DRAFT

INITIAL WATERSHED ASSESSMENT
WATER RESOURCES INVENTORY AREA 13
DESCHUTES RIVER WATERSHED

Open-File Technical Report 95-10

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1 Introduction

1.1 Background

Population growth in the past several decades has imposed significant pressure upon Washington State's limited water resources. Ecology is charged with protecting and managing these resources for the greatest public benefit. Currently, Ecology receives almost 2,000 applications per year for new water-use permits. Almost two thirds of these applications are for ground-water withdrawals. Historically, Ecology has evaluated most water-right applications on an individual basis. This case-by-case approach requires a substantial amount of time and often leads to duplication of effort. In addition, this process may result in inconsistent and scientifically indefensible conclusions because the evaluation does not consider a regional perspective on the natural hydrogeologic system.

It has become apparent to resource planners that water rights decisions can be most appropriately evaluated in the context of a drainage-basin-wide analysis of a hydrologic system. The drainage-basin evaluation or watershed assessment involves the development of a comprehensive conceptual and quantitative hydrologic understanding which considers the interaction of climate, surface water, and ground water. The watershed assessment also needs to consider existing allocations, withdrawals, water quality, and riparian values such as fisheries habitat.

Initial watershed assessments are currently being performed for 16 of the State's 62 Water Resource Inventory Areas (WRIA's). The assessments are considered "initial" because they are based on readily available information and do not include collection or analysis of new or unpublished data. This initial assessment attempts to address the "health" of the Deschutes Basin, largely by focussing on critical indicators which reflect the effects of withdrawals on water availability. The health of the system is also assessed from the conditions of surface-water quality and fish stocks.

The intent of this initial assessment is to provide improved hydrologic understanding of the Deschutes WRIA in order to assist Ecology in making water-right permitting decisions from a basin-scale perspective. The goal will likely be achieved with varied success, depending on the quality of available data. Ecology will reach conclusions regarding the potential availability of water within the WRIA and will develop a long-term approach to address water allocations.

1.2 Major Findings

Water Rights / Water Use:

- Water right allocations in the Deschutes WRIA, reported as maximum allowable annual withdrawals (Qa's), are on the order of 59,270 acre-feet per year. Ground-water permits and certificates comprise 87% of these allocations.

- Ecology currently has applications for 41 ground-water and 4 surface-water rights. The ground-water applications are requesting a total of 18,080 gallons per minute (40.26 cfs) maximum instantaneous withdrawal (Qi). The surface-water applications are requesting 0.07 cfs of stream diversions as Qi. *(Note: Requested Qi's are typically for a greater amount than* *issued by Ecology. Annual quantities (Qa's) are not indicated on applications and are only assigned once Ecology has completed its investigation of the application.)*

- Ground-water permits and certificates are primarily allocated for municipal use (41% of Qa) and domestic multiple use (31% of Qa). Commercial & industrial use comprises 16% of Qa and irrigation comprises 8%. Ground-water applications are requested primarily for municipal use (45% of Qi), domestic multiple use (29% of Qi) and for irrigation (24% of Qi).

- Surface-water permits and certificates are primarily allocated for irrigation (90% of Qa). This statistic does not consider the quantity of water required for maintaining instream flow requirements. Surface-water applications are requested for domestic single use (71% of Qi) and for wildlife propagation (29% of Qi).

- Water right claims in the WRIA are on the order of 9,540 acre-feet per year. Ground-water claims comprise 86% of the total annual volume. Claims are registered largely for irrigation, and to a lesser degree domestic and stock watering purposes.

- Ground-water withdrawals were estimated and compared to ground-water allocations (permits and certificates). Estimated 1988 ground-water withdrawals (22,460 ac-ft/yr) were about half the 1988 ground-water allocation. Similarly, estimated 1991 municipal withdrawals (8,310 ac-ft/yr) were about half of the municipal ground-water allocations. Sufficient data were not available to estimate surface-water withdrawals.

Surface-Water Hydrology:

- Minimum instream flow (MISF) requirements were enacted by the State for portions of the Deschutes River in 1980. The requirements were based on statistical and habitat considerations. Closures to further diversions were also set for portions of the Deschutes River and other streams within the watershed.

- The minimum instream flow requirements are in effect on the Deschutes River between November 1st and April 14th. On any day within this period, instream flows are not met more often than once in every ten years. There is no obvious indication that the standard is being met any less often at present than in the past, allowing for natural climatic variability.

- Analysis of total annual streamflow at three gages within the WRIA showed no discernable trends when normalized to precipitation. Normalized streamflow trends could reflect changes due to land-use activities or water withdrawals. No net effect would be discerned if activities causing decreased runoff were balanced by other activities causing increased runoff.

- The record of historical streamflows for the Deschutes River near Tumwater is somewhat incomplete; a lack of gaging data for the period 1964 through 1990 makes it difficult to evaluate trends. Although minimum annual baseflows appear to be stable, a single extreme-low event in 1992 (the last year of record) cannot be fully attributed to natural variability without assessing additional post-1990 data.

Ground-Water Hydrology:

- Major aquifers occur within alluvial deposits (Qal) along major rivers and streams, and in other unconsolidated sediments in the northern part of the WRIA. These other major aquifers are found in the Qva, Qc, and TQu deposits; and are typically separated by low permeability aquitards.

- Shallow aquifers (Qal, Qvr, and Qva) are directly connected to adjacent streams. Deeper aquifers (Qc & TQu) tend to be connected on a more regional scale to the major drainages (e.g. Deschutes and Nisqually Rivers) and to Puget Sound. Additional ground-water development from hydraulically connected aquifers will reduce streamflows and/or discharge to Puget Sound.

- An analysis of water-budget components estimated for the Deschutes WRIA suggests that almost 50% of precipitation goes to ground-water recharge. In addition, only about 6% of recharge goes to ground-water development. The remaining recharge exits the WRIA as ground-water subflow or discharges to springs, streams, and Puget Sound. Water budgets cannot be rigorously used to assess resource availability because they do not allow prediction of how the system will adjust to additional withdrawals.

- Water-level trends were assessed to determine if long-term declines (critical indicators of ground-water over-extraction) were evident. There was no indication of over-extraction, however, data are quite limited for the WRIA. Only four records longer than 10 years were available, none of which showed significant decline.

- Ground-water quality in the Deschutes WRIA is generally good. However, localized, elevated concentrations of anthropogenic (human caused) or naturally occurring ground-water constituents may affect ground-water development in some areas. Seawater intrusion is noted along the WRIA's peninsular coastlines; organic chemicals have locally degraded ground-water quality in the lower Deschutes River valley, a portion of downtown Lacey, northwest of the Olympia airport, and south of Pattison Lake; and naturally occurring high levels of iron and manganese are noted in the deeper (Qc and TQu) aquifers.

Stream-Water Quality and Fisheries:

- Urbanization in the lower reaches of the WRIA is contributing to deterioration of water quality in some reaches. Streams flowing through urban areas generally showed the greatest degree of contamination, particularly in fecal-coliform levels. Temperature may be a concern through mid-reaches of the Deschutes River, where water velocities slow and agricultural land uses have removed shading streamside vegetation.

- Presently, fish stocks are generally considered healthy, however urbanization is contributing to the degradation of habitat for salmonids, particularly coho and chinook. Habitat degradation, accompanied by any future reductions in summer baseflows, may lead to declines in fish stocks in the future.

1.3 Recommendations

Monitoring & Data Collection:

- Establish a network of observation wells for long-term monitoring of regional water-level trends within all of the principal aquifer systems. The network established by the USGS as part of the GWMA studies would provide a framework for monitoring. Thurston County is currently coordinating a northern County monitoring effort that would include the USGS wells and other wells identified through wellhead protection studies. Static water levels for aquifers serving high-production wells should also be monitored on a regular basis. Data collection efforts should strive for monthly measurements.

- Continue to monitor flows at existing stream gages within the WRIA. Emphasis should be placed on amassing long-term, uninterrupted records. New gages should be established on some of the smaller streams which discharge to Puget Sound.

- Seepage studies should be conducted along the Deschutes River to determine gaining and losing reaches. Additionally, flows in the Deschutes River should be measured near the mouth at varying river stages to establish a relationship between discharge at the gage near Tumwater and discharge from the entire Deschutes drainage.

- Monthly water-use data should be collected for all major ground-water and surface-water sources to provide better definition of actual water withdrawals from the system. All new water sources should be fitted with flow-measuring devices that record cumulative statistics. Efforts should be made to retrofit flow meters on all existing wells with capacities greater than 50 gpm.

