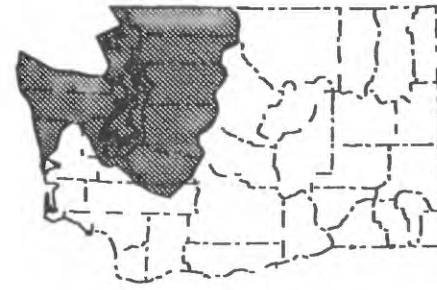
OBJECTIVES: The objectives of this project were to (1) verify the existence of a deep aquifer and attempt to describe its extent, thickness, and hydraulic characteristics; (2) refine the knowledge of flow directions of the "shallow" (upper three) aquifers; and (3) estimate the degree of interconnection between the shallow and deep aquifers.

APPROACH: All wells tapping the deep aquifer were located and data collected for use, along with existing geologic maps, in determining the extent and thickness of the aquifer. Data were also collected for wells drilled in the shallow aquifer since the 1979 investigation. Static water levels were measured in as many wells as possible, to verify ground-water-flow directions for the shallow aquifer, and to describe ground-water-flow directions in the deeper aquifer. The hydraulic conductivity and transmissivity of the deep aquifer were estimated, and the degree of connection between the shallow and deep aquifers was determined. A pumpage history was compiled for the tribal well field using data from the 1979 study and from tribal records. The zone(s) of influence were calculated for the well field under present pumping conditions and projected for increased withdrawals. The location, extent, and physiography of the waste-disposal site were determined. Surface-water runoff at the site was described and water-quality samples collected.

PROGRESS: Fifty-eight new wells, five of which are finished in the deep aquifer beneath a thick clay layer, were inventoried. Samples were collected from the five wells in the deep aquifer and from a small stream near the abandoned waste-disposal site, and were analyzed for selected constituents. An aquifer test by the driller on one of the tribal wells provided the data to describe the hydraulic characteristics of that aquifer. Several maps from the previous (1979) investigation were updated with information collected during this project. In addition, a map of the generalized geology of the study area, precipitation contours, and regional precipitation-recharge relations for the Puget Sound area were used to create a map of recharge on the reservation. Also, a map was created showing zones of influence for the tribal well field under present pumpage conditions and with projected increased withdrawal.

PLANS FOR FY 1992: The report for this project will receive technical review and will be submitted for approval to publish.

PROJECT TITLE: Upstream Boundaries for the State of Washington Shoreline Management Act of 1971



PROJECT NUMBER: WA-359

STUDY LOCATION: Statewide

COOPERATING AGENCY: Washington Department of Ecology

PROJECT CHIEF: Scott M. McKillop

PROJECT DURATION: July 1990 to June 1992

PROBLEM: The State of Washington Shoreline Management Act of 1971 applies the term "upstream" to the point on each stream where the mean annual flow is 20 ft3/s (cubic feet per second). The Act also defines "shorelines of state-wide significance" as bounded upstream in western Washington by points at which mean annual flow is 1,000 ft3/s. In order to carry out the provisions of the act, these points must be located on streams. In a 1971 study in cooperation with the WDOE, the USGS estimated the 20-ft3/s upstream boundary points for most streams in the State. In that study, if the 20-ft3/s point occurred upstream of certain political boundaries, such as national forest, Indian reservation, and national park boundaries, the Management Act boundary was set (downstream) at the political boundary.

OBJECTIVES: The objectives of this project are to enhance and modify the work of the earlier study by (1) defining the 20-ft3/s points for streams that were missed in the 1971 study; (2) locating the upstream boundaries for the "shorelines of state-wide significance;" (3) ignoring political boundaries in setting these boundary points; (4) using additional data that have accumulated since 1971; and (5) determining the boundary points using 20 ft3/s in the determining equations, rather than 20 ft3/s plus standard error of the determining equations, as had been done in the 1971 study. This study focuses on streams of northwestern Washington tributary to Puget Sound; follow-up studies will include the streams of southwestern Washington, the streams of the Columbia River basin of eastern Washington, and lakes throughout the State.

