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Environmental Setting of the Granger Drain and DR2 Basins, Washington, 2003–04

Scientific Investigations Report 2007–5102

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photographs of crops in Granger Drain Basin, Washington.
Large Photo: Wine grape vines with Snipes Mountain in distance (Photograph by Henry M. Johnson, U.S. Geological Survey, May 4, 2005).
Inset 1: Concord grapes (Photograph by Henry M. Johnson, U.S. Geological Survey, October 3, 2003).
Inset 2: Corn and concord grapes (Photograph by Henry M. Johnson, U.S. Geological Survey, August 17, 2005).

Environmental Setting of the Granger Drain and DR2 Basins, Washington, 2003–04

By Karen L. Payne, Henry M. Johnson, and Robert W. Black

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Foreword

The U.S. Geological Survey (USGS) is committed to providing the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (http://www.usgs.gov/). Information on the quality of the Nation's water resources is critical to assuring the long-term availability of water that is safe for drinking and recreation and suitable for industry, irrigation, and habitat for fish and wildlife. Population growth and increasing demands for multiple water uses make water availability, now measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, and local information needs and decisions related to water-quality management and policy (http://water.usgs.gov/nawqa). Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities.

From 1991-2001, the NAWQA Program completed interdisciplinary assessments in 51 of the Nation's major river basins and aquifer systems, referred to as Study Units (http://water.usgs.gov/nawqa/studyu.html). Baseline conditions were established for comparison to future assessments, and long-term monitoring was initiated in many of the basins. During the next decade, 42 of the 51 Study Units will be reassessed so that 10 years of comparable monitoring data will be available to determine trends at many of the Nation's streams and aquifers. The next 10 years of study also will fill in critical gaps in characterizing water-quality conditions, enhance understanding of factors that affect water quality, and establish links between ***sources*** of contaminants, the ***transport*** of those contaminants through the hydrologic system, and the potential ***effects*** of contaminants on humans and aquatic ecosystems.

The USGS aims to disseminate credible, timely, and relevant science information to inform practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

Robert M. Hirsch
Associate Director for Water

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Conversion Factors and Datums

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C = (1.8 x °C) + 32.

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude as used in this report refers to distance above the vertical datum.

Environmental Setting of the Granger Drain and DR2 Basins, Washington, 2003–04

By Karen L. Payne, Henry M. Johnson, and Robert W. Black

Abstract

The Granger Drain and DR2 basins are located in the Yakima River basin in south central Washington. These agricultural basins are one of five areas in the United States selected for study as part of the National Water-Quality Assessment Program Agricultural Chemicals: Source, Transport, and Fate Study. The Program is designed to describe water-quality conditions and trends based on representative surface- and ground-water resources across the Nation. The objective of the Agricultural Chemicals topical study is to investigate the sources, transport, and fate of selected agricultural chemicals in a variety of agriculturally diverse environmental settings. The Granger Drain and DR2 basins were selected for the Agricultural Chemicals topical study because they represent the irrigated agricultural setting that characterizes eastern Washington. These basins are located in one of the most productive agricultural areas in the United States. This report describes the environmental setting of the Granger Drain and DR2 basins in the context of how agricultural practices, including agricultural chemical applications and irrigation methods, interface with natural settings and hydrologic processes.

Introduction

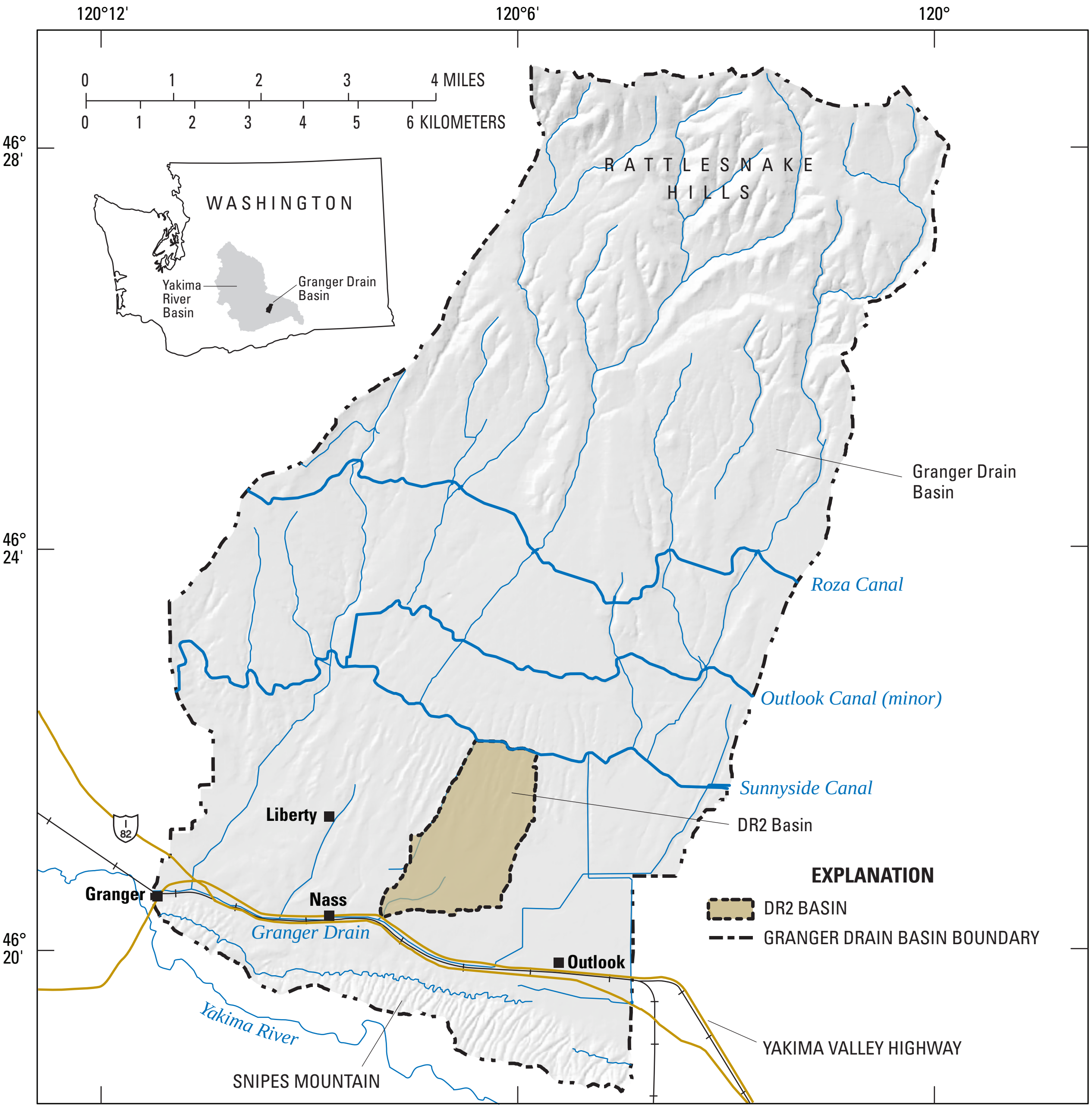
The Granger Drain and DR2 basins are located in the Yakima River basin in south central Washington (fig. 1). These agricultural basins are one of five areas in the United States selected for study as part of the National Water-Quality Assessment Program (NAWQA) Agricultural Chemicals: Source, Transport, and Fate Study (ACT). These basins are located in one of the most productive agricultural areas in the United States. As in many agricultural areas, crop production, pastures, and animal feeding operations in the Granger Drain and DR2 basins have been identified as sources of chemical contamination for surface and ground water in the area (Morace and McKenzie, 2002). To improve our understanding of how agricultural chemicals move through the environment and ways to best manage these chemicals, intensive chemical studies within the Granger Drain and DR2 basins were begun in 2001. Chemical samples were collected from all major hydrologic compartments within these basins, including the atmosphere, the subsurface unsaturated zone, ground water, overland flow, surface water, and the streambed surface-water/ground-water interface. This report details the environmental setting within Granger Drain and DR2 basins. The information presented here is intended for scientists and managers working in these and similar basins and provides a context in which to evaluate current and future work conducted as part of the NAWQA program in these basins.

Purpose and Scope

The purpose of this report is to present an overview of the current environmental setting of the Granger Drain and DR2 basins and identify factors influencing water quality in these basins. The environmental factors described here include the natural factors of physiography, geology, soils, hydrology, and climate, and the cultural factors of population and land use. This report largely represents a compilation of the results of selected water-quality studies and existing data with respect to the environmental factors in these basins. However, some new data are presented on land use and pesticide application rates.

Environmental Setting of Granger Drain and DR2 Basins

The Granger Drain and DR2 basins are located in south central Washington State. The study area is bounded on the south by the Yakima River and Snipes Mountain and on the north by the Rattlesnake Hills (fig. 1). Granger Drain basin includes about 62 mi^2, and the DR2 basin, nested within the Granger Drain basin, has a drainage area of 2.1 mi^2 (fig. 1). Because the region lies in the rain shadow east of the Cascade Mountains, it receives about 7 in. of precipitation per year (Western Regional Climate Center, 2005). The city of Granger, a community of about 2,500 people, is in the southwest part of the basin. Agriculture is the primary economic activity in these basins. The area was selected for this study because environmental conditions and agricultural practices are similar to other parts of the lower Yakima River basin.



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Shaded-relief base from 1:100,000-scale Digital Elevation Model based on the North American Datum of 1983.

Figure 1. Study areas in the Yakima River Basin including the Granger Drain and DR2 basins, Washington.

Physical and Cultural Features

The defining physical and cultural features in Granger Drain basin include two major highways, numerous rural agricultural roads, a railroad, the city of Granger, one minor and two major canals, and dozens of irrigation distribution laterals and agricultural drains. Interstate 82 runs east-west through Granger Drain basin and effectively divides it, resulting in a steep, narrow strip south of the interstate which includes Snipes Mountain and a vastly larger northern area, which constitutes most of the Granger Drain basin. Parallel to and north of the interstate highway is a lightly-traveled spur to the main railroad and the Yakima Valley Highway (an important local east-west county road), and Granger Drain, an agricultural drain providing the only surface-water outlet from the basin. Paved and unpaved rural roads are located mostly on section and quarter section lines and run north-south and east-west through the basin. The small community of Outlook is located in the southeast corner. The city of Sunnyside is about 2 mi east of the basin and the city of Zillah is just outside the western boundary.

Two large canals cross the Granger Drain basin from west to east: the Roza Canal to the north and the Sunnyside Canal to the south. Water delivered to farms in the Granger Drain basin eventually drains to Granger Drain by surface and groundwater flow, which enters the Yakima River downstream of the city of Granger.