- Class A temperature violations were recorded in the mainstem Deschutes River and on one tributary in the middle reaches of the watershed. However, tributary data referenced for this report consisted of only two readings and may not reflect prevailing conditions. Because of previous violations, additional information on water temperatures in this portion of the basin should be collected. If this information is unavailable from other sources, additional temperature monitoring is recommended in middle reaches of the watershed during low flow periods.

- Fecal coliform levels violated state standards at several locations in the middle and lower reaches of the basin. However, information on the sources of this contamination was not available for this report. Additional information on point sources of fecal coliform, such as leaking sewer lines, sewer outfalls and agricultural operations, should be collected.

- Deschutes basin dissolved oxygen (DO) readings referenced for this report were not collected during low flow periods when levels are usually at their most critical stage. If this data is not available from other sources, additional readings should be taken during low flow periods to determine the extent of DO violations.

- In general, little information on water quality in Swift, McLane, Woodward and Woodland Creeks was identified for this report. Additional water quality data is needed to assess conditions in these streams.

- The south Puget Sound summer/fall chinook stock spawns throughout the Deschutes River and tributaries during the summer low flow period. Although the stock is considered healthy, present chinook use of some drainages in the WRIA is minimal due to low flows during migration and spawning periods. Instream flow needs for chinook should be considered in determining future water withdrawals.

- Coho stocks spawning in the WRIA, although presently healthy, are being affected by widespread habitat destruction in the basin. Coho populations should be monitored and the location and condition of habitat determined. Future coho production will depend on successful maintenance of natural habitat-forming processes and restoration of habitat affected by past land use.

- Little information on Henderson Inlet chum (inhabiting Woodward and Woodland Creeks) or Eld Inlet winter steelhead (inhabiting McLane Creek) was identified in preparation of this report. Additional information on the status of these stocks should be collected.

Additional Analysis:

- The surface-water analyses performed in this report should be extended to include additional post-1990 data in order to determine if the extreme-low baseflow noted in 1992 is due to natural climatic variability or other causes. Preliminary 1993 and 1994 data are available from the USGS, and could be incorporated into updated analyses.

- As more streamflow data become available it may be prudent to perform a more detailed analysis of annual minimum flows in which recorded flows are normalized to climatic variations. Corrections could be made for climatic variability by using a simple hydrologic model to develop synthetic minimum flows as a function of weighted antecedent precipitation.

- o Additional water-use and ground-water-level data should obtained from the files of the major water purveyors in the WRIA. These data should be used to identify trends and correlate water use with ground-water levels.

- o After several years of the monitoring recommended above and compilation of additional water purveyor data, a more extensive water budget could be prepared (and balanced) which includes seepage data, Darcian estimates of subflow to/from the WRIA, ground-water-use reports, ground-water discharge to Puget Sound, estimates of runoff for the entire Deschutes River drainage, and estimates of actual surface-water diversion.

- o Seawater intrusion trends along Puget Sound should be examined by compiling water-quality data and making time-series plots for individual wells.

Conservation and Water Reuse:

Conservation measures can result in a net reduction of withdrawal. Many measures can be undertaken by utilities to conserve water such as leak detection, rate structures, and public education. Programs that promote use of low flow devices for home irrigation, showers, and toilets have been very successful in reducing water consumption. Water conservation and the resultant decrease in water demand not only reduces potential impacts to the water resources but can also delay or extend utility requirements for new source and distribution facilities.

Water reuse involves using treated wastewater to provide a supply to a use which would otherwise need a potable supply source. Like conservation, reuse can represent a gallon-for-gallon reduction in demand.

Regional Planning:

Lacey, Olympia, Tumwater, and Thurston County are currently initiating a cooperative process towards regional water supply planning and development. Long-term data collection programs, data management, and other resource protection activity and studies should be accomplished through a regional management approach.

Artificial Recharge and Storm-Water Management:

Artificial recharge and storm-water management could be used to augment local ground water systems. Sources of water for artificial recharge might include excess surface-water flows or possibly treated waste water. Storm-water management programs are generally directed towards reducing the peak flow regimes that occur within urban watersheds using detention ponds. Efforts should also be made to design and develop facilities that promote infiltration of runoff to the ground water system.

Surface-water Diversion Inventories:

Water diversion along all of the major stream corridors should be inventoried to identify quantity, period, and types of water use relative to water rights permit information. Illegal surface-water diversions should be identify and eliminate. Any elimination of illegal diversions will result in a direct reduction of impact to streamflow.

Water Rights Relinquishment and Transfers:

Every possible attempt should be made to remove inactive water rights from the State's water rights database. Water use reporting policies, for example, could be used to remove discontinued water withdrawals from the records. Preferably *after* unused water rights are relinquished, transfers should be encouraged throughout the watershed as a means of converting unused water rights back to active rights. Transfers should only be granted in proof of continued use for the preceding five years can be provided for existing permits and certificates.

2 Watershed Description

2.1 Geographic Description

The Deschutes WRIA 13 is located in the southern Puget Sound region and contains portions of Thurston and Lewis Counties (Figure 1-1). The Deschutes WRIA encompasses a relatively long and narrow area of approximately 173,250 acres (270 sq. miles). This 270-square-mile area includes both surface-water and land areas, but excludes WRIA area in Puget Sound. The Nisqually watershed (WRIA 11) and the upper Chehalis watershed (WRIA 23) adjoin to the east and to the west of the Deschutes WRIA, respectively.

The watershed of the Deschutes River comprises about 60 percent of the Deschutes WRIA. The Deschutes River flows approximately 60 miles in a northwesterly direction and discharges to Capitol Lake. Flow of water from Capitol Lake to Puget Sound is occurs via the Capitol Lake dam. Tributaries to the Deschutes River occur throughout its watershed and are considerably more abundant in the southern part of WRIA (Figure 1-1).

The watersheds of smaller streams, namely Woodland, Woodward, Percival, and McClane Creeks, comprise some of the remainder of WRIA 13. These creeks convey water directly to Puget Sound in the northeastern and northwestern parts of the WRIA.

The climate of Deschutes WRIA is a marine type characterized by warm, dry summers and cool, wet winters. The mean annual air temperature is approximately 50°F (USGS, 1994). July is the warmest month with a mean temperature of 63°F, and January is the coldest month with a mean temperature of approximately 37°F. The mean annual precipitation for the is 51 inches, but varies spatially from 40 inches in the northeast part to 90 inches in the southern part of the WRIA.

The highest point in the WRIA is Cougar Mountain at 3,870 feet mean sea level (msl) and the lowest point is the shoreline (at sea level) along Puget Sound. The topography is relatively steep in the southern part of the WRIA with slopes of 30 percent and greater. The central part of the WRIA consists of undulating topography with slopes ranging from 5 to 30 percent. The northern part of the WRIA is relatively flat grass-type prairies with localized steep slopes along Puget Sound.

2.2 Land Cover and Land Use

Land cover and use affects the quantity and quality of surface waters throughout the WRIA. Natural vegetation and forest land provide the optimal biological and physical characteristics for maintaining healthy stream and lake habitats. However, use of these lands for timber harvesting, roads, and pastures, can significantly degrade the water quality of runoff. These activities can cause increases in storm-water flows and increases in surface-water contaminants such as: sediment loads, water temperature, anthropogenic chemicals, bacteria/viruses, and organic debris. Urbanization development greatly increases the amount of impervious surfaces which invariably increases storm-water runoff. Storm-water runoff can carry the following contaminants: metals, nutrients, bacteria/viruses, and organic compounds. Ultimately, the contaminants that result from either forest land or urban land use can impair or destroy habitats for fish and other organisms in streams, lakes, and Puget Sound.

Increases in the amount of runoff from certain types of land cover and use also affect the ground-water system. A proportion of precipitation in the Deschutes WRIA naturally infiltrates the land surface, and thus recharges the ground-water system. Construction of impervious surfaces and surface-water-conveyance systems result in localized reduction of ground-water recharge to shallow aquifers and increases in surface runoff to surface-water bodies. Over the long term, this can potentially reduce ground-water levels which, in turn, reduces water availability to wells and reduces streamflows (where ground water discharges to a stream). In addition, ground water that discharges to streams (known as baseflow) is typically of better quality than surface runoff related to storm events.