APPROACH: The approach is to develop and apply relations of streamflow to precipitation and basin area expressed in the form of the regression equation

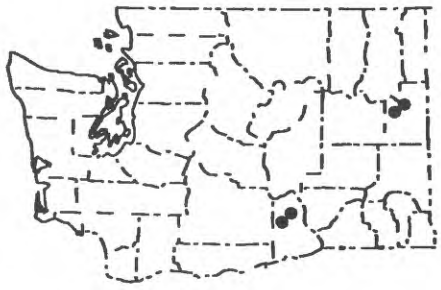
$$Q = aP^bA^c,$$

where Q is mean annual flow; P is mean annual precipitation, and A is basin area, for the drainage basin upstream of the point on the stream at which mean annual flow Q is desired; and a, b, and c are parameters determined in the regression. Setting Q equal to one of the boundary point values (20, 200, or 1,000 ft3/s) results in a relation between basin area and mean annual precipitation that must be satisfied at the point.

PROGRESS: Contributing basins for most existing gaging stations were digitized to allow regression of gaged discharge against basin area and precipitation. The contour map of average precipitation was digitized and extended into Canada using point data. Long-term precipitation records were found to compare closely with the mapped precipitation at the station locations. Regression analysis was completed for the first region, and calculation of 20-ft3/s locations has started.

PLANS FOR FY 1992: The regression analyses will be completed for northwestern Washington, including (1) digitizing of basin areas, (2) calculation of average precipitation, (3) regression analysis, and (4) calculation of the 20-ft3/s locations. The summary report will be prepared and submitted for technical review.

PROJECT TITLE: Estimating Actual Evapotranspiration Using Bowen Ratio and Penman Combination Methods--Phase II



PROJECT NUMBER: WA-362

STUDY LOCATION: Eastern Washington

COOPERATING AGENCY: Washington Department of Ecology

PROJECT CHIEF: Stewart A. Tomlinson

PROJECT DURATION: October 1990 to September 1992

PROBLEM: Evapotranspiration (ET) is a major component of the hydrologic cycle and one of the most difficult to quantify accurately. Good estimates of ET are needed to increase the accuracy of other water-budget components, notably ground water. Because long-term ET data generally are not available, stations to collect such data need to be established in the major climate and plant regimes throughout Washington.

OBJECTIVES: The objectives of this project are to (1) accurately define ET in several major climate and plant regimes in Washington; (2) begin to develop long-term ET data bases for these regimes; and (3) investigate a method simpler than the Bowen ratio method for calculating actual ET from routinely collected data.

APPROACH: The approach of this study will be to continue monitoring ET at the site established in Phase I (project WA343), and to establish three new sites in eastern Washington. Collected data will be used to calculate ET through the Bowen ratio equation and the Penman-Monteith equation. The data and ET results will be analyzed to determine whether a simplified Penman approach might be used.

PROGRESS: Data were collected from four sites in eastern Washington. The site established in Phase I at Snively basin was monitored with both Bowen ratio and Penman instrumentation. A location close to the original site was similarly instrumented from April through mid-May to take advantage of weighing-lysimeter data available there. That instrumentation was then moved to a grassland on the Turnbull National Wildlife Refuge near Cheney. An additional Penman site was set up in a wetland on the Refuge. Collected data were downloaded to a personal computer where ET calculations, energy-budget computations, and resultant plots were made.

PLANS FOR FY 1992: Data collection using the Penman instrumentation will continue at the Snively basin site and at the two Turnbull National Wildlife Refuge sites through April 1991. The summary report will be written and submitted for technical review.