Physiography and Topography

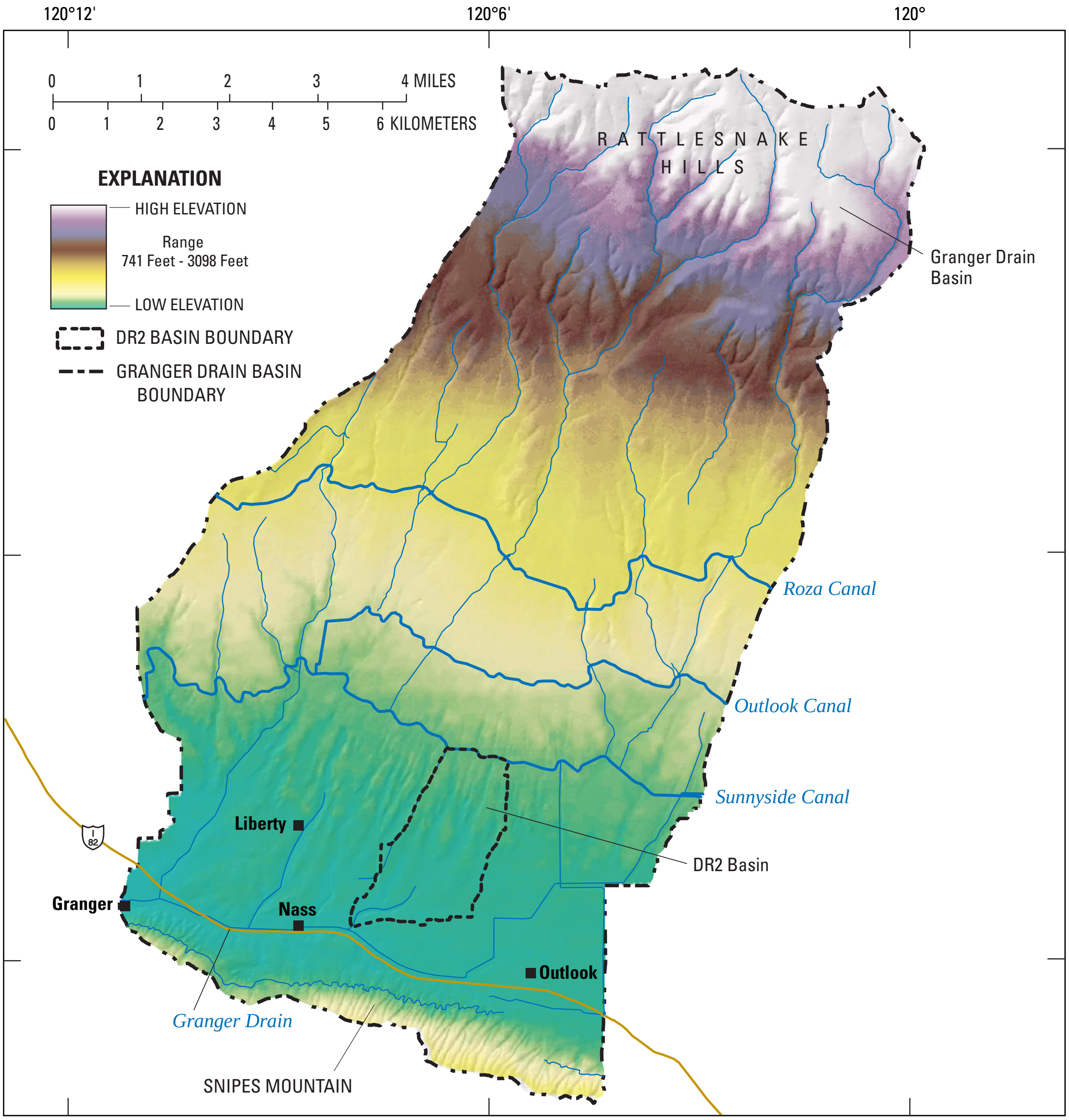
The Granger Drain basin is bounded on the north by the Rattlesnake Hills and the south by Snipes Mountain (fig. 2). The eastern and western divides are marked by well defined ridges in the uplands and poorly defined, low rises in the valley bottom. Excepting the north-facing slope of Snipes Mountain, most of the Granger Drain basin slopes to the south. The entire basin slopes gently to the southwest. Land surface elevation ranges from 740 ft in the valley bottom to 3,020 ft along the divide in the Rattlesnake Hills. Maximum elevation along Snipes Mountain is 1,300 ft. The Granger Drain basin is characterized by generally flat, agricultural land. In the cultivated portion of Granger Drain basin, the median land slope is 3.1 percent with an interquartile range of 1.8 percent to 5.7 percent.

Elevations in the DR2 basin range from 745 ft along DR2 drain in the south to 850 ft along the Sunnyside Canal in the north. Median land slope is 2.3 percent with an interquartile range of 1.1 to 4.5 percent. The upper part of the DR2 basin is dissected by north-northeast trending ridges. Up-slope, to the north-northeast, the ridges grade into the smooth alluvial apron in the central part of the basin. Down-slope, to the south-southwest, the ridges taper to a rounded point that gently slopes down to the valley bottom. The ridges are of modest relief, averaging 10–20 ft above the adjacent low lands.

Geology and Stratigraphy

Regionally, the Granger Drain basin lies in the Yakima fold belt near the western margin of the Columbia Plateau physiographic province. In this area, Miocene-aged basalts of the Columbia River Basalt Group have been folded into east-west trending synclinal basins and anticlinal ridges. Thick deposits of alluvium, fluvial deposits, debris flows, and loess have accumulated along the margin of and between the rising ridges. These deposits are largely unconsolidated; however, beds of moderately to highly indurated material are exposed throughout the area. For brevity, further references to these deposits in this text will describe them simply as "unconsolidated" to contrast them with the underlying basalt rock.

Geology of the Granger Drain basin is interpreted from 1:100,000 scale geologic maps produced by the Washington State Department of Natural Resources (Schuster, 1994). The Granger Drain basin is in a structural basin bounded on the north by the Rattlesnake Hills and on the south by Snipes Mountain (fig. 3). Basalts of the Saddle Mountains Basalt Formation outcrop on both of these ridges and are believed to underlie the unconsolidated surficial deposits in the basin. The maximum thickness of the unconsolidated sediments is uncertain, but is known to exceed 300 ft based on well logs. Interpolation from nearby surficial outcrops and wells indicates a likely depth of approximately 650 ft. The unconsolidated sediments fall into four broad groups. The oldest are assigned to the Ellensburg Formation, which in this area are Miocene-age lahars and sands and gravels deposited by the ancestral Columbia River, Yakima River, and tributaries. Overlying these are Pleistocene to Quaternary-aged alluvial fan deposits shed from the rising ridges and large areas of loess. These deposits are spatially heterogeneous and discontinuous. Blanketing the entire basin at an elevation below approximately 1,000 ft is a sequence of alternating fine sand and silt deposited by the Late Pleistocene Missoula Floods (Bretz, 1930; Waitt, 1984). A thin veneer of Quaternary-aged loess overlies the Missoula Flood silts in isolated areas.



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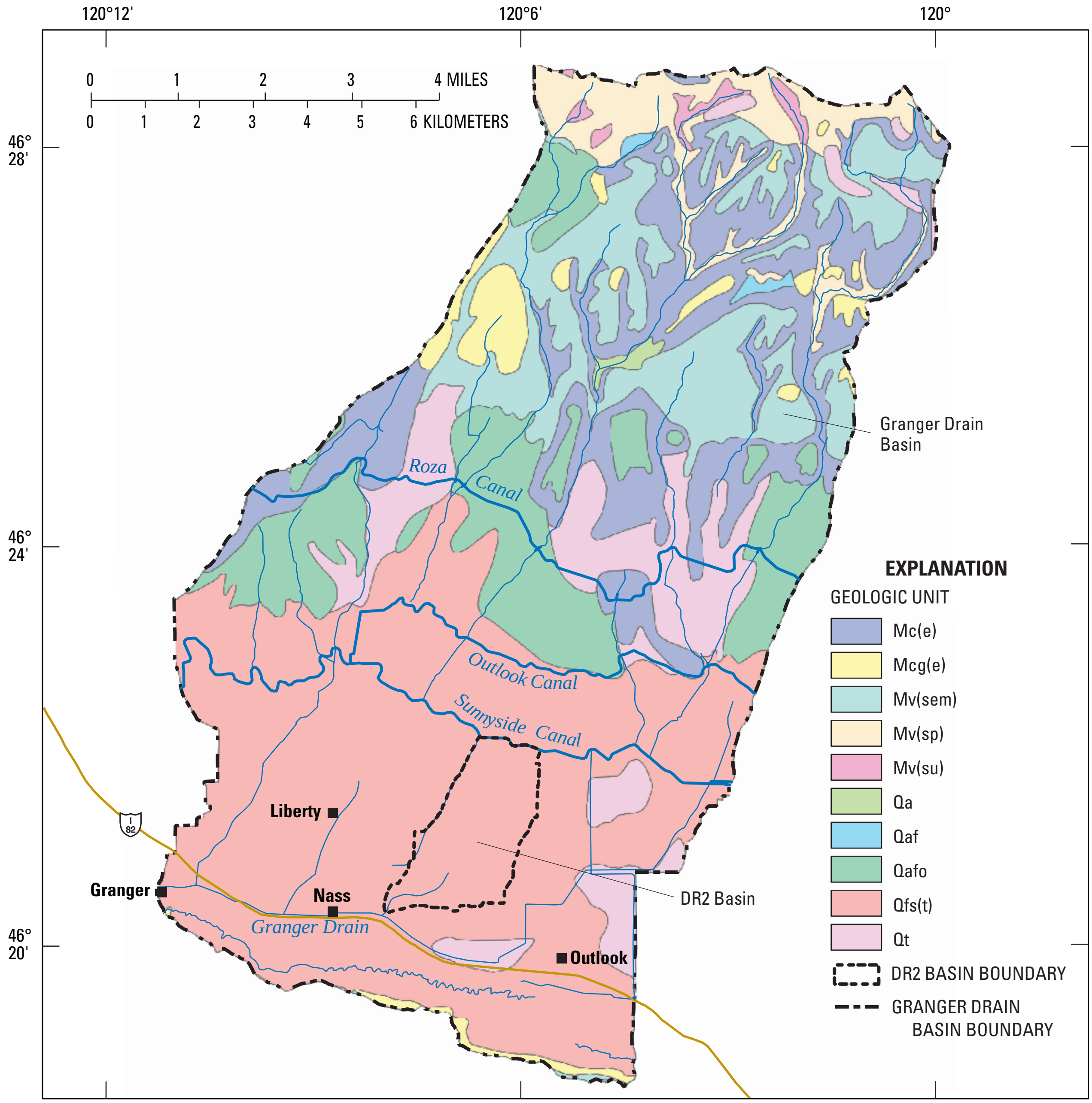
Shaded-relief base from 1:100,000-scale Digital Elevation Model based on the North American Datum of 1983.

Figure 2. Physiographic relief of the Granger Drain and DR2 basins, Washington.



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Shaded-relief base from 1:100,000-scale Digital Elevation Model based on the North American Datum of 1983.

Figure 3. Bedrock geology of the Granger Drain and DR2 basins, Washington (Schuster, 1994). Mc(e) = Miocene (middle to upper) – continental sedimentary deposits or rocks; Mcg(e) = Miocene (upper) – continental sedimentary deposits or rocks, conglomerate; Mv(sem) = Miocene (upper) – basalt flows (Elephant Mountain Member [CRB, SMB]); Mv(sp) = Miocene (late) – basalt flows (Pomona Member [CRB, SMB]); Mv(su) = Miocene (middle) – basalt flows (Umatilla Member [CRB, SMB]); Qa = Quaternary – alluvium; Qaf = Quaternary – alluvial fan deposits; Qafo = Quaternary – alluvial fan deposits, older; Qfs(t) = Pleistocene – outburst flood deposits, sand and silt, late Wisconsinan; Qt = Quaternary – loess. (Source: Washington Division of Geology and Earth Resources, 2005.)

Geology of the DR2 basin was determined from nearby outcrops, cores collected from wells drilled for this study, and well logs from existing wells. As in the Granger Drain basin, the Ellensburg Formation underlies the entire DR2 basin. When encountered in wells constructed for this study, the Ellensburg formation is notably coarser than overlying material, consisting of medium to coarse sand interbedded with thinner layers of silt and gravel. Overlying the Ellensburg Formation is the Pleistocene to Quaternary-aged alluvial fan and loess material previously described, which occurs as 15 to 30 ft of geographically heterogeneous clay- to gravel-sized material. The upper 10–30 ft are the Late Pleistocene Flood Silts. Approximately 25 to 35 flood sequences are present in the study area. Sequences are between 10 and 25 in. thick and typically contain a 0.25- to 5-in. thick basal deposit of silty sand capped by 8–20 in. of clayey silt to very fine sand. Observations of nearby exposures indicate the flood deposits in the study area likely are dissected by vertical to sub-vertical planar clastic dikes.

Soils

Identification of soil types in the Granger Drain and DR2 basins (fig. 4) were based on field mapping data contained within the Soil Survey Geographic (SSURGO) database. SSURGO is the most detailed level of soil mapping done by the Natural Resources Conservation Service (NRCS) (U.S. Department of Agriculture, 2005). The soils found within the basin were formed in alluvium, eolian sand, lake sediment, loess, and residuum derived from basalt and sandstone. Most of the soils are well drained. The soils are sandy to clayey in texture and are very shallow (surface to 10 in.) to very deep (surface to 60 in.). In irrigated areas, the soils are nearly level to strongly sloping and moderately steep to steep in the non-irrigated areas.