Land cover by acreage and percent area is summarized in Table 2-1. This table summarizes land cover for an approximately 270-square-mile area that includes only land-surface area in the WRIA. The largest percentage of land cover is "other natural cover" at approximately 44 percent, and "deciduous, coniferous, and mixed forest land" at approximately 44 percent of the total area. Other land covers include "high and low density built-up" at 9 percent. Most of the natural cover and forest land occurs in the central and southern parts of the WRIA. The urbanized "built-up" areas occupy the northern part of the WRIA.

Within the Deschutes WRIA, two main land-use changes are occurring, one permanent and the other cyclic (Puget Sound Cooperative River Basin, 1990). The permanent land-use change is urban development and the associated change is increased peak streamflows during storms. These increases promote increased stream-bank erosion and sediment loading to streams, lakes, and Puget Sound. The cyclic land-use change is timber harvesting in the central and southern parts of the WRIA. Following timber removal, runoff and, therefore sediment loads increase. As the forest re-establishes, the water and sediment yields gradually diminish, returning to the lower, natural levels in about 10 years.

In summary, urbanization in the northern part of the Deschutes WRIA probably will result in increased peak storm-water runoff, decreased recharge to aquifers, and water-quality degradation. These problems can be reduced using appropriate storm-water-management practices that include construction of storm-water-detention and infiltration facilities as part of land-development projects. The cyclic timber harvesting could periodically impair surface-water quality. Appropriate management of timber lands using Timber-Fish-and-Wildlife standards would prevent or reduce such problems.

3 Water Allocation and Use

The State of Washington regulates ground-water and surface-water withdrawals through a system of permits. Water withdrawals for all but limited small ground-water uses must be authorized by Ecology. Upon receiving an application for a water right, Ecology may issue a permit to develop the water resource. Water right certificates are issued after the water withdrawal has been perfected (actually put to beneficial use). In this report, permits and certificates are collectively referred to as water rights. Water rights have been recognized by existing water laws since 1917 (for surface water) and 1945 (for ground water). Not all uses of water developed before these dates were registered as part of the water-rights process. In order to protect active withdrawals developed prior to these two dates, the State allowed individuals to register withdrawals during a "claims period" between 1969 and 1974. A water-right claim is not an authorization to use water, but rather a statement in claim to a water withdrawal developed prior to 1917 or 1945. In most cases, the validity of existing claims has yet to be determined.

Quantities of water allocations are not necessarily equal to quantities of water use. Allocations state legally permissible quantities of withdrawal. Experience has shown that these permissible quantities are seldom achieved, and a significant discrepancy can exist between allocations and use. A distinction between allocation and use must be drawn in assessing stress on the hydrologic system due to withdrawals. Actual use cannot be enumerated through water-allocation statistics, but must be arrived upon by surveying major water users and estimating the sum of minor uses. Although total allocation may differ from actual use, total allocation is a significant figure because it represents the maximum legally permissible withdrawal from the hydrologic system.

3.1 Instream Resource Protection Program - Deschutes River Basin

The Instream Resource Protection Program (IRPP) for the Deschutes River Basin (Chapter 173-513 WAC) was enacted in 1980 in order to retain instream flows in perennial rivers, streams, and lakes at levels necessary to protect wildlife, fish, scenic, aesthetic, environmental values, recreation, navigation, and water quality. Chapter 173-513 was preceded by two key pieces of enabling legislation: 1) the Water Resources Act of 1971 (Chapter 90.54 RCW), and 2) Chapter 90.22, Minimum Water Flows and Levels. Chapter 90.54 set forth fundamental precepts for water management to insure that the State's waters are protected and fully used to the greatest benefit. Chapter 90.22 authorizes Ecology to establish minimum water flows or levels for streams, lakes, or other public waters to protect fish, game, birds, other wildlife resources, recreation, aesthetic values, and water quality.

The IRPP for the Deschutes River basin established instream flows for the Deschutes River at control station number 12080000, and defined minimum flows or closure periods for other reaches of the Deschutes River, its tributaries, and other streams in the basin (Figure 3-1 and Appendix A). In addition, the IRPP tied the issuance of future ground-water withdrawals to surface-water minimum flows and closures, when it could be clearly demonstrated that issuance of a ground-water right could impact a regulated surface-water body.

3.2 Reservation of Future Public Water Supply for Thurston County

Chapter 173-591 WAC, Reservation of Future Public Water Supply for Thurston County, was adopted in 1986 to reserve ground waters within Thurston County for future public water supply, sufficient to serve an estimated population of 288,092 in fifty years (2036). The reservation provides for peaking capacity (supplemental supply) on a daily basis, and applies to all public water supply systems within the reservation boundaries (Appendix A).

Supplemental water rights issued under the reservation are given a priority date of August 13, 1986, the effective date of the reservation. All other rights issued after the effective date of the reservation are junior in priority to public water supplies. Reserved quantities are issued subject to existing rights and in accordance with adopted instream flows. The Department of Ecology may limit or condition junior water rights to ensure availability of the reserved ground water, and will not authorize a permit that will lower water levels below a reasonable and feasible pumping lift for a senior water right holder.

Chapter 173-591 reserved 40,589 gallons per minute for peaking purposes, and limited peaking withdrawals to 22,931 acre-feet/year. The total annual withdrawal from all sources within the reservation area is not to exceed 48,225 acre-feet/year. This amount may be reviewed or revised by the Department in light of new information, changing conditions, or statutory modifications.

The Department maintains a record of all ground-water permits issued pursuant to the reservation, debiting supplemental withdrawals from the reservation's annual withdrawal limit. Quantities from wells withdrawing less than 5,000 gallons per day are not subtracted from the reservation. Past record keeping, doubt concerning the accuracy of the calculations used in the WAC, and uncertainties concerning the amount of water actually available within the reservation boundaries, have made administration of the WAC difficult.

3.3 Water Rights and Claims

Water permits and certificates within the Deschutes WRIA are recorded in the WRIS (Water Rights Information System) database. The database contains specific information for each entry, including: location of extraction, date of application and approval, maximum allowable withdrawal, purpose(s) of use, and irrigated acreages where applicable. There are 12,500 surface water permits/certificates which were issued before 1970 (statewide) that have no annual quantity specified on the document. For this reason, discussion of surface-water permits and certificates as annual withdrawals may involve some underestimation. Withdrawal quantities are also often unspecified for a large number of claims. Estimation techniques (described below) were used to approximate total annual quantities associated with claims.

It is important to note that, due to the nature of ground-water flow, there may be some significant ground-water rights located outside of the Deschutes WRIA that are associated with hydrologic conditions in the Deschutes WRIA. A prime example is the City of Olympia's water right to

McAllister Springs. Although, the Springs are in the Nisqually watershed (WRIA 11), a large portion of the area that contributes flow to the Springs lies in the Deschutes WRIA. Therefore, the City's McAllister Springs water right of 30.33 cfs (instantaneous withdrawal rate) is associated with substantial amounts of ground-water flow in the Deschutes WRIA (City of Olympia, 1994).

3.3.1 Water Rights and Claims Over Time

The cumulative increase in water permits and certificates over time in the Deschutes WRIA is shown in Figure 3.2. This cumulative increase reflects growing stress on the hydrologic system due to withdrawals. Quantities are reported as maximum allowable withdrawal volumes (Qa) in acre-feet/year (af/yr). As previously mentioned, the surface-water allocations may be somewhat underestimated due to database entries without registered Qa values. Reported Qa's for surface-water permits/certificates in the Deschutes WRIA have grown to 6,446 af/yr (8.90 cfs) from the first registered right in 1922 to 1988, the priority date of the last-issued water right. Reported Qa's for ground-water permits/certificates have grown to 43,285 af/yr (59.75 cfs) from the first registered right in 1913 to 1991, the priority date of the last-issued water right.

It should be noted that instantaneous withdrawal rates (Qi's) associated with a given water right may exceed maximum allowable annual volumes (Qa's). The implications of this discrepancy are greatest for surface-water withdrawals, where the effect of a diversion is immediately imposed on a stream. Surface-water withdrawals for irrigation may commonly divert their entire allocated Qa within the summer growing season (approximately 4-6 months). Ground-water allocations are considered best reported as Qa because pumping often does not instantaneously affect surface-water bodies. The effects of ground-water pumping on surface water are sometimes rapid, and sometimes delayed and spread out over time. On average, effects of ground-water pumpage on surface water are likely to be delayed due to aquifer storage, distances between wells and rivers, and the presence of intervening aquitards.