PROJECT TITLE: National Water Quality Assessment, Central Columbia Plateau

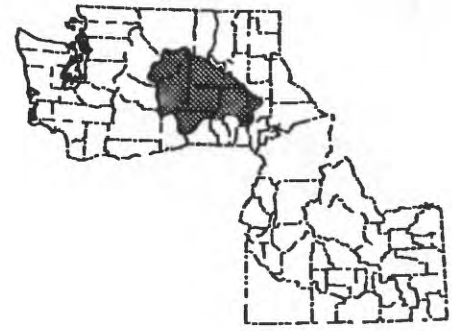
PROJECT NUMBER: WA-365

STUDY LOCATION: Central Washington

COOPERATING AGENCY: None, U.S. Geological Survey funds only

PROJECT CHIEF: Alex K. Williamson

PROJECT DURATION: June 1991 to September 1996



PROBLEM: The Central Columbia Plateau study unit is hydrologically important because water that flows out of the area, both on the surface and underground, eventually discharges to the Columbia River, a major national resource. The area is also important because of large-scale agricultural activities that require both ground water and surface water from the Columbia Basin Irrigation Project (CBIP) of the U.S. Bureau of Reclamation. Persistent ground-water-level declines have occurred locally because of extensive pumping of ground water for irrigation. In other parts of the basin, water levels have risen hundreds of feet because of the large quantities of surface water applied for irrigation. Therefore, the different irrigation and farming practices in the area have a major effect on both ground- and surface-water quality. In areas where water levels are declining, the effects of agricultural practices on ground-water quality may take longer to develop because of the increased distance between the water table and land surface. In areas of high water table where drains have been installed, shallow ground water containing large concentrations of nitrate is intercepted and routed to parts of the CBIP drainage system. Most of the drain water eventually reaches the Columbia River, but in transit, some of it moves through lower Crab Creek and other water bodies where the large nutrient concentrations may cause excessive plant growth and related problems.

OBJECTIVES: The long-term goals of the Central Columbia Plateau National Water Quality Assessment (NAWQA) study are to (1) describe the status and trends in the quality of the surface- and ground-water resources of this study unit; and (2) provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources. In meeting these goals, the study will produce water-quality information that will be useful to policy makers and managers at the national, State, and local levels.

APPROACH: To adequately address water-quality issues at the national scale, an integrated program of water-resources investigations is required that is consistent at all scales. In contrast with many previous water-quality studies, this study will include analysis of chemical loads, as well as concentrations, in order to help assess the effects of the chemicals resulting from natural or anthropogenic processes. Seasonal variations in water quality because of climate and agricultural practices will be taken into account. The quality of incoming and outgoing water in areas with nearly homogeneous land-use and hydrologic conditions will be compared in order to determine the mechanisms causing water-quality degradation.

PROGRESS: A generalized fact sheet (USGS Open-File Report 91-164) was published; three mailings were sent to more than 70 Federal, State, local, and university representatives to the liaison committee; a data source list and a prioritized list of water-quality issues in the study area were compiled; a work plan was submitted to Regional and National Headquarters; and an abstract was presented orally at a meeting of the American Geophysical Union in Richland, Wash., September 20, 1991.

PLANS FOR FY 1992: Reconnaissance water-quality sampling will be planned in detail and executed. A retrospective analysis of all available data on water quality and aquatic biology will be summarized, plotted, and compared. The first drafts of two reports will be 70-percent complete this fiscal year. Liaison meetings will be held in the spring and fall, both to inform the group of progress and to solicit ideas and review comments on methods and findings.

PROJECT TITLE: Ground-Water Sources in the Puget Sound Lowland

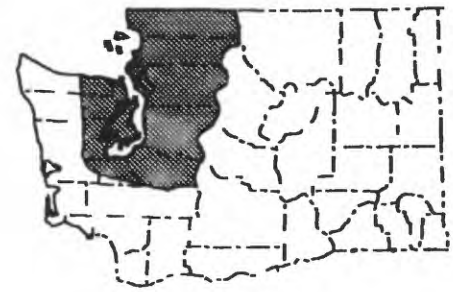
PROJECT NUMBER: WA-367

STUDY LOCATION: Puget Sound region, western Washington

COOPERATING AGENCY: Washington Department of Ecology

PROJECT CHIEF: Ronald C. Lane

PROJECT DURATION: October 1990 to June 1992



PROBLEM: Water supplies in the Puget Sound region will need to expand in the near future to meet the needs of an expanding population. Because surface-water sources are fully allocated, additional supplies most likely will come from ground water. Water developers need to know, on a regional scale, the best areas for ground-water development, and what the effects of development will be.