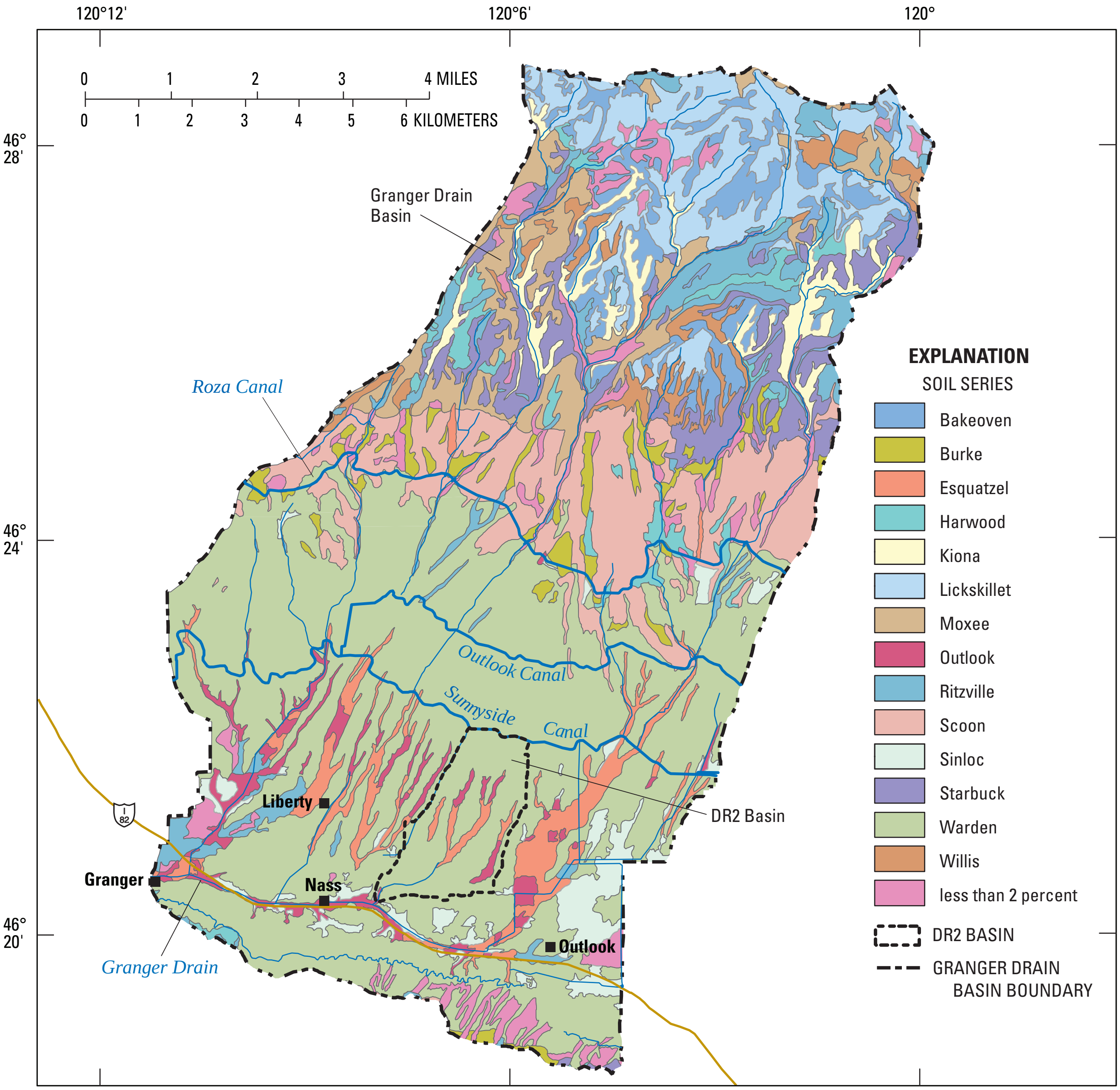
In the Granger Drain basin, 29 generalized soil series are present (fig. 4). Many of these generalized series are composed of 2–4 slope-defined phases (table 1). Of the 29 soil series, 2 represent over 50 percent of the basin. The remaining 27 soil series individually account for no more than 6.89 percent of the basin. The most abundant soil type is the Warden silt loam series with 5 slope-defined phases ranging from 0 to 30 percent slopes. The most dominant Warden phase is the 2 to 5 percent slope phase, which accounts for 22 percent of the basin. In total, the Warden silt loam series accounts for 41 percent of the Granger Drain basin.

Table 1. Percentage of abundance of soil types within the Granger Drain and DR2 basins, Washington, based on SSURGO.

[Source: U.S. Department of Agriculture, 2005]

Soil series	Percentage of Granger basin area	Percentage of DR2 basin area
Warden	41.00	87.00
Scoon	10.49	
Lickskillet	6.89	
Starbuck	5.27	
Moxee	4.66	
Bakeoven	4.64	
Esquatzel	3.71	8.00
Sinloc	2.91	
Kiona	2.81	
Willis	2.25	
Burke	2.22	
Outlook	2.22	5.00
Harwood	2.07	
Ritzville	2.04	
Shano[1]	1.79	
Gorst[1]	1.63	
Selah[1]	.66	
Cleman[1]	.65	
Hezel[11]	.61	
Scooteney[1]	.51	
Mikkalo[1]	.41	
Wenas[1]	.40	
Quincy[1]	.32	
Renslow[1]	.31	
Finley[1]	.29	
Ritzville Variant[1]	.09	
Pits[1]	.08	
Prosser[1]	.02	
Wanser[1]	.02	

[1]Minor soil series combined into one group in figure 4.



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Shaded-relief base from 1:100,000-scale Digital Elevation Model based on the North American Datum of 1983.

Figure 4. Soil types in the Granger Drain and DR2 basins, Washington. Soil types based on SSURGO data (U.S. Department of Agriculture, 2005). See table 1 for an explanation of the 15 soil series combined in the "less than 2 percent" group.

In the DR2 basin, 87 percent of the basin is composed of the Warden series. The Warden silt loams are very deep, well drained soils on terraces. Warden soils were formed in lacustrine sediment and have a mantle of loess. Typically, the surface layer is a brown silt loam about 5 in. thick and the subsoil is a pale brown silt loam about 14 in. thick. The substratum extends to a depth of 60 in. or more and is a light gray to pale brown stratified silt loam, loam, and very fine sandy loam. In some areas the surface layer is fine sandy loam. Permeability of the Warden series is moderate and available water capacity is high. Runoff for the Warden series is slow and the water erosion hazard is slight. The Warden series generally is used for irrigated field and orchard crops and generally has very few limitations in terms of crops and irrigation methods below 8 percent slopes. In irrigated areas with slopes greater than 8 percent, runoff and erosion can be a problem. A plowpan can develop in this soil, but can be broken by chiseling or subsoiling when the soil is dry.

The Esquatzel silt loam accounts for 8 percent of the DR2 basin and has two slope-defined phases: 0–2 percent and 2–5 percent. The Esquatzel silt loam is a very deep, well drained soil usually located on flood plains and is dissected by intermittent and perennial streams. Typically, the surface layer is a brown silt loam about 17 in. thick. The surface layer can be a fine sandy loam, stratified with thin lenses of sandy loam or very gravelly loamy sand to a depth of 36 in. or more. The surface layer is underlain by a more pale brown silt loam to a depth of 60 in. Permeability of this soil is moderate and available water capacity is high. Runoff potential for the Esquatzel series is low.

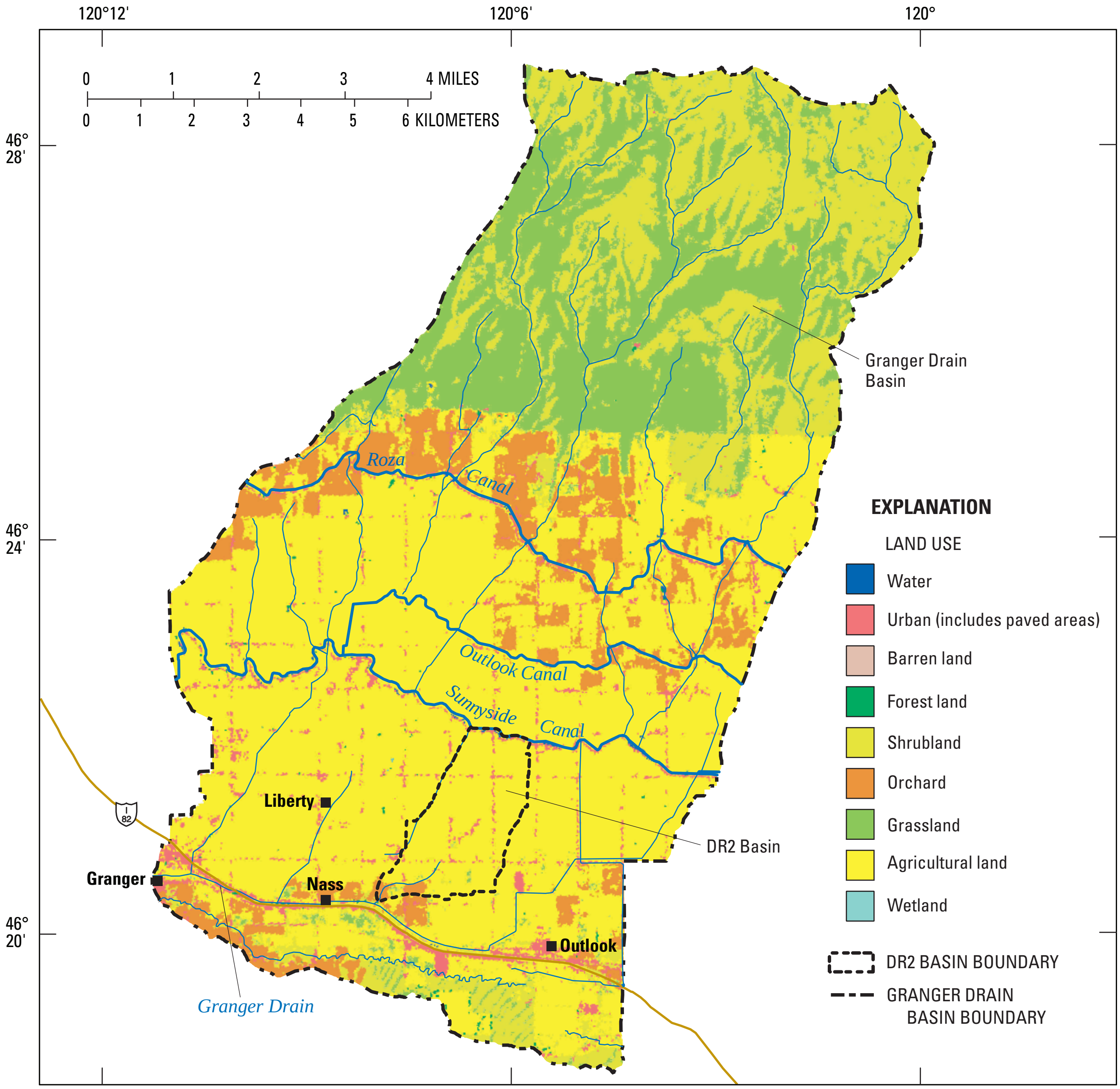
The Outlook silt loam accounts for 5 percent of the DR2 basin and is a very deep, artificially drained soil usually located on flood plains. The Outlook silt loam has a slope of 0 to 3 percent. Typically, the surface layer is a very dark brown, very dark grayish brown and dark grayish brown silt loam about 8 in. thick and has a yellowish brown or dark yellowish brown mottling. It is strongly alkaline. The subsoil is a grayish brown, mottled silt loam about 10 in. thick. The substratum to a depth of 60 in. or more is dark brown silt loam. The subsoil and substratum are moderately alkaline. Permeability of this soil is moderate and available water capacity is high. Runoff generally ponds and the hazard of water erosion is slight. This soil generally needs to be drained to be agriculturally productive.

Land Use and Population

Agriculture

Land use—Major land use activities in the Granger Drain and DR2 basins include irrigated agriculture, dairies, grazing on non-irrigated land, and limited urbanization (fig. 5). Based on field mapping conducted by U.S. Geological Survey (USGS) in 2003 and 2004 (table 2), the major crops within the Granger Drain basin consisted of alfalfa and other hays, asparagus, corn, hops, mint, pasture, juice grapes, wine grapes, and apple, pear, and cherry orchards. The DR2 basin contains a less diverse mixture of crops with most agricultural land dedicated to the production of corn, juice grapes, and pasture. Numerous dairies varying in size from a few hundred dairy cows to more than a thousand dairy cows operate within the Granger Drain and DR2 basins (Washington State Department of Ecology, 2005). The dairy industry substantially influences the crops grown in the basin as dairies require enormous amounts of corn and alfalfa for feed.