Many water-right claims have been in use long before the first water rights were granted. Water was claimed primarily for agricultural purposes, yet claim quantities were not always consistent with potentially irrigable acreages. In order to better estimate actual water applications and assign water duties to the claims Ecology applied the following irrigation relation, which is consistent with current allocation processes for water rights issued in Western Washington:

$$Qi = \text{Acreage} \times 9 \text{ gpm} = \text{Acreage} \times 0.02 \text{ cfs}$$
$$Qa = \text{Acreage} \times 2 \text{ af/yr}$$

Claims for domestic and stock uses, which include up to half an acre non-commercial lawn and garden, were assigned a Qi of 0.02 cfs and a Qa of 2 af/yr. Claims within the WRIA, based on these water duty assignments, are summarized in the table below. Comparisons between claims and permits/certificates are also summarized in this table and presented graphically on Figure 3.3a.

	PERMITS AND CERTIFICATES			CLAIMS			TOTALS
	Qi (cfs)	Qa (af/yr)	Irrigated Acres	Qi (cfs)	Qa (af/yr)	Irrigated Acres	Qa (af/yr)
Surface Water	51.53	6,446 (8.90 cfs)	2,907	15.62	1,375 (1.90 cfs)	594	7,821
Ground Water	209.22 (93,900 gpm)	43,285 (59.75 cfs)	1,760	114.00 (51,165 gpm)	8,164 (11.27 cfs)	2,479	51,449
TOTALS	260.75	49,731	4,667	129.62	9,539	3,073	59,270

Ground-water withdrawals dominate both rights and claims within the Deschutes WRIA, accounting for 87% of the total Qa. For both ground water and surface water, the majority of registered withdrawals are held as permits and certificates. Note that Qi:Qa ratios for pemits/certificates are not consistent (Qi:Qa ratios for claims reflect the formulas discussed above). This contrast may reflect differences in the permitting process for ground-water and surface-water rights.

3.3.2 Spatial Distribution of Water Rights and Claims

The spatial distribution of surface-water rights (permits/certificates) and claims are depicted in Figures 3-4 and 3-5, respectively. Surface-water rights are primarily distributed along the Deschutes River, the Tri-Lakes (Hicks, Long and Pattison Lakes), Woodland Creek, and Woodward Creek. Other areas with large and/or abundant permits/certificates occur near Mudd Bay, and near Chambers Lake (T18N, R1W, Sections 29 and 32). The locations of surface-water claims (Figure 3-5) is similar; however, the claims are largest and/or most abundant in the Woodward Creek vicinity, in the tri-Lakes area, north of Spurgeon Creek, and in the central part of the WRIA along the Deschutes River.

The spatial distribution of ground-water rights (permits/certificates) and claims are depicted in Figures 3-6 and 3-7, respectively. Ground-water rights are primarily distributed along central part of the Deschutes River, and throughout the northern part of the WRIA. The locations of ground-water claims (Figure 3-7) are primarily along the peninsular areas, particularly in the vicinity of Woodward Creek, and to lesser extent south of Lacey and Tumwater.

3.3.3 Water Rights and Claims by Use

All water rights are registered by purpose of use. Within the WRIS database, water rights typically have one, if not several, stated purposes. Examining the distribution of water rights by purpose provides understanding of how water is used within the WRIA. Discerning the major uses can assist in formulating policy for water conservation or water-rights administration.

In order to present water rights by use, permits and certificates were classified according to the larger of their first two stated purposes. The relative distribution of surface-water rights by use is presented on Figure 3.3b. Percentages of total use are calculated in terms of maximum allowable annual withdrawals (Qa's). Surface-water resources in the Deschutes WRIA are primarily allocated for irrigation (90%). Allocations for commercial and industrial use comprise 6%, and single domestic uses comprise about 3%.

The relative distribution of ground-water rights by use is presented on Figure 3.3c. Ground-water resources in the Deschutes WRIA are primarily allocated for domestic use. Seventy two percent of allocations are distributed between domestic municipal (41%) and multiple domestic (31%). Commercial and industrial uses account for 16% of the allocations, irrigation accounts for 8%, and other uses account for the remaining 4%.

Water-right claims are primarily registered for irrigation use. Within the Deschutes WRIA (based on Ecology's formulas for water duty assignments), 86% of the surface-water claims and 61% of the ground-water claims (by Qa) are registered for irrigation. Irrigation use for ground-water claims is likely higher than 61%, however a number of claims were missing irrigated acreages.

3.4 Water-Right Applications

There are currently 45 applications for new water rights within the Deschutes WRIA on file with Ecology. Maximum withdrawal information for water-right applications is generally limited to instantaneous extraction rates (Qi), largely because Ecology has not made final decisions as to maximum allowable annual withdrawals. The table presented below provides a summary of water-right applications in the Deschutes WRIA, expressed as Qi. Applications cannot be directly compared to allocations where allocations are reported as Qa. The ratio between Qi and Qa varies, however Qi values generally exceed Qa values. For instance, Qi:Qa ratios for permits/certificates in the Deschutes WRIA range from about 3.5 for ground water to 12 for surface-water.

Source	Number of Applications	Total Qi (cfs)
Surface Water	4	0.07
Ground Water	41	40.26
TOTAL	45	40.33

Applications for ground-water rights comprise the largest component (99.8%) of potential future water allocations. Currently, 41 ground-water applications exist for 40.26 cfs (18,070 gpm) and 4 surface-water applications exist for 0.07 cfs. Figure 3.3d shows the distribution of applications by stated purpose. The majority of the total requested Qi (76%) is for domestic ground-water withdrawals and is divided between domestic municipal (45%) and multiple domestic (29%). Applications for ground-water withdrawals for irrigation comprise 24% of the total requested Qi, and other ground-water uses comprise the remaining 2%.

The geographic distribution of water-rights applications is presented in Figures 3-8 and 3-9. Surface-water applications (Figure 3-8) occur in the Pattison and Long Lake vicinity and Henderson/Budd Inlet area. Ground-water applications (Figure 3-9) are generally concentrated in the northeastern and northwestern parts of the WRIA, and the lower Deschutes River valley. Other ground-water applications occur southeast of the tri-Lakes and near the Town of Rainier.

3.5 Estimates of Actual Use and Comparison with Issued Water Rights

Estimates of water use are important in assessing the quality of water rights documentation and in constructing a water budget for the WRIA. Actual water used will differ from the allocations described above because inactive water rights occur in the WRIS database and because various factors may constrain development of allocated resources. Optimally, water use data would include long-term records which report withdrawals by user, purpose and source. Unfortunately, data records of this type are typically incomplete, although some categories of water users, such as the municipalities of Lacey, Olympia, and Tumwater, meter their ground-water use and provide these data in Water Comprehensive Plans.

3.5.1 Ground-Water Use

Estimates of actual ground-water use by categories are summarized by the USGS (1994) for the Ground-Water Management area (GWMA) study of the northern Thurston County. Selected water use data from this study are presented in the table below.

Use Category	1988 Withdrawals (ac-ft/yr)
Public Supply (Classes I and II)	8790
Domestic (Class IV and Private)	5140
Industrial (Self Supplied)	6660
Irrigation	1870
Total	22460

Notes: At the time the GWMA study was conducted, Washington state public water systems were divided into four classess. Class I = 100 or more service connections or a transitory population of 1,000 or more people per day. Class II = 10 to 99 service connections or a transitory population of 300 ot 999 people per day. Class III (not included in GWMA data) = transient population of 25 - 299 per day. Class IV = 2 to 9 service connections or a transitory population of 25 people per day.

Although the USGS GWMA study area includes portions of the adjacent WRIA's (Nisqually, 11 and Chehalis, 23), the estimated 1988 withdrawals are considered representative of withdrawals in the Deschutes WRIA. Most withdrawals within the Deschutes WRIA are from the public supply Class I wells owned by Lacey, Olympia, and Tumwater. Withdrawals by Class II systems include mostly small water systems located throughout the Deschutes WRIA. Approximately 90 percent of industrial withdrawals in 1988 occurred from a single manufacturer in the lower reaches of the Deschutes River valley, and nearly all of the irrigation withdrawals in 1988 include water pumped from agricultural wells along Yelm Highway in the Deschutes WRIA. A small portion of the withdrawals in the adjacent WRIA's are included in the 22,460 ac-ft/yr estimate, and a small portion of withdrawals in the central and southern Deschutes WRIA are not included in the 22,460 ac-ft/yr estimate.

In addition to ground-water withdrawals summarized by the USGS for 1988, municipal water-use data were compiled from 1988 to present. These water-use data are summarized in the table below and represent pumpage from wells located only in the Deschutes WRIA.