OBJECTIVES: The objectives of this project are to (1) identify geographic areas of the Puget Sound region that have the greatest potential for ground-water development from a shallow (less than 250 feet) and a deep (greater than 250 feet) aquifer system; and (2) characterize the likely effects of such development on ground-water levels.

APPROACH: This project will produce a series of maps using an ARC/INFO data base that portrays various aspects of well yield and replenishment. For the shallow aquifer system, specific-capacity data will be used as a surrogate for the ease of ground-water extraction. A map of the areal distribution of specific-capacity data will be prepared using data from the NWIS ground-water data base and from published reports. The availability of ground water from the deep aquifer system will be assumed to be proportional to the thickness of the unconsolidated sediments that lie between the bottom of the shallow aquifer system and the top of the bedrock. A map of the thickness of these sediments will be prepared using the best available geologic, geophysical, and depth-to-bedrock maps and data for the Puget Sound region. The amount of recharge from precipitation will be used as a relative measure of how fast the withdrawn volumes would be replenished. A recharge map of the study area will be prepared by overlaying information about the precipitation-recharge relations observed in previous studies on a map of the surficial geology of the study area. This geologic map will be prepared using the best available surficial geology maps of the Puget Sound region.

PROGRESS: An atlas-style report was outlined and a mock-up was prepared. The GIS coverages needed to describe the geology of the study area were obtained.

PLANS FOR FY 1992: The report will be submitted for technical review and approval for publication.

PROJECT TITLE: Magnitude and Frequency of Water Available for Runoff During Rain-On-Snow Events at Selected Sites in Washington State

PROJECT NUMBER: WA-370

STUDY LOCATION: Statewide

COOPERATING AGENCY: Washington Department of Natural Resources

PROJECT CHIEF: Steven N. Berris

PROJECT DURATION: October 1990 to April 1993

PROBLEM: Runoff from rain falling on snow causes mass-wasting of hillslopes, damage to river banks, downstream flooding, and loss of life. Forest managers, among others, in Washington are concerned about the effects that timber harvest may have on runoff from rain on snow. Watershed and plot-scale studies in the Pacific Northwest suggest that timber harvest can affect the quantity of water available for runoff (WAR) from rain on snow. Currently, there is only a fair understanding of the physical processes of WAR when rain falls on snow and how these processes may be affected by both timber harvest and topography. The significance of rain on snow needs to be understood from a regional, probabilistic perspective. The USGS will investigate the frequency of rain falling on snow in different climatic regions, and will estimate the magnitude of WAR that could be expected from sites with different amounts of forest cover and different slopes and aspects.

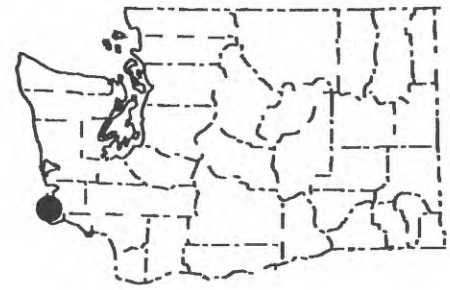
OBJECTIVES: The objectives of this project are to (1) design, calibrate, and test a numerical computer model for estimating WAR when rain falls on snow; (2) use the model for investigating the effects of forest-canopy density, land slope, and aspect on the magnitude and frequency of WAR when rain falls on snow; and (3) compare the magnitude and frequency of WAR when rain falls on snow with those from rainfall only.