Crop maps were obtained for the 1992 growing season and some significant shifts in cropping patterns were noted in comparing the 1992 to the 2003-2004 data sets. In the Granger Drain basin, the largest change in crop type was a 24 percent increase in grapes and orchards. The increase in grape and orchard acreage was largely at the expense of asparagus, hops, and mint, which decreased 21 percent over the same period. Although it cannot be discerned from the 1992 data, large amounts of wine grapes and cherries also were planted in the decade between crop maps. In the DR2 basin, notable decreases in acreages of asparagus, hops and mint (26 percent) occurred between 1992 and 2003, although corn increased by 17 percent. Between 2003 and 2004, changes in crop type were much smaller. Both asparagus and squash decreased by 3.8 and 2.2 percent, respectively, while corn increased by 7.7 percent. The dairy and beef industries expanded rapidly in the past decade, resulting in an 83 percent increase in the number of dairy animals in the watershed from 1989 to 2000 (20,000 to 36,500) (Bohn, 2001). Most animals are maintained in confined lots or small pastures and do not range freely.



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Shaded-relief base from 1:100,000-scale Digital Elevation Model based on the North American Datum of 1983.

Figure 5. Land cover in the Granger Drain and DR2 basins, Washington.

Table 2. Summary of crop and irrigation types in the Granger Drain and DR2 basins, Washington, calendar years 1992, 2003, and 2004.

[Percentage data from South Yakima Conservation District 1992 (Bohn, 2001). Percentages are based on agricultural land and do not include the area of drains, right of ways, and infrastructure. –, not available]

Crop type	Granger Drain basin (39,536 acres)				DR2 basin (1,359 acres)					
	1992		2003		1992		2003		2004	
	Area	Percentage of total area	Area	Percentage of total area	Area	Percentage of total area	Area	Percentage of total area	Area	Percentage of total area
Corn	5,782.7	18.95	8,805.5	22.27	248.8	18.21	473.3	34.83	577.4	42.49
Grapes (wine and juice)[1]	–	–	3,300.6	8.35	–	–	223.0	16.41	230.8	16.98
Pasture	4,666.1	15.29	2,824.8	7.14	157.1	11.50	177.7	13.08	153.8	11.32
Asparagus[2]	7,928.8	25.98	952.1	2.41	499.5	36.55	146.5	10.78	94.8	6.97
Alfalfa	4,666.1	15.29	3,377.0	8.54	157.1	11.50	28.9	2.13	42.6	3.14
Dairy/Feedlot (includes manure management)	1,311.0	4.30	1,434.2	3.63	45.7	3.35	35.6	2.62	36.0	2.65
Grass	0	0	566.3	1.43	0	0	21.9	1.61	23.2	1.71
Fallow	1,680.6	5.51	2,475.7	6.26	56.3	4.12	23.1	1.70	20.5	1.51
Peas	0	0	33.5	.08	.0	0	0	0	12.6	.93
Leaks	0	0	0	0	0.0	0	0	0	5.3	.39
Orchard[1]	3,709.9	12.16	11,008.1	27.84	168.8	12.36	0	0	0	0
Small grain	0	0	847.4	2.14	0	0	0	0	0	0
Hops[2]	–	–	576.6	1.46	–	–	0	0	0	0
Hay	0	0	503.5	1.27	0	0	16.0	1.18	0	0
Seeded	0	0	428.0	1.08	0	0	0	0	0	0
Mint[2]	–	–	367.7	.93	–	–	0	0	0	0
Nursery	0	0	230.3	.58	0	0	7.2	.53	0	0
Squash	0	0	182.2	.46	0	0	37.0	2.72	0	0
Dry beans	0	0	53.9	.14	0	0	0	0	0	0
Carrots	0	0	51.8	.13	0	0	0	0	0	0
Silage	0	0	23.8	.06	0	0	0	0	0	0
Onion	0	0	18.7	.05	0	0	0	0	0	0
Flowers, berries, melon	770.6	2.53	0	0	33.4	2.45	0	0	0	0
Wetland	0	0	0	0	0	0	40.7	2.99	41.1	3.02
Drains, rights of way, infrastructure (for example: houses, golf course)	–	–	1,474.4	3.73	–	–	128.2	9.43	120.9	8.89
Irrigation methods										
Sprinkler	7,599.3	24.90	222.0	56.14	204.0	14.93	196.8	14.48	254.1	18.70
Rill	17,505.0	57.36	94.7	23.94	951.4	69.63	924.2	68.00	884.7	65.10
Na	0	0	33.4	8.45	0	0	188.9	13.90	189.1	13.91
None	5,411.4	17.73	28.0	7.09	211.0	15.44	48.9	3.60	31.3	2.30
Drip	0	0	17.3	4.38	0	0	0	0	0	0

[1] 1992 data values for orchard crop type include grapes.

[2] 1992 data values for asparagus crop type also include hops and mint.

Chemical use—Agricultural chemical use within the Granger Drain and DR2 basins is difficult to determine because the state of Washington has no public record of how much agricultural chemicals are used on specific fields. Estimates of agricultural chemical applications were derived from county-level data compiled by the National Agricultural Statistics Service (NASS) Agricultural Chemical Use Database for the state of Washington (National Agricultural Statistics Service, 2005). After compiling chemical use for each crop type found within the Granger Drain basin, private and university agricultural extension crop consultants in the Yakima River basin reviewed and updated the chemical list and application rates. The data were reviewed one last time by crop and pesticide-use scientists at the Washington State Department of Agriculture. The list of potential pesticides and application rates in the DR2 basin is provided in table 3. It should be noted that this table contains a list of potentially used compounds and likely application rates. Given the limits of the data and this method, there is no way to know whether any particular field was treated or even if the pesticide was applied in the DR2 basin. Confidence can be gained in aggregated, basin-wide application estimates for a given chemical if (1) the crop is common in the basin, (2) the crop is grown by multiple farmers, and (3) the NASS-reported percentage of crop treated is high, for example, terbacil is applied to 70 percent of the mint in Yakima County. An additional degree of confidence was obtained if the chemical has been detected in recent water-quality data from Granger Drain and (or) DR2 basins. With varying degrees of confidence, the most abundantly applied fungicides in the DR2 basin in 2004 were sulfur, fenarimol, triflumizole, and myclobutanil; the most abundantly applied herbicides were EPTC, glyphosate, acetochlor, and metolachlor (all of which are commonly used on corn); and the most abundantly applied insecticides were petroleum distillates, disulfoton, chlorpyrifos and carbaryl.

As was the case with pesticide application information, detailed information about fertilizer applications in Granger Drain and DR2 basins does not exist. University extension publications (Washington State University, 1999) provide the best estimate of application rates for nitrogen, phosphorus, potassium, sulfur, and various micronutrients. Estimates are typically expressed as a range due to variations in natural soil fertility. In this part of the Yakima Valley, however, liquid and solid manure from local dairy operations is commonly used as a primary or supplemental source of nitrogen and phosphorus, particularly on fields planted in corn and the various types of grass hay used for cow feed, for example, matua, triticale, and sudan grass. Lagoon liquid, fresh solid, and composted solid manures vary widely in the ratios of nitrogen to phosphorus and in the forms of nitrogen. When used, manure is typically supplemented with a commercial fertilizer to achieve the desired nitrogen – phosphorus – potassium ratio, as well as any desired micronutrients.

USGS studies in the late 1980s demonstrated that Granger Drain was a source of nutrients and pesticides to the Yakima River (Rinella and others, 1999). Additional work in the late 1990s characterized the intra-annual variability of agricultural contaminants in Granger Drain and noted substantial decreases in suspended sediment and dichlorodiphenyltrichloroethane (DDT) and DDT metabolites compared to samples collected a decade earlier (Ebbert and Embrey, 2002; Ebbert and others, 2003; Fuhrer and others, 2004). Numerous agricultural chemicals and transformation products were identified in water samples collected from Granger Drain and DR2 basins in 1999 and 2000 (Ebbert and Embrey, 2002; Ebbert and others, 2003). During the 1999 and 2000 sampling, concentrations of total phosphorus ranged from 0.15 to 1.1 mg/L, with highest concentrations occurring during the irrigation season and typically associated with high concentrations of suspended sediment. Concentrations of dissolved nitrate ranged between 2 and 4 mg/L during the irrigation season and increased to about 6 mg/L after the irrigation season. Insecticides and herbicides and breakdown products detected in Granger Drain and DR2 basins, in order of detection frequency included: atrazine (100 percent), carbaryl (100 percent), deethylatrazine (100 percent), *p,p'*-DDE (96 percent), trifluralin (88 percent), simazine (83 percent), azinphos-methyl (79 percent), acetochlor (54 percent), terbacil (54 percent), malathion (38 percent), diazinon (25 percent), tebuthiuron (8 percent), cyanazine (4 percent), dieldrin (4 percent), and metolachlor (4 percent) (Ebbert and Embrey, 2002; Ebbert and others, 2003).

Table 3. Summary of potential pesticide use in the DR2 basin, Washington, during calendar years 2003 and 2004.

[–, not available. **Compound detected:** Y, yes; N, no]

Chemical	Type	Estimated area applied (average 2003–2004, acres)	Estimated percentage of basin applied (2003–2004)	Estimated pounds applied (average 2003–2004)	Estimated percentage of pounds applied (2004)	Crops (order reflects application rates based on pounds)	Compound detected 2003–2004
Petroleum distillate	Insecticide	34.03	2.5	667.05	9.7	Grape	–
Fonofos	Insecticide	129.20	9.5	195.56	2.8	Potato, asparagus, corn	Y
Disulfoton	Insecticide	60.31	4.4	180.94	2.6	Asparagus	N
Chlorpyrifos	Insecticide	86.92	6.4	107.80	1.6	Corn, grape, grass	Y
Carbaryl	Insecticide	68.55	5.0	71.79	1.0	Asparagus, grape, squash	Y
cis-Permethrin	Insecticide	129.20	9.5	67.15	1.0	Corn, apple, asparagus	Y
Malathion	Insecticide	34.09	2.5	66.48	1.0	Asparagus, hay, squash	Y
Permethrin	Insecticide	117.99	8.7	65.00	.9	Corn, asparagus, squash	–
Methomyl	Insecticide	56.23	4.1	39.92	.6	Corn, squash	Y
Terbufos	Insecticide	31.52	2.3	35.94	.5	Corn	Y
Esfenvalerate	Insecticide	189.03	13.9	20.69	.3	Corn, pea, squash	–
Carbofuran	Insecticide	9.75	.7	11.95	.2	Corn, squash, hay	Y
Endosulfan	Insecticide	3.70	.3	7.57	.1	Apple, squash	–
Methoxychlor	Insecticide	3.70	.3	4.62	.1	Apple, grape	Y
Bifenthrin	Insecticide	45.73	3.4	4.54	.1	Corn, squash	–
Phorate	Insecticide	5.25	.4	4.10	.1	Corn	Y
Azinphos Methyl	Insecticide	3.70	.3	3.70	.1	Apple, squash	Y
Oxamyl	Insecticide	3.70	.3	3.52	.1	Apple, onions	N
Dimethoate	Insecticide	10.78	.8	3.18	.0	Hay, pea, squash	–
Ethoprophos	Insecticide	1.26	.1	2.88	.0	Potato, bean	Y
Tefluthrin	Insecticide	26.27	1.9	2.63	.0	Corn	–
Diazinon	Insecticide	4.26	.3	2.29	.0	Peas, squash	Y
Methyl parathion	Insecticide	6.69	.5	3.42	.0	Corn, apple, pea, bean, alfalfa	Y
Chlorethoxyfos	Insecticide	5.25	.4	.74	.0	Corn	–
Imidacloprid	Insecticide	22.69	1.7	.46	.0	Grape	–
Cyfluthrin	Insecticide	15.76	1.2	.09	.0	Corn	–
BT	Insecticide	.00	.0	.00	.0	Squash	N
Dieldrin	Insecticide	–	–	–	–	Canceled	Y
Dinoseb	Insecticide	–	–	–	–	Canceled	Y
Glyphosate	Herbicide	390.70	28.7	1,022.66	14.9	Grape, corn, asparagus, rights of way, ditch, canal, pea, squash	–

Table 3. Summary of potential pesticide use in the DR2 basin, Washington, during calendar years 2003 and 2004.—Continued

[–, not available. **Compound detected:** Y, yes; N, no]