Use Category	Water Use by Year (ac-ft/yr)							
	1988	1989	1990	1991	1992	1993	1994	Record Average
Lacey Municipal	4570	4810	5020	5020	na	na	na	4860
Olympia Municipal	na	210	1050	na	na	1810	na	1020
Tumwater Municipal	1670	1880	2090	2530	na	na	na	2040
Rainier Municipal	na	na	150	na	na	160	180	160
Total			8310					8080

Note: Data sources for : Lacey - Draft Water Comp. Plan, 6/18/93; Olympia - 1994 Water Comp. Plan, and pers. comm. EES, 12/6/94 regarding 1993 data; Tumwater - 1992 Water Comp. Plan.; Rainier - pers. comm. Town of Rainier, 1/3/95. "na" indicates data is not available.

Water use for some of the years is listed above as "not available". In this case "not available" means either the data were not readily available in a summarized format for presentation in this report, or the data were not properly metered and collected. In spite of the incomplete records shown above, the data suggest that municipal water use, and therefore ground-water withdrawal in the WRIA, has increased from 1988 to present. These trends are related to population increases in the areas served by these purveyors (pers. comm. EES, 1/20/95). Based on the data given above, the average withdrawals over the period of record was 8,080 ac-ft/yr.

Two comparisons can be made between ground-water withdrawals and ground-water allocations. First, the estimate of 1988 ground-water withdrawals of 22,460 ac-ft/yr is about half the 1988 ground-water allocations of approximately 42,500 ac-ft/yr (Figure 3-2). Second, the 1990 municipal withdrawals (water use) of 8,310 ac-ft/yr are about half of the municipal ground-water allocations of approximately 17,500 ac-ft/yr (Figure 3-2 and 3-3c).

Based on the USGS 1988 withdrawal data (see above table), public and domestic water supply accounts for approximately two-thirds of ground-water use in the WRIA. Population within Thurston County is projected to increase by approximately 25 percent between year 1990 and 2000 (Thurston Regional Planning Council, 1994). Assuming this statistic applies to population in the Deschutes WRIA, proportional increases in public and domestic ground-water use may occur in the WRIA. Conservation measures can reduce public and domestic water use by 5 to 10 percent. Making projections for industrial and irrigation water use is beyond the scope of this assessment.

3.5.2 Surface-Water Use

Water-use data for surface-water diversions are not available for the Deschutes WRIA. This information should be inventoried for the major surface-water users and estimated for the minor users.

4 Precipitation

4.1 Spatial Distribution

The mean annual precipitation throughout the WRIA is 51 inches, but varies spatially from 40 inches in the northeast part of the WRIA to 90 inches in the headwater areas that occur in the southern WRIA. During the winter months, most of the precipitation falls as rain at altitudes below 1,500 feet, as rain or snow between 1,500 and 2,500 feet, and as snow above 2,500 feet (USGS, 1994). The spatial distribution of precipitation within the WRIA is shown in Figure 4-1, an isohyetal map of the WRIA based data records for years 1930-1957 and topographic adjustments (USDA, 1965).

Precipitation data from five gaged stations in the vicinity of the WRIA were reviewed. Three of these gages are located within the WRIA, and two are located outside the WRIA. Only one station in the WRIA (Olympia Airport) has a significant length of record. The two stations located outside the WRIA are considered representative of high-elevation conditions in the headwater areas of the WRIA and have sufficient records to provide long-term statistics. Gages with sufficient records for analysis are listed in the table shown below, and data for these stations are provided in Appendix B. The location of the Olympia Airport gage (station 6114) is shown on Figure 3-1.

Station ID	Description	Period of Record	Record Mean
6114	Olympia Airport	1949-present	50.25 in/yr
4764-05	Longmire Rainier	1931-1978	82.40 in/yr
6896-04	Rainier Ohanapecosh	1949-present	75.94 in/yr

Mean annual precipitation at the above three gages corresponds fairly well with the precipitation distribution shown on Figure 4-1.

4.2 Precipitation Trends

Temporal variation and trends in precipitation occur on seasonal, short-term (several years), and long-term (decades) scales. On a seasonal basis, seventy-nine percent of the precipitation at Olympia falls in the 6-month period from October through March. Additionally, total rainfall for the driest months of June, July, and August is less than seven percent of the annual total. Departures from these seasonal statistics, such as "dry winters" or "wet summers" occur.

Long-term precipitation trends are demonstrated on Figure 4-2 which presents precipitation at Olympia between 1878 and 1993. The data are compiled from the Olympia Airport and earlier existing rain gages. A 10-year moving average of annual precipitation is also presented to help identify long-term cycles in weather patterns In general, high variability can be seen throughout the period of record. Above average precipitation before 1880 was followed by below average periods between 1880-1890, 1922-1930, and 1985-1993. Notable above average periods occurred between 1890-1910 and 1930-1940. Although cyclic patterns to departures from average have been proposed (e.g. on the order of 30-40 years), such a pattern is not apparent in Figure 4-2.

Short-term variations occur over periods of several years, and are also demonstrated on Figure 4-2. Occurrence of these short-term departures from the average appears to be highly variable, and to lack discernable patterns.

5 Surface-Water Assessment

5.1 Description of Drainage Network

The Deschutes Water Resource Inventory Area (WRIA) comprises about 270 square miles total basin area, extending from the Cascades' foothills to the Puget Sound as shown by Figures 1-1 and 3-1.

The Deschutes River and its tributaries define the principal surface-water drainage network for the area. In total, the Deschutes River system includes over 143 identified streams providing over 256 linear miles of drainage. Major tributaries to the Deschutes include Percival Creek, Spurgeon Creek, Fall Creek, Mitchell Creek, Johnson Creek, Thurston Creek, and the Little Deschutes River. Major lakes in the WRIA include Patterson Lake, Lake Lawrence, Long Lake, Macintosh Lake, Hicks Lake, Chambers Lake, and Capitol Lake.

The headwaters of the Deschutes River are located in the foothills of the Cascade Range in Thurston and Lewis Counties. The river flows about 60 miles generally northwest in a broad gentle valley until reaching a series of falls near Tumwater, just upstream of Capitol Lake in Olympia. Capital Lake is a man-made lake on the main-stem Deschutes River channel, formed by impoundment of the Deschutes and Percival estuaries. From Capitol Lake, the river discharges directly into Budd Inlet on Puget Sound.

There are additional, smaller drainage basins at lower elevations in the Deschutes WRIA which are independent of the Deschutes River system. The three largest such independent basins are Woodland Creek, Woodward Creek, and McLane Creek, each of which discharge directly to inlets to south Puget Sound.

5.2 Established Minimum Instream Flows

Minimum instream flows, and other rules which limit surface-water withdrawals in the Deschutes WRIA, are published in the Washington Administrative Code (WAC) Chapter 173-513, titled "Instream Resources Protection Program - Deschutes River Basin, Water Resource Inventory Area (WRIA) 13." These rules were promulgated in 1980 pursuant to the Revised Code of Washington (RCW) chapter 90.54 (Water Resources Management Act of 1971), and chapter 90.22 RCW (Minimum Water Flows and Levels).

Chapter 173-513 WAC established instream flows and closures for the streams in WRIA 13. Downstream of Deschutes Falls (river mile 41), the Deschutes River is closed to further consumptive appropriations from April 15th through October 31st. From November 1st through April 14th, the WAC lists instream flows for the river on the 1st and 15th of each month and refers to the report "Deschutes River Basin Instream Resource Protection Program" for a day-to-day listing of instream flows required on intervening days. The control point for these flows is at river mile 3.4 where the river enters Capital Lake, and corresponds to USGS gage 12080000 ("Deschutes River near

Olympia"). Later in this report, these regulatory minimum instream flows are presented graphically together with measured streamflows for this gage. Above Deschutes Falls, the river and its tributaries are closed all year to further consumptive appropriations. No instream flows are listed for tributaries to the Deschutes River

Surface-water-source limitations are presented by WAC 173-513 for nine other streams or lakes in the Deschutes WRIA in addition to the Deschutes River instream flow control point described above. The limitations consist primarily of year-round closure to any additional surface-water appropriations. The entire basin for Woodland Creek, one of the few streams in the WRIA for which USGS streamflow data are available, is closed year-round to additional surface-water appropriations. Of the streams subject to source limitations, continuous flow data are available only for the Deschutes River and Woodland Creek. Due to the lack of data, this report does not address any of the other streams subject to low-flow limitations or closures.

5.3 Quantification of Streamflow

Streamflow data considered in this preliminary assessment comprised all continuous streamflow records recorded and published for the Deschutes WRIA by the U.S. Geological Survey. Data are available for the five USGS gaging stations shown on Figure 3-1 and listed below.