APPROACH: The interception routine and snow-accumulation and melt routine of the Precipitation Runoff Modeling System (PRMS) numerical model will be used to synthesize the WAR data from existing climatic data. The PRMS model has not been used extensively in this climatic region, so some refinement of the model algorithms may be required. The PRMS model will be calibrated and tested using existing climate and WAR data sets collected at 22 sites in the Pacific Northwest. The tested model will be used to synthesize long-term time-series data of WAR at 38 National Weather Service sites in Washington. The synthesized records will represent WAR from rain on snow for various cover-slope-aspect combinations. The synthesized WAR records will then be analyzed statistically to determine magnitude-frequency relations, one relation for each cover-slope-aspect condition at each weather-station site. The magnitude-frequency relations will be compared with one another for significant differences. The final task will be to calculate magnitude-frequency relations of WAR from rainfall only at the 38 weather stations, and to compare these relations with those of WAR from rain on snow.

PROGRESS: Existing climate and snowpack data sets recorded at forested and open sites in Oregon and British Columbia were received for processing, and data sets for Washington are forthcoming. Time series of the data are being constructed for model calibration and testing. Supplementary measurements of snowpack characteristics at selected sites in the northern Cascade Range of Washington were completed. The supplementary snowpack data were processed and will be used, together with data sets recorded at those same sites, to guide model calibration.

PLANS FOR FY 1992: Model input codes will be developed, and the PRMS model will be calibrated to simulate water delivery to the ground when rain falls on snow. Once calibrated and tested with the existing data sets, the model will be used to synthesize long-term time series of water delivery to the ground at 38 weather station sites in Washington. These stations are representative of sites with open conditions and level topography. Once satisfactory results are obtained, the model will be used to investigate water delivery at those same sites, but with various combinations of cover, slope, and aspect. This synthesized information will represent a broad areal distribution from which the effects of timber harvest on water delivery to the ground during rain-on-snow events can be investigated. Magnitude-frequency relations will be determined for each cover-slope-aspect combination at each weather station.

PROJECT TITLE: Water-Table Altitudes and Water Quality in the Shallow Aquifer of Long Beach Peninsula, Washington



PROJECT NUMBER: WA-371

STUDY LOCATION: Long Beach Peninsula, southwestern Washington

COOPERATING AGENCIES: Pacific County and Washington Department of Ecology

PROJECT CHIEF: Blakemore E. Thomas

PROJECT DURATION: October 1990 to February 1994

PROBLEM: Long Beach Peninsula extends for about 20 miles north from the southwestern corner of Washington. It has an average width east to west of about 1.5 miles and separates Willapa Bay from the Pacific Ocean. Water supplies are derived mostly from a local shallow, dune- and marine-sand water-table aquifer. Throughout much of the peninsula, the water table is less than 10 feet below land surface during much of the year. Sewage treatment and disposal at most locations is by septic tanks with drainfields. Major industries on the peninsula are tourism, growing and processing of cranberries, and processing of oysters that are harvested from Willapa Bay. There is concern that leachate from septic systems and return flow of water from cranberry-growing areas may be degrading the quality of water in the shallow aquifer; and that ground water containing pesticides, nutrients, and bacteria may be discharging to Willapa Bay and affecting oyster production.

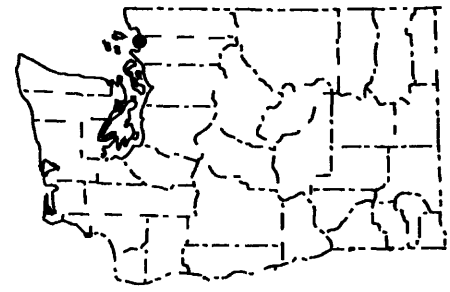
OBJECTIVES: The general objective of this study is to provide information on ground-water flow and water quality in the shallow aquifer of Long Beach Peninsula. Specific objectives are to: (1) determine the areal distribution and seasonal fluctuations of water-table altitudes; (2) determine directions and rates of ground-water flow, and flow directions between ground and surface water; (3) determine concentrations of common ions, nutrients, bacteria, and pesticides in the shallow aquifer; (4) estimate if pesticides are present in the shallow aquifer and the rate at which pesticides are likely to be transported by ground water to Willapa Bay; and (5) determine, to the extent that historical data allow, time trends in water levels and water quality.