Chemical	Type	Estimated area applied (average 2003–2004, acres)	Estimated percentage of basin applied (2003–2004)	Estimated pounds applied (average 2003–2004)	Estimated percentage of pounds applied (2004)	Crops (order reflects application rates based on pounds)	Compound detected 2003–2004
Metam sodium	Herbicide, Fungicide	3.70	0.3	569.73	8.3	Squash	–
Diuron	Herbicide	152.08	11.2	429.48	6.3	Asparagus, grape, alfalfa, rights of way, ditches, canal	Y
EPTC	Herbicide	134.92	9.9	419.58	6.1	Corn, alfalfa	Y
Bromacil	Herbicide	74.71	5.5	398.44	5.8	Rights of way, ditch, canal	Y
2,4 D	Herbicide	261.73	19.3	324.10	4.7	Corn, pasture, asparagus, alfalfa, rights of way, ditch, canal, grass, squash	Y
Acetochlor	Herbicide	131.35	9.7	242.99	3.5	Corn	Y
Metolachlor	Herbicide	152.36	11.2	228.54	3.3	Corn	N
Dicamba	Herbicide	79.53	5.9	201.52	2.9	Rights of way, ditch, canal, asparagus	Y
Alachlor	Herbicide	105.08	7.7	157.62	2.3	Corn	Y
Norflurazon	Herbicide	62.75	4.6	98.70	1.4	Grape, asparagus	N
Atrazine	Herbicide	79.75	5.9	95.65	1.4	Corn, pasture, grass	Y
Oryzalin	Herbicide	34.03	2.5	89.85	1.3	Grape	N
Simazine	Herbicide	58.16	4.3	63.71	.9	Asparagus, grape, apple	Y
Dimethenamid	Herbicide	78.81	5.8	63.05	.9	Corn	-
Trifluralin	Herbicide	52.58	3.9	59.49	.9	Asparagus, pea, squash	Y
Metribuzin	Herbicide	39.41	2.9	51.08	.7	Asparagus, corn, hay	Y
Bentazon	Herbicide	66.71	4.9	50.47	.7	Corn, pea	N
Cyanazine	Herbicide	63.05	4.6	50.44	.7	Corn	N
Paraquat	Herbicide	62.14	4.6	45.12	.7	Grape, asparagus, corn, alfalfa, squash	–
Linuron	Herbicide	36.19	2.7	32.21	.5	Asparagus	N
Bromoxynil	Herbicide	112.23	8.3	31.23	.5	Corn, alfalfa	Y
Oxyfluorfen	Herbicide	45.38	3.3	30.86	.4	Grape	–
DCPA	Herbicide	3.70	0.3	28.88	.4	Squash, onions	Y
Sulfometuron	Herbicide	49.81	3.7	10.89	.2	Rights of way, ditch, canal	–
Hexazinone	Herbicide	14.31	1.1	8.59	.1	Alfalfa	–
Triclopyr	Herbicide	24.90	1.8	7.47	.1	Rights of way, ditch, canal	N
Terbacil	Herbicide	1.79	.1	4.29	.1	Alfalfa	N
Picloram	Herbicide	28.82	2.1	3.75	.1	Grass, pasture, rights of way, ditch, canal	N
Clomazone	Herbicide	3.73	.3	3.15	.0	Squash, pea	–

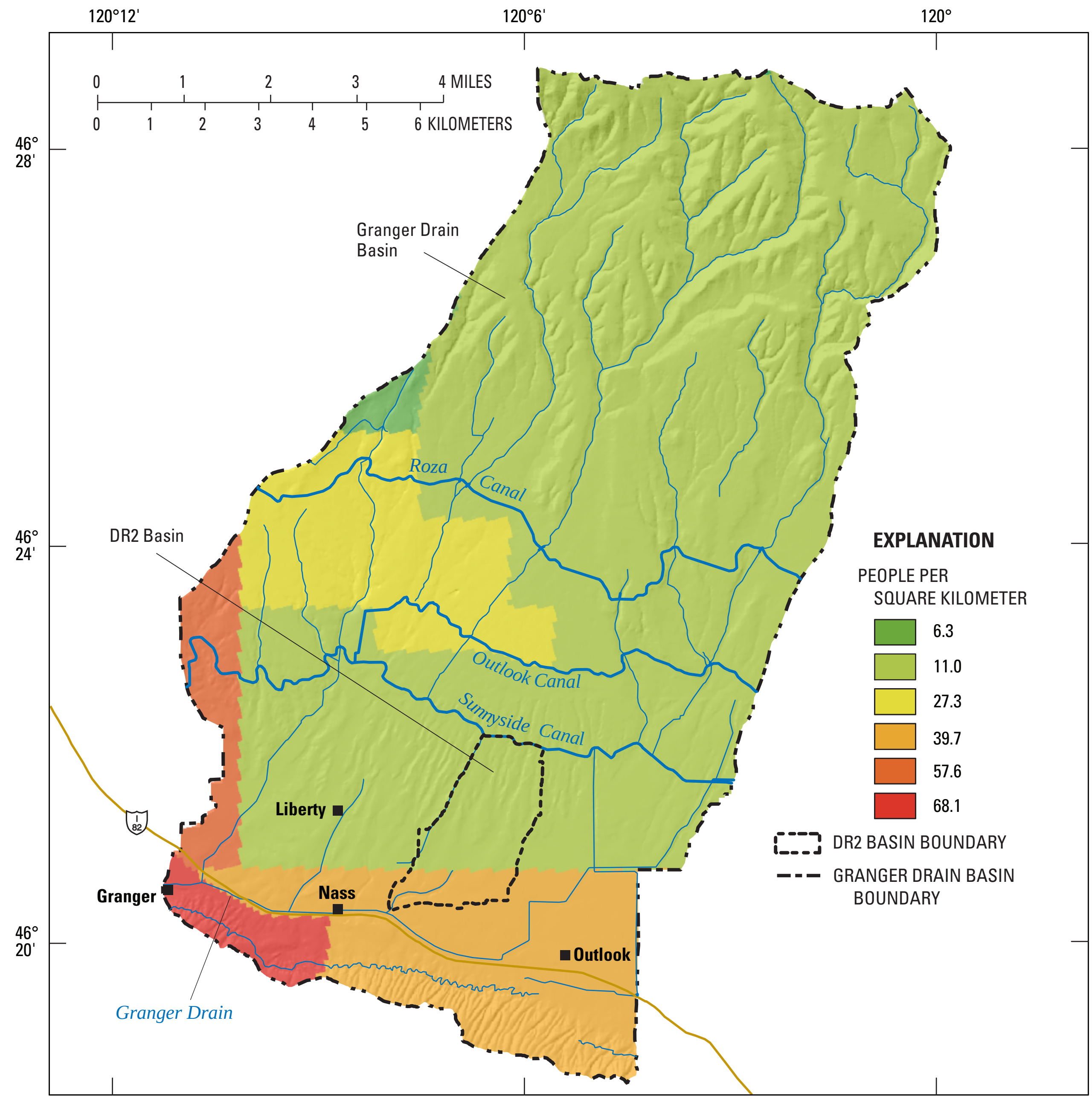
Table 3. Summary of potential pesticide use in the DR2 basin, Washington, during calendar years 2003 and 2004.—Continued

[–, not available. **Compound detected:** Y, yes; N, no]

Chemical	Type	Estimated area applied (average 2003–2004, acres)	Estimated percentage of basin applied (2003–2004)	Estimated pounds applied (average 2003–2004)	Estimated percentage of pounds applied (2004)	Crops (order reflects application rates based on pounds)	Compound detected 2003–2004
S-metolachlo	Herbicide	1.26	0.1	1.89	0.0	Pea	–
Sethoxydim	Herbicide	4.90	.4	1.75	.0	Alfalfa, squash, pea	–
Triallate	Herbicide	.95	.1	.95	.0	Pea	–
Pendimethalin	Herbicide	.95	.1	.62	.0	Pea	Y
MCPA	Herbicide	2.21	.2	.53	.0	Pea	N
Ethephon	Herbicide	3.70	.3	.39	.0	Squash	–
Imazethapyr	Herbicide	2.10	.2	.08	.0	Pea, alfalfa	–
Quizalofop-ethyl	Herbicide	.76	.1	.05	.0	Pea	–
Benfluralin	Herbicide	–	–	–	–	Apples, grapes, alfalfa	Y
Ethalfluralin	Herbicide	–	–	–	–	Squash	Y
Prometon	Herbicide	–	–	–	–	Rights of way	Y
Propyzamide	Herbicide	–	–	–	–	Alfalfa, right of ways	Y
Tebuthiuron	Herbicide	–	–	–	–	Non-agricultural soil sterilizer	Y
Sulfur	Fungicide	52.17	3.8	346.12	5.0	Grape, pea, squash	–
Mancozeb	Fungicide	3.70	.3	34.49	.5	Squash	–
Copper Sulfate	Fungicide	28.42	2.1	30.80	.4	Rights of way, ditches, canal	–
Chlorothalonil	Fungicide	3.70	.3	29.03	.4	Squash	N
Fenarimol	Fungicide	79.41	5.8	4.82	.1	Grape	–
Triflumizole	Fungicide	22.69	1.7	4.31	.1	Grape	–
Myclobutanil	Fungicide	18.15	1.3	3.81	.1	Grape	–
Benomyl	Fungicide	3.70	.3	2.54	.0	Squash	–
Metalaxyl	Fungicide	3.70	.3	1.71	.0	Squash	–
Triadimefon	Fungicide	3.70	.3	.43	.0	Squash	–
2,6-Diethylaniline	–	–	–	–	–	Alachlor breakdown product	Y
Deethylatrazine	–	–	–	–	–	Atrazine breakdown product	Y
Alpha-HCH	Insecticide	–	–	–	–	Lindane breakdown product	Y

Urban

Population in the Granger Drain basin is concentrated in the southern and southwestern areas with approximately 68 people per square kilometer (fig. 6). The DR2 basin has a population density ranging from 11 to approximately 40 people per square kilometer (fig. 6). The southeastern part of the basin has a population density of approximately 40 people per square kilometer, and the remaining central and northern parts of the basins contain less than 30 people per square kilometer. In the town of Granger, the only urbanized area in the Granger Drain basin, population increased by nearly 500 people in the past decade and reached 2,500 people in 2000 (fig. 7). The rest of the population resides in rural areas.



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Shaded-relief base from 1:100,000-scale Digital Elevation Model based on the North American Datum of 1983.

Figure 6. Population density in the Granger Drain basin, Washington (U.S. Geological Survey, 2005).

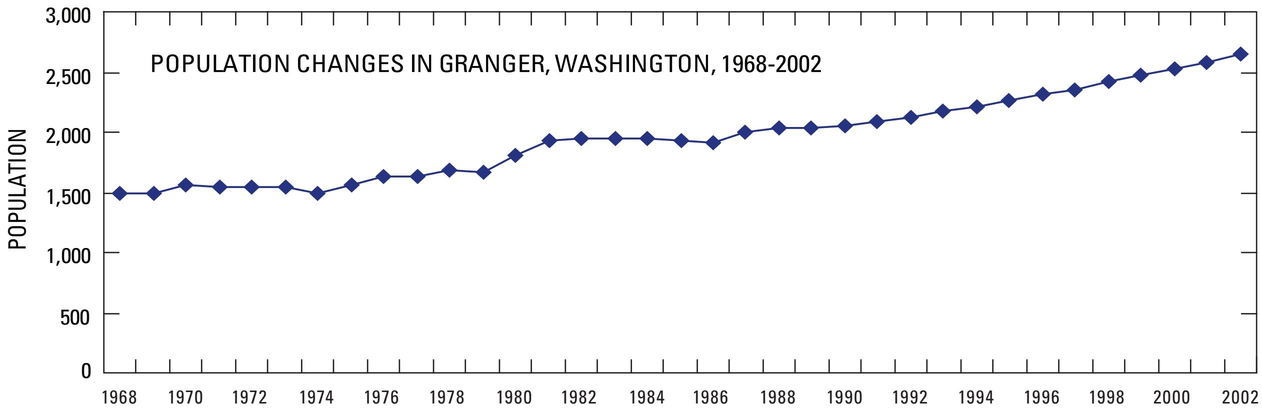


Figure 7. Population change from 1968 to 2002 in Granger, Washington (Washington State Office of Financial Management, 2005).

Climate

The climate of the Granger Drain basin is characterized by hot, dry summers and cold winters with limited snow and rain. The nearest long-term weather station is located 10.75 mi east of the city of Granger at the Sunnyside airport. This site is part of the Western Regional Climate Center network of weather stations that are funded and administered by the United States National Oceanic and Atmospheric Administration (NOAA). Data for this station is available online at http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wasunn (accessed December 7, 2005) (fig. 8). For the period of record, 1948-2004, the average minimum temperature was 39.4°F and the average maximum temperature was 65.5°F (fig. 8). The warmest months are July and August with average monthly high temperatures of 89.7 and 88.5°F, respectively, and average monthly lows of 55.8 and 54.2°F, respectively. The coldest months are December and January with average monthly high temperatures of 40.6 and 39.6°F, respectively, and average monthly lows of 25.9 and 23.9°F, respectively. Mean temperatures for most months during 2004 were slightly higher than temperatures during the past 56 years.