Gage ID	Name	Basin Area sq mi	Years of Record
12078650	Snyder Creek near Olympia	0.52	1971-1974
12079000	Deschutes River near Rainier	89.8	1949-1975 1980-1993
12080000	Deschutes River near Olympia	160	1945-1954 1957-1964
12080010	Deschutes River at E St Bridge at Tumwater	162	1990-1993
12081000	Woodland Creek near Olympia	24.6	1949-1969 1988-1990

Data for the two downstream gages on the Deschutes River (near Olympia and at the E Street bridge in Tumwater) were assessed jointly because of their close proximity. Contributing basin areas for these two gages are nearly identical and, accordingly, flows from these two gages effectively describe conditions at a single site. Combining these two stations was done to derive a relatively long period of record for analysis at the instream flow control point. Data for Snyder Creek are not assessed here because the four-year period of available data is too short to be useful for the objectives of this initial assessment.

In total, the streamflow data were assessed for three sites: two on the Deschutes main channel, and one on Woodland Creek.

The main objectives in reviewing and quantifying the streamflow data were:

1) To assess whether there is any obvious indication of declining stream flows not related to natural climatic fluctuations; and

2) To compare actual stream flows to the regulatory minimum instream flows and to assess the frequency with which the regulatory instream flows are actually met during the period of effect (November 1st through April 14th).

Streamflow data are published by the USGS following a "water-year" convention where water year 1990, for example, begins on (calendar year) October 1, 1989 and ends September 31, 1990. The water-year convention is useful to many aspects of hydrologic analysis, but may confuse readers not familiar with the convention. To minimize confusion, all data presented in this report are expressed with calendar year dates. The streamflow data together with summary statistics used for the streamflow analyses are listed Appendix B of this report.

5.4 Streamflow Trends and Critical Indicators

For each of the three gages with sufficient continuous record, assessments were made to determine whether there were any indications of declining streamflow over time, unrelated to natural climatic fluctuations. For the single gage with established instream flow standards, the data were reviewed to assess the day-to-day and long-term variability of flows relative to the established standards.

Streamflow trend analyses were made considering the total volume of runoff from each gaged basin, and also minimum annual streamflows. These are discussed separately.

The annual runoff volume (average annual flow) analysis was made using annual precipitation for Olympia to correct for climatic fluctuations. Annual precipitation and annual runoff are hydrologically related. In a natural system, the difference between annual precipitation and annual runoff is equal to evapotranspiration plus losses to "deep" ground water (ground water which does not re-emerge as surface flow above the gaging point) plus the change in the volume of water held in storage as "shallow" ground water (ground water which over time drains back into the stream above the gaging point.) In basins with significant winter snowfalls, the difference between rainfall and runoff in any given year is also affected by changes in the volume of water stored in the snowpack at the end of each year. While the computed value of rainfall minus runoff will vary from year to year due to these and other factors which are discussed below, the value does serve to correct for natural climatic fluctuations and is generally much less variable than either precipitation or runoff considered alone.

The difference between annual precipitation and runoff is also influenced by certain human development activities which may significantly affect annual runoff volumes and mean flows, independent of climatic fluctuations. Land development activities, such as logging, paving, and other creation of impervious areas, will cause an <u>increase</u> in the annual volume of runoff by reducing plant transpiration and infiltration to ground water. Water development activities (either withdrawals from streams or ground water), will cause a decrease in the annual volume of runoff, as some of the water is consumed (i.e., turned into a gaseous state by plants or industrial activity) or may be exported for use at a location where wastewater flows are not returned to the stream.

Because human development activities have increased over recent decades, any significant net hydrologic changes due to human activities should be apparent from a shift or trend in the difference between annual precipitation and runoff. A net effect would result if activities causing a decrease in runoff were not balanced by other activities causing an increase in runoff.

Figures 5-1, 5-2, and 5-3 each show two graphs to analyze annual runoff volume trends for the three gaged basins. The lower graph shows the recorded average annual streamflow together with rainfall at Olympia, using dual scales. The left axis (scale) shows the average annual flow rate in cfs, and the right axis shows the equivalent flow expressed as inches of runoff over the watershed. Similarly, the right axis shows the annual rainfall at Olympia, and the left axis shows the average flow rate which would result if all that rainfall fell on the basin and was expressed as runoff. Actual rainfall over the Woodland Creek basin is expected to be very similar to the rainfall recorded at Olympia. The rainfall at Olympia is about 30% less than the average basin precipitation above the two Deschutes River gages, but probably is a good indicator of the year-to-year variability in precipitation for those watersheds.

The upper graph on each of Figures 5-1, 5-2, and 5-3 shows the results of the trends analysis. Again, dual scales are provided to express the same information as either an average annual flow rate in cfs or as inches over the basin area. The bar chart shows whether average flows (or total runoff) were higher or lower than the long-term average for the period of record. The rectangular symbols show the difference between rainfall and runoff in each year: this represents the total volume (or depth) of water "lost" to evapotranspiration, ground-water recharge, or abstractions (e.g. ground-water withdrawals or surface-water diversions). Finally, a linear regression line is fitted to the rainfall-minus-runoff data, using time as the independent variable. Any significant trends in annual flow volumes should be visually apparent from the upper graph. In particular, an upward slope to the regression line would indicate that less precipitation is being expressed as runoff, and hence that streamflows are declining with time.

Inspection of Figures 5-1, 5-2, and 5-3 does not reveal any obvious trends in the annual flow volumes at the three gages. The possible trend indicated for the Deschutes River near Olympia is misleading due to a combination of no annual data for years 1964 through 1991, coupled with relatively low precipitation in years 1991 and 1992. The data do not show any obvious trends of either increased or decreased annual flow volumes.

An assessment was also made on trends in the minimum annual streamflow recorded at each of the three gages. The minimum flow trend assessment was conducted by a simple visual analysis. Annual precipitation alone is generally not a good indicator of minimum flows for the year due to timing effects. It would be possible to develop synthetic minimum flows as a function of weighted antecedent precipitation in a simple hydrologic model and then to use the synthetic values to correct for climatic variability. However, this level of detailed minimum-flow analysis was beyond the scope of this study.

Figures 5-4, 5-5, and 5-6 each show two graphs to analyze minimum streamflow trends for the three gaged basins. The lower graph shows the minimum flow recorded during each year of record, and the upper graph shows the departure of flow from the average of all minimum flows at each gage (for the purposes of this study, the minimum flow meas the minimum-daily-mean flow). Inspection of these graphs does not reveal any obvious time-series trends in minimum stream flows for any of the gages. However, due to long gaps in the data records, it is possible that trends exist which simply are not apparent due to lack data.

Finally, an assessment was made of flow hydrographs and flow statistics for the instream control point on the Deschutes River near Olympia. Figures 5-7, 5-8, and 5-9 were produced for this assessment. Figure 5-7 shows the instream flow standard together with the earliest available (1945 through 1954) flow hydrographs for the control site, illustrating the natural variation of flows relative to the flow standard at that time. Figure 5-8 shows the instream flow standard together with the most recent (1990 through 1993) flow hydrographs for the site. Hydrographs for additional recent years are not available due to abandonment of the gage from 1965 through 1990. Comparison of the two figures shows that the variability of stream flows relative to the standard is generally similar for both the early and recent periods, but that year 1992 stands out as having unusually low flows. Year 1992 had record-low flows for seven consecutive months from April through October (Appendix B).

Figure 5-9 presents flow exceedance curves for the Deschutes River instream flow control site. For the period of minimum instream flows defined by Chapter 173-513 WAC, the instream flows on any given day are "violated", on average, more often than once in every ten years. Referring back to Figures 5-7 and 5-8, it is noted that the standard is generally not violated consistently throughout the entire November 1st-to-April 14th season, but that, in any given year, it is met on some days and violated on others. Calendar year 1992 was unusual in having flows below the minimum flows for most of the period open to further appropriations (January 1st to April 14th, and November 1st to December 31st).

Without year 1992, we would conclude that there is no indication that regulatory instream flows are not being met more often at present than in the past, allowing for natural climatic variability. But in light of the record-low flows experienced in 1992 additional data collection and analysis is warranted to assess streamflow variability.

In summary, the streamflow data analysis did not detect any obvious trends in either annual flow volumes or minimum flows. Regulatory instream flows established for the Deschutes River appear to not be met, on average, more often than once in every ten years (Figure 5-9). Record-low flows were experienced on the Deschutes during the summer of 1992, but it has not been determined whether these were the result of natural climatic variability or some other cause.