APPROACH: A monitoring network will be created by installing about 25 staff gages at existing surface-water sites and 90 shallow wells, and water levels at those sites will be measured monthly for 1 year. The resulting data will be used to define the areal and temporal distribution of water-table altitudes, directions and rates of ground-water flow, and the directions of flow between ground and surface water. The quality of the ground water will be assessed by analyzing water samples collected once in early spring and again in early fall from about 60 wells and 15 surface-water sites. Possible time trends in water levels and water quality will be analyzed by comparing historical and current data.

PROGRESS: The results of previous investigations were reviewed and historical data were compiled. A field inventory was made of about 200 ground-water wells. The locations of the sites for the monitoring network were specified. A GIS data base was started with coverages of shorelines, major roads, and well locations. The results of the well inventory were reviewed and checked, and the information entered in a computerized data base.

PLANS FOR FY 1992: The 25 staff gages at surface-water sites and 90 shallow wells will be installed. Monthly measurements of water levels at ground- and surface-water sites will begin. Water samples will be collected and analyzed twice during the year. Slug and small-scale aquifer tests will be made. Geographic and cultural information will be entered into the GIS data base. Interpretation of the data and report writing will begin.

PROJECT TITLE: Occurrence and Quality of Ground Water on Guemes Island, Skagit County, Washington



PROJECT NUMBER: WA-372

STUDY LOCATION: Skagit County, northwestern Washington

COOPERATING AGENCIES: Skagit Conservation District and Guemes Island Environmental Trust

PROJECT CHIEF: Sue C. Kahle

PROJECT DURATION: April 1991 to June 1993

PROBLEM: The year-round population of Guemes Island is only about 700, but the summer population is typically about 3,000. The evidence suggests that the island population growth is accelerating. As a result, long-term residents are increasingly concerned that the ground-water resource on which most domestic water supplies are based may not be adequate to support this additional development, or that the additional demands on the resource may adversely affect its quantity and quality. Even though little is known about the island's ground-water resource in general, previous studies have shown evidence of local seawater intrusion. In addition, residents are aware that arsenic has been reported in some wells on Lummi Island, directly north of Guemes Island.

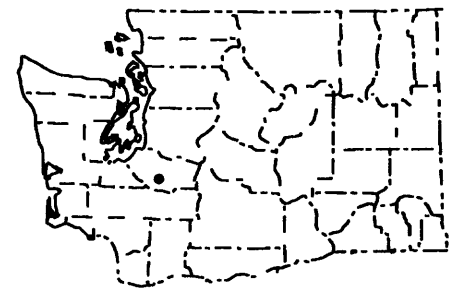
OBJECTIVES: The objectives of this project are to (1) describe the ground-water system using existing or readily collectable data; (2) determine the general chemical characteristic of waters in the significant aquifers; (3) describe any apparent widespread ground-water contamination, including seawater intrusion; (4) prepare a generalized water budget of the study area; and (5) design a long-term monitoring network for ground-water levels and ground-water quality based on the results of the study.