For 1948–2004, the average annual precipitation was 7.27 in. (fig. 9*A*). More than 50 percent of precipitation occurs between November and March (fig. 9*B*). Snowfall is common in December and January and averaged 9.85 in. per year over the period of record. July and August usually are the driest months, and the area typically receives less than 0.25 in. of rain per month during those months. It is not unusual for several weeks to pass in the summer without a trace of precipitation. The driest year during the 56-year period was in 1999 when a scant 1.33 in. of precipitation fell at the Sunnyside weather station. The wettest year was in 1995 when 12.92 in. of precipitation were recorded. In 2004, June and August were unusually wet and received nearly 1.5 in. each month. January, February, and October were slightly wetter than normal, while November was atypically dry. Total precipitation for 2004 was 8.7 in., nearly 1.5 in. greater than normal.

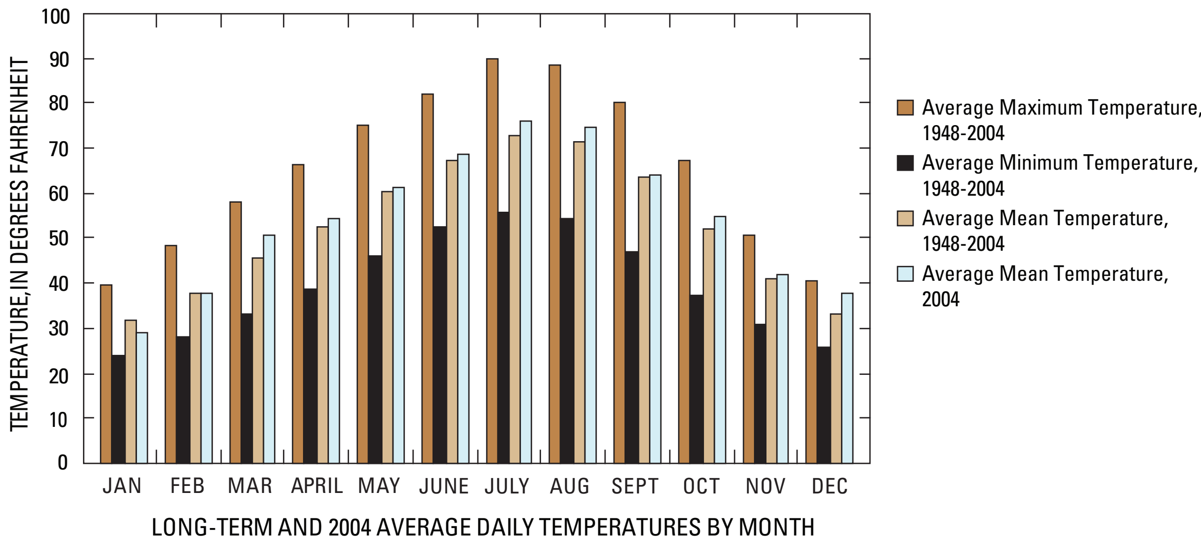


Figure 8. Long-term and 2004 average daily temperatures, by month, in the Granger Drain basin study area, Washington.

Hydrology

Prior to agricultural development in 1893, Granger Drain basin was covered with “sagebrush and smaller desert shrubs” like other low-lying areas of the lower Yakima River Valley (Waring, 1913). Historical documents provide no indication of flowing or standing water in the Granger area. Mapped ephemeral streams in the Granger Drain basin terminate near what is now the Roza canal. Referencing soil maps published in 1901, Waring (1913) reported that “alkali was present in objectionable amounts at the surface in only a few places.” Depth to water near Sunnyside in the 1890s exceeded 40 ft. With the construction of Sunnyside Canal from 1890 to 1907 and the resultant expanding agricultural development, there was a rapid rise in the water table by 1906. This, compounded by an underdeveloped drain system, had rendered large tracts of land in the lower elevations of Granger Drain basin unsuitable for agriculture by turning the area into seasonal wetlands or concentrating alkali in the soils (United States Reclamation Service, 1912). To prevent further loss of agricultural land and in an attempt to return damaged areas to production, the Bureau of Reclamation constructed Granger Drain and connected, deepened, and widened major tributary drains, including DR2. Further agricultural development was made possible by the construction of Roza Canal from 1941 to 1950. The modern surface-water and shallow ground-water systems are entirely a result of irrigated agriculture.

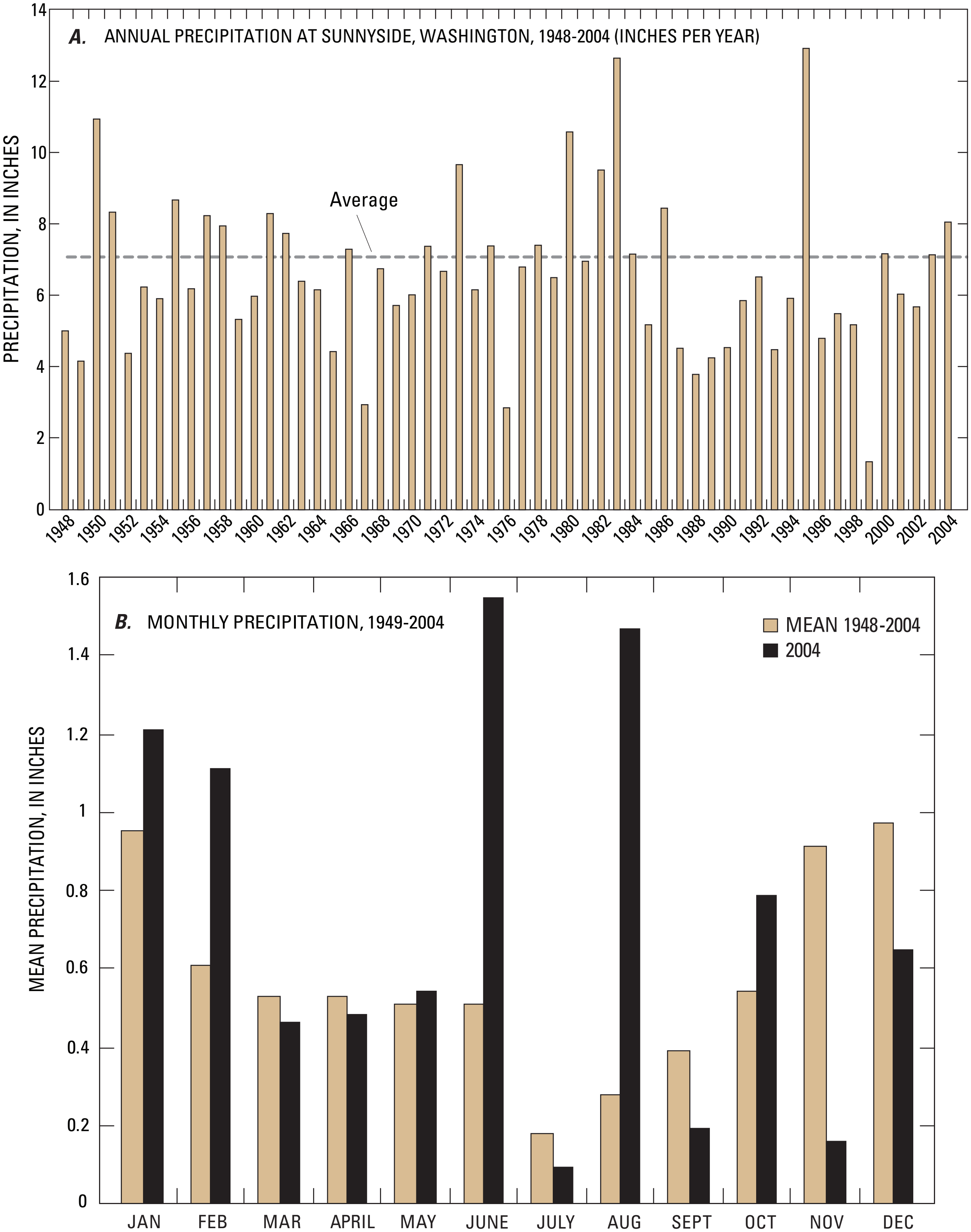
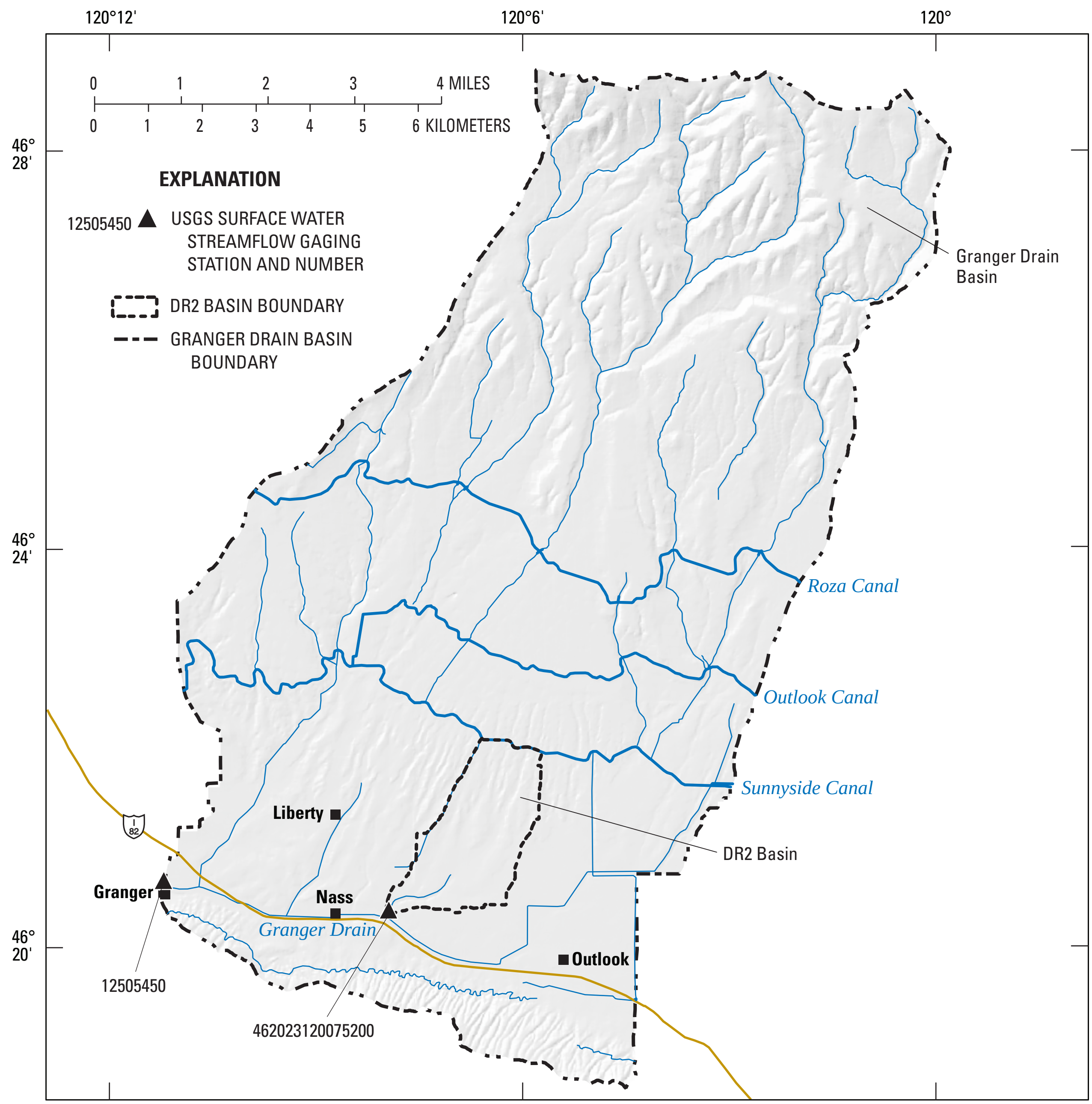


Figure 9. Annual precipitation from 1948–2004 measured adjacent to the Granger Drain basin study area and mean monthly precipitation from 1948–2004 and monthly precipitation for 2004 measured adjacent to the Granger Drain basin study area in Sunnyside, Washington. Data collected in the town of Sunnyside, Wash., located along the southeastern boundary of the Granger Drain basin watershed.