More conclusive results might be reached through a more comprehensive analysis which would construct and calibrate a simple water balance model to simulate minimum streamflows. Such an analysis would also extend the period of streamflow record for recent data to include at least 5 years through 1994 by including preliminary (unpublished) streamflows from the USGS.

5.5 Water Allocations Compared to Stream Flows and Volumes

This section presents a comparison of stream flows and volumes relative to total water rights allocations in the WRIA. The objective is to determine how large water allocations are relative to streamflows, and hence to determine whether the presently-authorized water rights have the potential to significantly deplete streamflows.

The comparison presented here differs in a number of respects from the streamflow trends analysis presented in Section 5.4. That analysis looked at the combined actual effect of all development effects, including possible flow-increasing effects which would offset the flow-reducing effects expected from consumptive water withdrawals. The analysis presented here looks only at authorized (paper) water rights allocations. This is necessary because, as discussed in Section 3, there is considerable uncertainty as to how much of the authorized water rights historically have been, or currently are, being used.

The difference between actual water use and authorized water rights is very significant to decisions on issuing additional water-rights allocations. In the streamflow analysis, we examined the effects of water withdrawals through year 1992 without knowing the quantity of the actual withdrawals. If actual water withdrawals are significantly less than the authorized water rights, then the streamflow analysis does not tell us the effects of the presently-authorized water rights. If the difference between presently-authorized water rights and actual uses is large, there is a risk that streamflows could be significantly depleted in the future even without any additional water-rights allocations.

Figure 5-10 was produced to compare streamflows to total water-rights allocations in the watershed. As with earlier figures, two graphs using dual scales are presented to allow for a direct comparison of the data using various units of measurement. Volume units of acre-feet per year are included because this is a standard unit of measurement for water-rights allocations.

The comparison of water-rights allocations and stream flows presented by Figure 5-10 is approximate. Water rights for the entire 270 square mile WRIA are compared to the downstream Deschutes River gage which measures flows from only about 60% (161 square miles) of the total WRIA area. Identification and compilation of the water-rights allocations only within the 161-square mile Deschutes River basin and within aquifers hydrologically connected to that basin was beyond the scope of this work.

The lower graph on Figure 5-10 shows a time-series comparison of minimum annual stream flows at the downstream Deschutes River gage and annual water-rights allocations for the entire WRIA.

Water-rights allocations are broken down by ground-water and surface-water sources based on the data presented Figure 3-2. The left axis presents the data as a flow rate in cubic feet per second, corresponding to the standard unit of measurement for streamflow. The right axis presents the data as an annual volume in acre-feet, which is a standard unit of measurement for water rights allocations. The minimum flow data, read on the acre-feet axis, gives the annual volume which would result with the minimum flow occurring for a full 365-day period.

The ground-water allocations shown on Figure 5-10 correspond exactly to the annual allocations presented in Figure 3-2. The ground-water allocations, read on the cubic-feet-per-second axis, gives the average rate of the ground-water rights over the year. The surface-water rights shown on Figure 5-10 are three times larger than the annual allocations presented in Figure 3-2. This adjustment was made to reflect the fact that surface-water allocations are primarily used for four months of irrigation during the dry-season, and are not distributed uniformly over the year. The three times multiplier was used to give a more accurate average rate for surface-water allocations during the summer period when the lowest streamflows occur. The surface-water allocations are accurately presented when read from the cubic-feet-per-second axis, but overstate the actual annual water rights by a factor of three when read from the acre-feet-per-year axis.

The upper graph on Figure 5-10 shows the total annual volume of runoff for the downstream Deschutes River gage for the same period of record presented in the lower graph.

From Figure 5-10, it is apparent that water-rights allocations are about equal to minimum annual streamflows in the Deschutes River. On an annual basis, the water-rights allocations are equal to about one quarter of the river's average annual flow. These ratios are very approximate and overstate the magnitude of water rights allocations relative to the flows in the Deschutes River near Olympia because a substantial percentage (probably around 50%) of the water rights allocations are for withdrawals in other sub-basins of the Deschutes WRIA (i.e. smaller basins in the northern part of the WRIA).

The water-rights allocations presented in Section 3 are sufficiently large relative to minimum streamflows as to potentially cause substantial streamflow reductions during the summer months. There is great uncertainty as to what proportion of the water-rights allocations are presently being exercised as actual withdrawals, and hence, what additional hydrologic stress remains to be placed on the hydrologic system. A more detailed analysis, as discussed in Section 5.3, is required to determine whether there is any evidence of declining minimum streamflows due to increasing water withdrawals in the basin.

6 Ground-Water Hydrology

6.1 Aquifer Descriptions

6.1.1 Geologic Framework and Hydrogeologic Characteristics

The geology of the WRIA is characterized by both unlithified sediments and sedimentary and volcanic rocks (Figure 6-1). Unlithified sediments occur in the northern part of the WRIA and north of the Deschutes River in the central and southern part of the WRIA. These sediments consist of deposits of glacial and nonglacial origin that form a sequence of geologic units that have variable water transmitting and storage properties. Well logs and geophysical data indicate that as much as 1,000 feet of these deposits may occur in the extreme northern part of the WRIA. The sediments generally thin from the northern to the central part of the WRIA. In the central and southern parts of the WRIA, Tertiary sedimentary and volcanic rocks are exposed at land surface.

The most significant geologic units in the Deschutes WRIA and their hydrogeologic character can be summarized as follows (from ground surface to depth):

Geologic Unit	Hydrogeologic Character
Recent Alluvium (Qal)	Silt, sand, and minor gravel (wetlands, tidelands, and stream deposits; aquifers were saturated and relatively permeable)
Vashon Recessional Deposits (Qvr)	Sand and gravel, and silt (variable saturation)
Vashon Till (Qvt)	Silt-bound sand and gravel (aquitard)
Vashon Advance (Qva)	Sand and gravel (aquifer)
Kitsap Formation (Qk)	Silt and sand (locally an aquitard)
Sea Level Deposits (Qc)	Sand and gravel (aquifer)
Undifferentiated Deposits (TQu)	Sand and gravel (aquifers); silt (aquitards)
Tertiary Bedrock (Tb)	Andesite, claystone, siltstone, sandstone (low -yield local aquifers)

A hydrogeologic cross section oriented as shown on Figure 6-1 was constructed for a transect in the northern part of the WRIA. The stratigraphic position of these units and the significant water-bearing zones are shown on Figure 6-2. The following includes a description of each geologic unit and its significance in the context of Deschutes WRIA hydrology.

Recent Alluvial Deposits

The youngest deposits in the area are the Recent Alluvium (Qal). These deposits consist primarily of clay, silt, sand and wood fragments with minor amounts of gravel. The deposits occur within topographic lowlands of the principal rivers, streams, and wetlands throughout the WRIA.

Recent studies by Washington Department of Natural Resources and several drilling projects in the Deschutes River Valley have indicated the occurrence of a substantial thickness of moderately well sorted fine to medium sand with zones of silt, clay, wood, and minor coarse sand and gravel (pers. comm. W. Gerstel, DNR, 1994; Pacific Groundwater Group, 1993). The thick sequence of sand in the Deschutes Valley (Figure 6-2) is interpreted to be fluvial sediments (Qal/Qvr) deposited at the end of the Vashon recession and during the glacial Lake Russell period (Bretz, 1913). The depth of this deposit is uncertain and the lateral extent of these deposits on the east side of the Deschutes Valley is not known. However, based on the observed sediment texture in boreholes completed in the vicinity of the section A-A', the bottom of the unit likely occurs at elevations of near mean sea level. These sediments form important aquifers for domestic, municipal, and industrial wells in the Tumwater area.

Vashon Recessional Outwash

The Vashon recessional outwash (Qvr) occurs at land surface over much of the north County area. This unit consists of sand and minor gravel, and was deposited by streams emanating from the melting and receding Vashon glacier. Thickness of Qvr ranges from 10 to 50 feet. Saturated conditions in the Qvr occurs locally and seasonally. In general, the limited saturated thickness constrains well yields and restricts the use of this unit to domestic supply.

Vashon Till

The Vashon till (Qvt) occurs below the Qvr and locally at land surface. The till typically separates Qvr and the underlying advance outwash sand and gravel, although locally, the till is absent. This unit consists of variably compacted sand and gravel in a matrix of silt and clay. The compact, consolidated character of the till resulted from the overburden pressure of the Vashon glacier. Well drillers commonly describe the till as "hardpan" or "cemented gravel". Locally, deposits that occur directly above or below the till and appear to have low permeability are mapped in the Qvt unit. The thickness of the till is variable and typically ranges from 10 to 100 feet.