APPROACH: The approach for this project is to (1) make a comprehensive inventory of 50 to 75 wells on the island, and the principal springs; (2) construct a net of hydrogeologic sections using drillers' logs and other available geologic data in order to correlate aquifers and confining units; (3) draw structure and thickness maps of significant hydrogeologic units from these correlations and, if possible, determine the configuration and altitude of the top of bedrock; (4) determine the general thickness of the glacial drift that covers most of the island and assign all project wells to a specific hydrogeologic unit; (5) construct water-level contour maps for the principal aquifers and determine ground-water flow directions; (6) choose 8 to 10 wells across the island within various hydrogeologic regimes and monitor water levels for a period of 1 year; (7) calculate the magnitude of seasonal water-level fluctuation within individual aquifers; (8) construct a generalized water budget of the study area based on calculations of recharge and the results of a water-use survey; (9) select 20 to 25 inventoried wells and 3 to 4 springs and conduct water-quality sampling; and (10) sample 10 to 12 coastal wells monthly for a period of 1 year and analyze the waters for chloride.

PROGRESS: Well inventory began, and historical water-quality and water-level data were gathered and reviewed. A seismic reflection survey was conducted across a portion of the island in order to map lithologic changes at depth.

PLANS FOR FY 1992: Plans for the next fiscal year include the following work items: (1) inventory and measure water levels in 50 to 75 wells; (2) create a data base and begin GIS coverages; (3) measure water levels in 8 to 10 wells monthly for 1 year; (4) sample for chloride concentration and measure water levels in 10 to 12 wells monthly for 1 year; (5) install 5 or 6 precipitation gages and measure weekly for 1 year; (6) construct hydrogeologic sections using existing surficial geologic maps, well drillers' records, and geologic data collected in the field; (7) construct water-level contour maps; (8) construct top and thickness maps of significant hydrogeologic units; (9) select 20 to 25 inventoried wells and 3 or 4 springs and conduct water-quality sampling for analyses of specific conductance, pH, dissolved oxygen, alkalinity, major ions, nitrate, iron, manganese, and fecal-coliform bacteria; (10) sample subsets of the wells for volatile organic compounds, arsenic, and septage-related constituents such as boron and MBAs (detergents); and (11) summarize the results of the investigation in a report for publication.

PROJECT TITLE: Petroleum in Soil and Ground Water at Longmire, Washington, Mount Rainier National Park



PROJECT NUMBER: WA-377

STUDY LOCATION: Longmire, Washington, Mount Rainier National Park

COOPERATING AGENCY: U.S. Department of the Interior National Park Service

PROJECT CHIEF: Steven S. Sumioka

PROJECT DURATION: August 1990 to October 1991

PROBLEM: An underground waste-oil storage tank leaked petroleum products to the surrounding soil. The extent of contamination of soil and of ground water was not known.

OBJECTIVES: The objectives of this project were to (1) identify the petroleum product(s) found in the soil; (2) determine the likely source(s) of the product(s); (3) determine the approximate extent of migration of the product in soil above the water table; (4) determine depth to the water table and direction of ground-water flow; and (5) determine if product has reached the water table and, if so, the approximate areal extent and relative magnitude of ground-water contamination.

APPROACH: Five wells were drilled to the water table in the vicinity of the underground storage tank. Samples of drill cuttings were collected to determine the degree of contamination of the soil. Water samples were collected to determine the degree of ground-water contamination. Water levels were measured in the five wells and in the nearby Nisqually River to determine local ground water-surface water relations.

PROGRESS: All field work scheduled for fiscal year 1991 was completed. Cuttings from the well closest (about 20 feet) to the tank had the largest concentration of petroleum product. Water samples from this well also had the largest concentration of product. Samples of diesel oil and waste motor oil were sent to the USGS Central Laboratory for analysis as a means of identifying the product responsible for the contamination.

PLANS FOR FY 1992: Ground water will be sampled again, and water-level measurements will continue in wells and the river. A summary report will be written and submitted for technical review.

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417-D. Chemical quality of the surface waters of the Snake River basin, by L.B. Laird. 1964.

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631. Analysis of a 24-year photographic record of Nisqually Glacier, Mount Rainier National Park, Washington, by F.M. Veatch. 1969.

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813-S. Summary appraisals of the nation's ground-water resources, Pacific Northwest Region, by B.L. Foxworthy. 1979.

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