Surface Water

Canals and delivery laterals operated by the Roza Irrigation District (RID) and Sunnyside Valley Irrigation District (SVID) as part of the Bureau of Reclamation Yakima Project serve irrigated land in the Granger Drain and DR2 basins (fig. 10). In a typical year, irrigation water is available to the farmers around March 15 and becomes unavailable around October 15. Unusually drier or wetter weather may affect the start and end dates of the irrigation season. Jointly, the Roza and Sunnyside Canals convey between 2,000 and 2,500 ft^3/s during the height of the irrigation season. An estimated 20 to 25 percent of this water is delivered to farmers



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Shaded-relief base from 1:100,000-scale Digital Elevation Model based on the North American Datum of 1983.

Figure 10. Locations of streams, canals, and gaging stations in the Granger Drain basin study area, Washington.

in Granger Drain basin. On average, each farmer takes delivery of 3–4 acre feet per acre of cultivated land per growing season. A network estimated at 13.8 mi of surface drains and 26.9 mi of subsurface drains conveys used irrigation water and end-of-system "spill" resulting from normal irrigation water delivery operations to Granger Drain and back to the Yakima River (Morace and others, 1999; Bohn, 2001).

The main stem of Granger Drain runs parallel to Interstate 82 and Yakima Valley Highway. It begins one-quarter mile west of the community of Outlook and extends westward to the city of Granger. In Granger, the drain turns southwest, passes through the town, and discharges into the Yakima River. Five significant drains enter Granger Drain from the north. Among these is the DR2 drain that joins Granger Drain approximately halfway between the communities of Granger and Outlook. Granger Drain and the lower reaches of these five tributary drains intercept the water table and, as a result, flow year-round.

Discharge data for the Granger Drain is collected at a stream gaging station located near the western city limits of Granger. For the period of record (2000–03), total annual discharge from Granger Drain ranged from 9,310 to 14,700 ft^3, with a mean of 12,300 ft^3 (fig. 11). Flow in Granger Drain is higher during the summer irrigation season and lower during the winter non-irrigation season (fig. 12). During the irrigation season, monthly average flows in the Granger Drain ranged between 34 and 52 ft^3/s. Streamflows during the non-irrigation season dropped to monthly average flows between 18.2 and 20.7 ft^3/s. Daily mean streamflow exceeded 64 ft^3/s only 5 percent of the time and was greater than 16 ft^3/s at least 95 percent of the time (table 4).

Discharge data for the DR2 Drain were collected from a gaging station located about 400 feet upstream from the confluence with Granger Drain. Daily mean flows within the DR2 Drain ranged between 2.6 to 10 ft^3/s with a mean of 5 ft^3/s (fig. 12**).** As in the Granger Drain, flows within the DR2 Drain were higher during the summer irrigation and lower during the winter non-irrigation season. Monthly average flows during the irrigation season ranged from 4.3 to 7.6 ft^3/s, while non-irrigation season flows ranged between 2.7 and 4 ft^3/s. Daily mean streamflow exceeded 8 ft^3/s only 5 percent of the time and was greater than 2.7 ft^3/s at least 95 percent of the time (table 4**).**

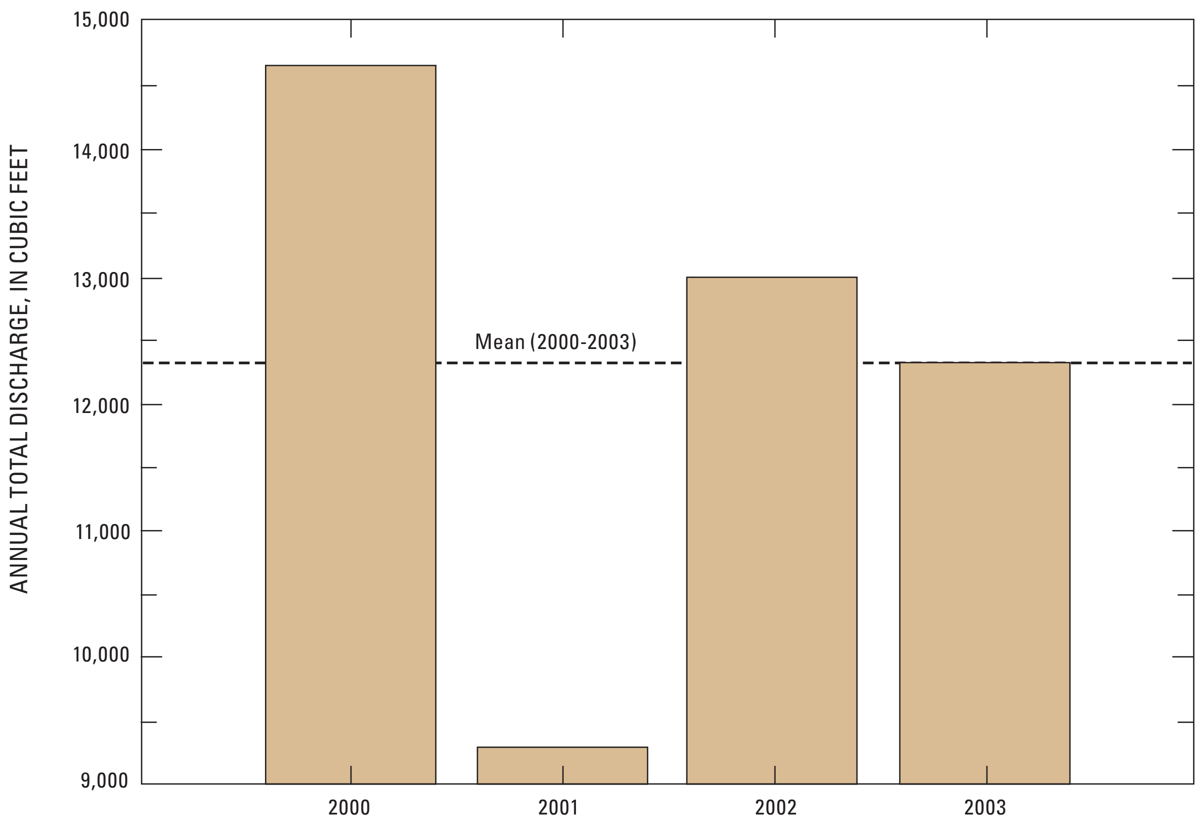


Figure 11. Annual total discharge measured during 2000 to 2003 at the Granger Drain (12505450) gaging station, Washington.

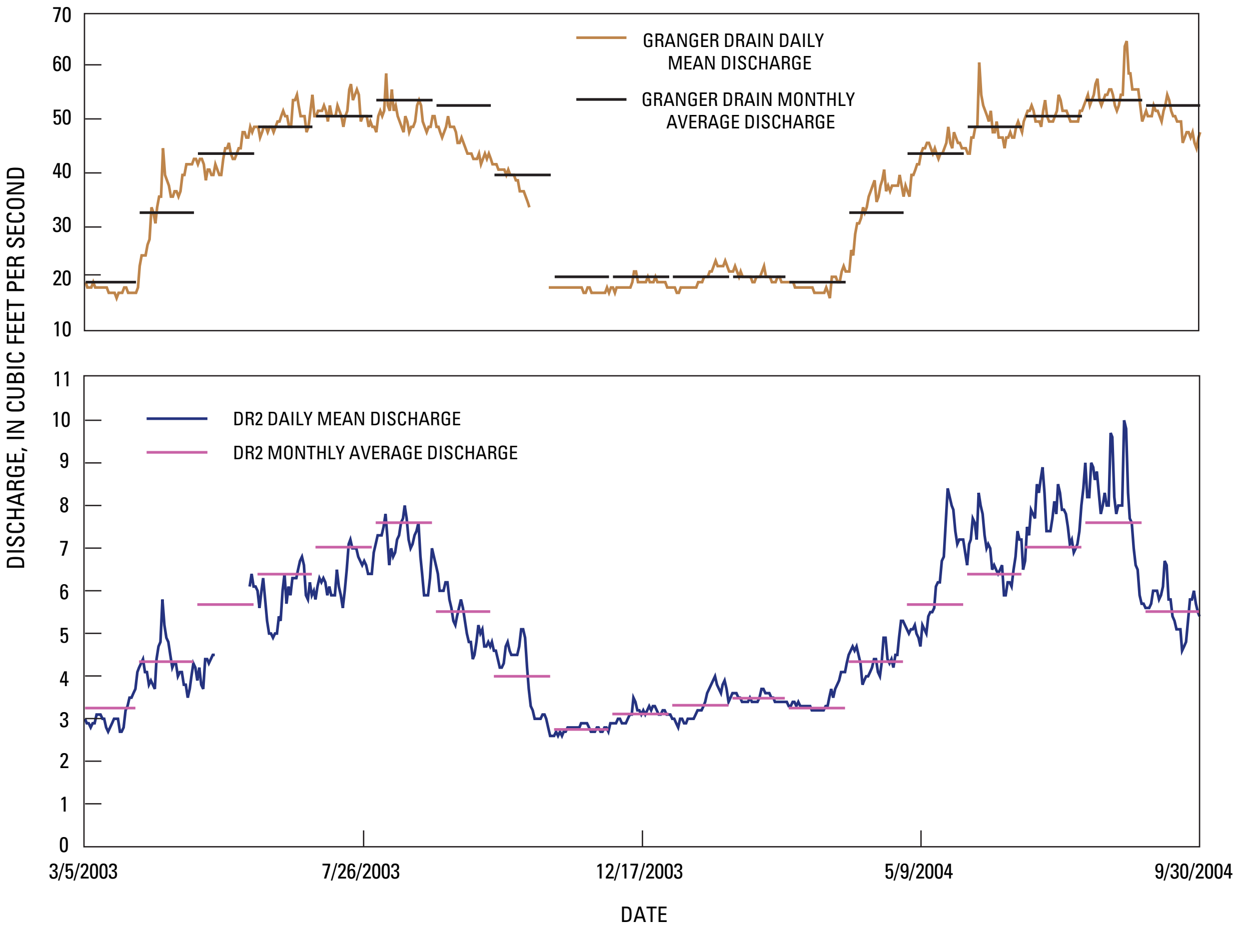


Figure 12. Daily mean and monthly average discharge during 2003 to 2004 for the Granger Drain (12505450) and DR2 basin (462023120075200) gaging stations, Washington.

Table 4. Summary of daily mean streamflow characteristics at the Granger Drain and DR2 gaging stations, Washington, during water years 2003–2004.

Gaging station name and No.	Percentage of time that daily mean streamflow was greater than or equal to value shown, in cubic feet per second							
	95	90	75	50	25	10	5	1
Granger Drain (12505450)	16	18	21	34	51	60	64	72
DR2 (462023120075200)	2.7	2.9	3.35	4.8	6.4	7.6	8	9

Ground Water

The ground-water system in the Granger Drain basin consists of a surficial unconfined to semi-confined aquifer composed of the unconsolidated surficial deposits described in the Geology and Stratigraphy section of this report. This aquifer is bounded on the bottom, north, and south by basalts of the Columbia River Basalt Group. Basalt aquifers underlying the surficial aquifer are believed to be isolated from the surficial aquifer and stream systems. A dramatic drop in head between deep wells in surficial deposits and the basalt reinforce this conceptual model. The remaining discussion focuses on the surficial aquifer.

Recharge to the surficial aquifer is largely the result of applied irrigation water, with a much smaller amount resulting from winter precipitation (Vaccaro and Olsen 2007), Ground-water movement is generally from the Rattlesnake Hills in the north toward the Yakima River in the south based on water levels observed in wells within and adjacent to the basin (fig. 13). Flow to the Yakima River is blocked by Snipes Mountain. Deep water in the surficial aquifer probably circumvents the obstruction to the east near Sunnyside and to the west near Granger based on local geology (fig. 14).

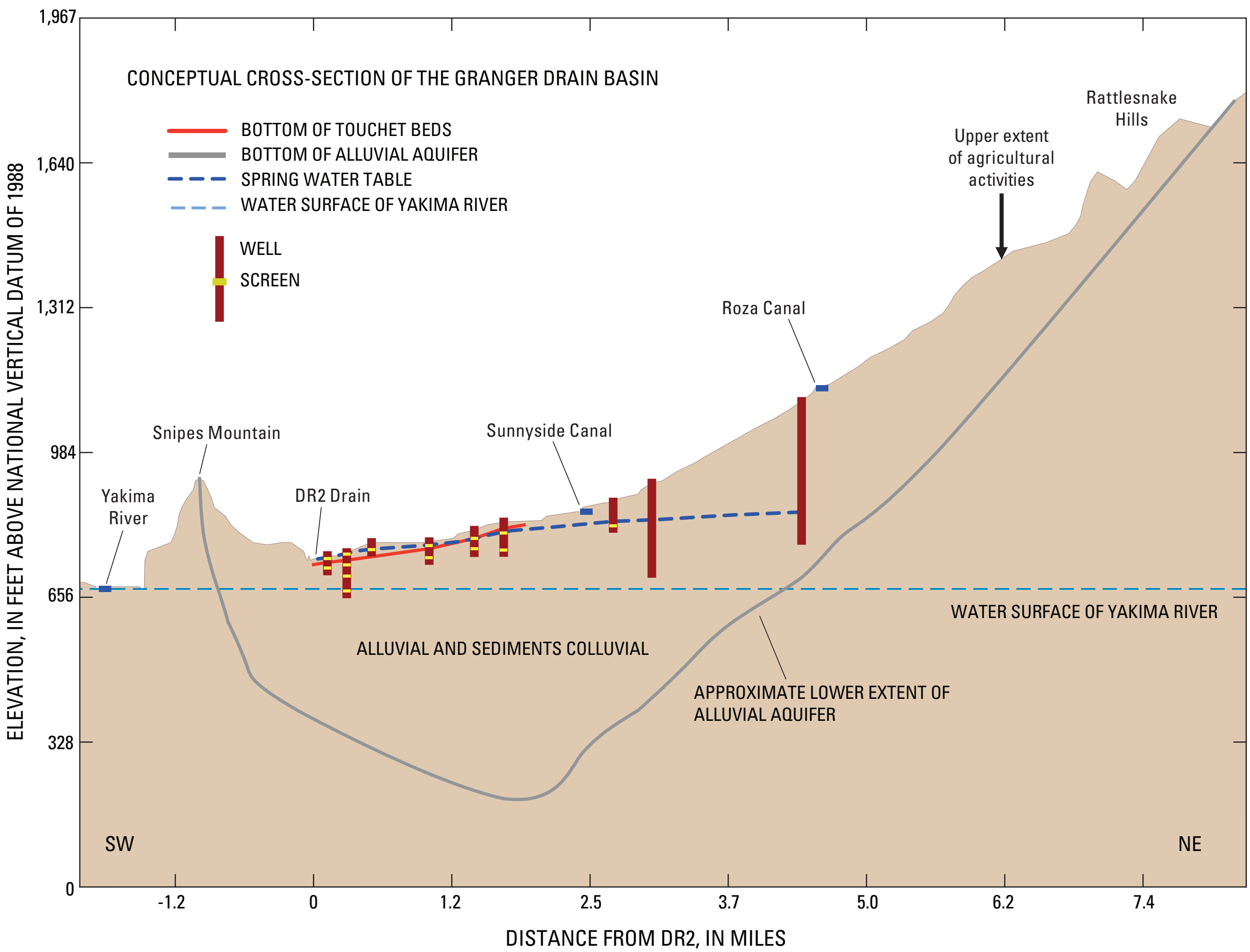
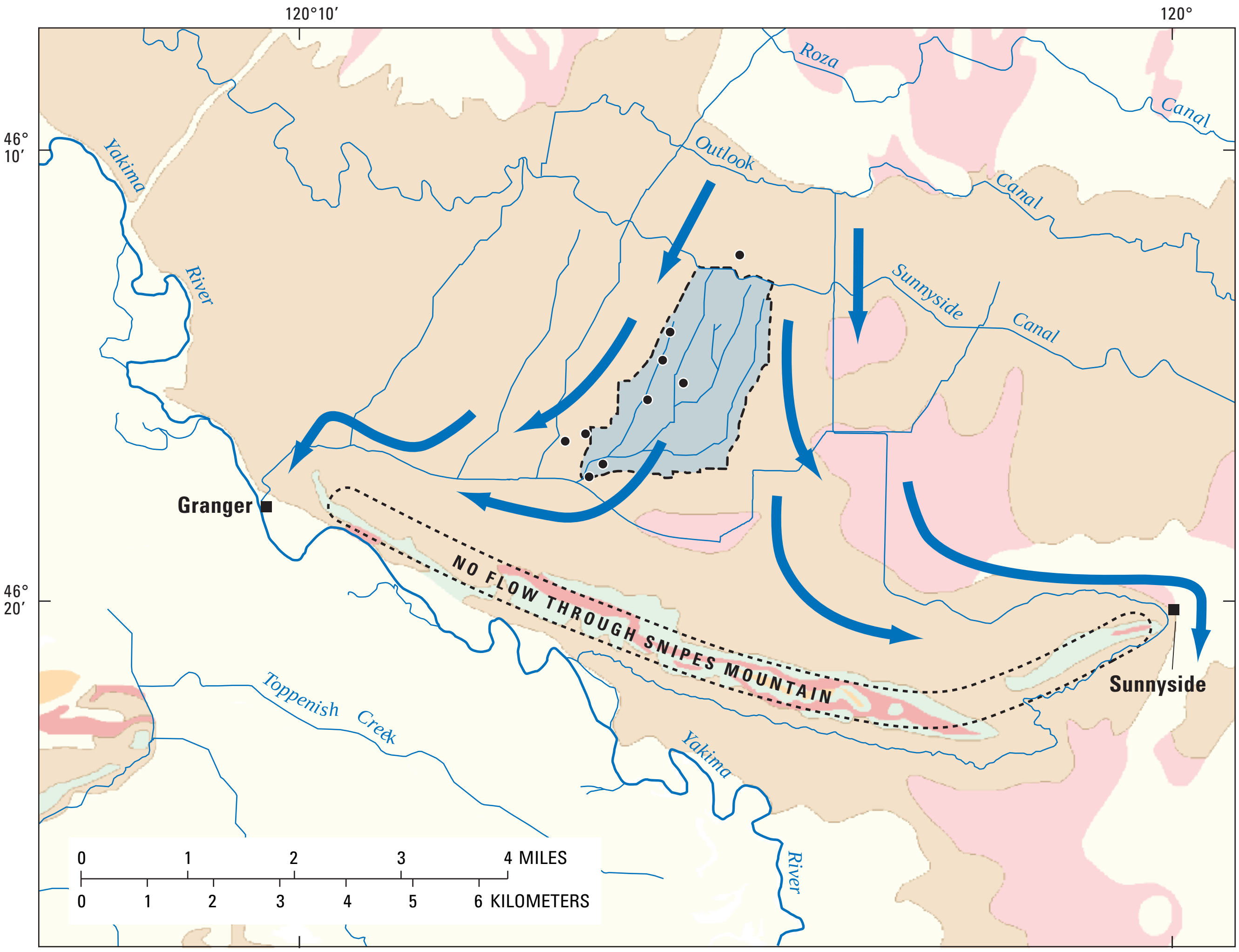


Figure 13. Conceptual cross section of the Granger Drain basin, Washington.



Albers projection, False_Easting: 0.00000000, False_Northing: 0.00000000, Central_Meridian: -119.00000000,
Standard_Parallel_1: 29.50000000, Standard_Parallel_2: 45.50000000, Latitude_Of_Origin: 23.00000000, Linear Unit: Meter.
Shaded-relief base from 1:100,000-scale Digital Elevation Model based on the North American Datum of 1983.

EXPLANATION

DR2 DRAINAGE BASIN

SURFICIAL GEOLOGY

- Saddle Mountain Basalt, Pamona member
- Saddle Mountain Basalt, Elephant Mountain member
- Ellensberg Formation, sedimentary interbeds
- Alluvium
- Touchet beds
- Loess

GENERALIZED DIRECTION OF GROUND-WATER FLOW

U.S. GEOLOGICAL SURVEY MONITORING WELLS

Figure 14. Conceptualized ground-water flow system for the Granger Drain basin, Washington.

Since the onset of irrigation in the 1890s, the water table in the Granger Drain basin has risen and in the lower elevations is within inches of the land surface. The magnitude of the rise remains uncertain, but is likely at least 40 ft based on water levels recorded near Sunnyside during the early period of development (Waring, 1913). An extensive artificial drainage network developed to control the water table and prevent alkali accumulation and water logged soils. The configuration of the water table is now strongly controlled by the elevations of tile drains and the streambed elevations along Granger Drain and major tributaries.

Within the DR2 subbasin, excess irrigation water that is not taken up by evapotranspiration infiltrates downward through a 5- to 25-ft thick unsaturated zone in the northern part of the DR2 subbasin. Once the water reaches the water table it moves laterally from north to south in a direction roughly parallel to the surface-water-drainage network. Upward vertical hydraulic gradients in the lower parts of the DR2 subbasin provide ground-water seepage that supply the DR2 and Granger Drains with base flow. The presence of Snipes Mountain to the south probably forces deeper ground-water moving from north to south to upwell near Granger Drain.

Superimposed on the north-south oriented system just described is a series of short, local, east-west trending flow systems. These originate along the crests and flanks of the north-south trending ridges that dissect the northern part of the DR2 basin. Ground water moves obliquely to the south down the sides of these ridges until it encounters the regional water table or an agricultural drain.

Floods and Droughts

In the Granger Drain basin, local climate, including extremes, has relatively little effect on the hydrology and agricultural activities in the area. The greatest effect on the local hydrology and farming community comes from the accumulation of snow pack in the Cascade Mountains. Extended deficiencies of snow pack result in water shortages and crop failures in the Granger Drain basin. A significant drought in 1977 prompted many farmers to reevaluate the types of crops being grown and the methods being used for irrigation (Fuhrer and others, 2004). More recently, 1992–94, 2001, and 2004 were notable for significant shortages of irrigation water.

Summary

This report describes the environmental setting of the Granger Drain and DR2 basin watersheds in the context of how agricultural practices, which include agricultural chemical applications and irrigation practices, interface with natural settings and hydrologic processes. These watersheds are part of the National Water-Quality Assessment Program (NAWQA) Agricultural Chemicals: Source, Transport, and Fate Study designed to understand the human and natural factors that control water quality within agricultural settings nationwide. The Granger Drain and DR2 basins are located within the Yakima River basin in south central Washington, and are dominated by a mixture of irrigated agriculture, pasture, and animal feeding operations. Granger Drain basin covers approximately 62 square miles and the DR2 basin, nested within the Granger Drain basin, has a drainage area of 2.1 square miles. Temperatures range from an average monthly low of 23.9 in January to an average monthly high of 88.5 in August.

Based on field mapping conducted by USGS in 2003 and 2004, the major crops within the Granger Drain basin consist of alfalfa and other hays, asparagus, corn, hops, mint, pasture, juice grapes, wine grapes, and apple, pear, and cherry orchards. The DR2 basin contains a less diverse mixture of crops with most agricultural land dedicated to the production of corn, juice grapes, and pasture. Numerous dairies varying in size from a few hundred dairy cows to more than a thousand dairy cows operate in the Granger Drain and DR2 basins. The dairy industry substantially influences the crops grown in the basin as dairies require enormous amounts of corn and alfalfa for feed.

Estimates of agricultural chemical applications indicate, with varying degrees of confidence, that the most abundantly applied fungicides in the DR2 basin in 2004 were sulfur, fenarimol, triflumizole, and myclobutanil; the most abundantly applied herbicides were EPTC, glyphosate, acetochlor, and metolachlor (all of which are commonly used on corn); and the most abundantly applied insecticides were petroleum distillates, disulfoton, chlorpyrifos, and carbaryl.

Because the region lies in the rain shadow east of the Cascade Mountains, it receives about 7 inches of precipitation per year. Agriculture within these basins and surrounding areas relies on extensive irrigation provided by canals located within these basins. Two large canals cross the Granger Drain basin from west to east: the Roza Canal to the north and

the Sunnyside Canal to the south. Water delivered to farms in the Granger Drain basin eventually drains to Granger Drain, which enters the Yakima River. For the period of record (2000–2003), total annual discharge from Granger Drain ranged from 9,310 to 14,700 cubic feet, with a mean of 12,300 cubic feet. Flow in Granger Drain is higher during the summer irrigation season and lower during the winter non-irrigation season. During the irrigation season, average monthly flows in the Granger Drain ranged between 34 and 52 cubic feet per second. Streamflows during the non-irrigation season dropped to monthly averages between 18.2 and 20.7 cubic feet per second.

The ground-water system in the Granger Drain basin consists of a surficial unconfined to semi-confined aquifer composed of the unconsolidated surficial deposits. This aquifer is bounded on the bottom, north, and south by basalts of the Columbia River Basalt Group. Basalt aquifers underlying the surficial aquifer are believed to be isolated from the surficial aquifer and stream systems. Recharge to the surficial aquifer is largely the result of applied irrigation water, with a much smaller amount resulting from winter precipitation.

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