The Qvt generally functions as a confining layer that retards the movement of ground water, and therefore, is a poor source of water. However, some domestic wells are completed in relatively thin, sand and gravel deposits within the till.

Vashon Advance Outwash

The Vashon advance outwash (Qva) occurs below the Qvt or merges with the Qvr where the till is absent. The advance outwash consists of sand and gravel that was deposited from meltwaters along the perimeter of the Vashon ice sheet. The thickness of the Qva typically ranges from 20 to 75 feet. The Qva is an important source of water for both domestic and municipal wells.

Kitsap Formation

The Kitsap Formation (Qk) is stratigraphically below the Qva. The Qk consists predominately of clay and silt with minor sand, gravel, peat, and wood. These sediments were deposited in shallow lakes and wetlands during an interglacial period. The thickness of the Qk unit typically ranges from 10 to 100 feet. Locally, fine-grained portions of the Qk unit retard the movement of ground water. At these locations the Qk unit serves as a confining layer that can cause substantial vertical head gradients between the Qva and the underlying Sea Level deposits. At other locations, coarse-grained portions of the Qk unit yield water to domestic wells.

Sea-Level Glacial Deposits

The sea-level glacial (Qc) deposits are stratigraphically below the Qk unit, or the Qva aquifer in areas where the Qk unit is absent. The Qc unit has been referred as the "Penultimate" or "Salmon Springs" glacial units. This unit consists of coarse sand and gravel. These sediments were deposited from glacial meltwater during a pre-Vashon glacial period. Locally, the uppermost portion of the Qc unit includes silt-bound sand and gravel that may represent a glacial till. The thickness of the Qc unit typically ranges from 20 to 50 feet.

Undifferentiated Deposits

The undifferentiated deposits (TQu) consist of all glacial and non-glacial sediments below the Qc unit below a depth of about 50 feet below mean sea level. This unit consists of sand and gravel aquifers with interbedded clay and silt, and minor peat, wood, and volcanic ash. The TQu unit is a layered sequence of water-bearing zones (aquifers) and confining layers (aquitards). In general, a fine-grained layer (included in the TQu unit) separates the Qc from the deeper TQu deposits. This fine-grained layer is causes small to moderate head differences between the Qc aquifer and the uppermost TQu aquifer.

Tertiary Bedrock

The Tertiary rocks within the WRIA include volcanic rocks such as andesite, and sedimentary rocks, such as claystone, siltstone, and sandstone. This bedrock (Tb) forms much of the surface exposure in the central and south parts of the WRIA (Figure 6-1). Locally, the Tb units yields small quantities to wells with open intervals that intersect fractures and joints. This unit is not a reliable source of water.

6.1.2 Principal Aquifers

Four principal aquifers occur throughout the WRIA which can yield substantial quantities of water to wells. These include the Recent alluvium/Vashon recessional outwash aquifer (Qal/Qvr), the Vashon advance outwash aquifer (Qva), the Sea Level aquifer (Qc), and older Undifferentiated aquifers (TQu). The vertical position of these aquifers is shown in the cross section on Figure 6-2.

Although the these aquifers extend laterally throughout much of the WRIA (where the unlithified sediments occur), the highest yielding regions are shown as the shaded areas on Figure 6-3. These "aquifer areas" were delineated based on the occurrence of numerous wells that yield 100 gpm or more (PGG, 1993). These relatively high yielding "aquifer areas" are considered approximate and do not necessarily define the lateral extent of an aquifer, but rather they indicate where ground-water development has occurred and is likely to occur in the future in the northern part of the WRIA.

A description of the important hydrologic features of the four principal aquifers is given below.

Qal/Qvr Aquifer

Throughout much of the lower reach of the Deschutes River valley, the Qal/Qvr aquifer yields small to substantial quantities of water to domestic, municipal, and industrial wells. While the Qal/Qvr aquifer is only moderately permeable (because it consists predominately of sand), the unit's large thickness provides storage capacity for substantial quantities of ground water. Some of the large-diameter supply wells in this area include the City of Tumwater's wells at the Palermo well field and the Pabst Brewery wells scattered throughout the Deschutes Valley.

In other areas of the WRIA the saturated Qvr deposits form a shallow unconfined aquifer perched on the Qvt (where the till is present). Well yields from this aquifer are generally limited to 50 gallons per minute (gpm) or less.

Qva Aquifer

The Qva aquifer occurs throughout most of the northern WRIA and locally yields large quantities of water to wells. Short-term yields from wells completed in this aquifer typically range from 250 to 750 gpm, although some wells completed in highly permeable sand and gravel are capable of pumping at rates of 1,000 gpm or more. Ground water in this aquifer is typically confined by the overlying the Qvt unit and underlying Qk unit. Locally, however, the overlying Qvt may be permeable or absent, and permeable Qvr and Qva units form a single unconfined aquifer.

Qc Aquifer

The Qc aquifer is the most productive aquifer in the north part of the WRIA. The USGS (1994) estimates that about half of 1988 ground-water withdrawals for northern Thurston County were pumped from the Qc aquifer. Short-term yields from wells completed in this aquifer typically range from 300 to 1,000 gpm. Ground water in this aquifer is typically confined by the overlying Qk unit. However, where the overlying Qk unit is absent or permeable, the Qc aquifer can be in more direct hydraulic continuity with the Qva aquifer.

TQu Aquifers

The Undifferentiated (TQu) aquifers occur throughout the northern part of the WRIA. As previously mention, the TQu consists of coarse-grained aquifers interbedded with confining layers. The lateral extent and thickness of aquifer zones and confining layers is uncertain because a relatively small number of wells penetrate this unit. In general, ground water in the TQu aquifers is thought to be confined by overlying and underlying deposits of silt, clay, and/or till. However, the uppermost fine-grained layer that separates the uppermost TQu aquifer from the overlying Qc aquifer is locally permeable, and therefore, allows more direct hydraulic coupling between the Qc aquifer and the uppermost TQu aquifer.

6.1.3 Hydraulic Continuity

Hydraulic continuity means the interconnection between saturated geologic units and between ground water and surface water. An aquifer is typically in hydraulic continuity with lakes, streams, rivers, or other surface-water bodies where saturation is continuous to the edge of these water bodies. Hydraulic continuity is particularly important where ground water discharges to surface water, such as in spring-fed lakes and gaining rivers; or where surface water discharges to ground water, such as from riverbed seepage to an adjacent alluvial aquifer. Over time, changing hydraulic conditions in a ground-water body will result in changes to connected surface-water bodies. For instance, pumping a well may reduce ground-water discharge to adjacent surface waters or induce seepage from surface water. Similarly, lowering the water level in a river or lake may decrease seepage to ground water or increase discharge from adjacent aquifers. In all these situations, water flows from higher head (water level) toward lower head.

Determining or predicting cause-and-effect stream/aquifer relations can be simple or complex depending on hydrogeologic conditions. In the case of ground-water withdrawals, potentially affected surface-water bodies must first be identified. Because shallow aquifers are generally dominated by local ground-water flow systems, withdrawals from shallow wells are most likely to influence nearby surface-water bodies. Most simplistically, a shallow well in an alluvial aquifer will likely affect flow in the adjacent river or stream. Deeper aquifers are more typically part of regional flow systems. The effects of pumping from a deep confined aquifer are likely to be more diffuse, affecting nearby streams as well as more distant river reaches, discharge rates to coastal saltwater bodies, or other surface-water bodies. The timing and magnitude of stream/aquifer interactions depends on many factors, including: the distance between the well and the surface-water body, the geometry and hydraulic properties of aquifers and aquitards between the well and the surface-water body, patterns of ground-water flow and recharge, and the hydraulic properties of riverbeds and lakebeds. Based on these factors, ground-water withdrawals may affect surface-water bodies almost instantaneously or may be delayed by months, years, or even decades. Similar delays can be expected in the hydraulic effects following reduction or discontinuation of pumping.

Interactions between surface water and ground water occur along the Deschutes River, and the numerous lakes and streams in the area. Ground-water flow patterns are described in the next section, and reveal sub-systems which discharge to specific surface-water features. The pathways of flow and the hydraulic conductivity of the stratigraphic units control the hydraulic interaction between aquifers and a stream. The pumping of Qal/Qvr and Qva aquifers would potentially have the greatest effect on surface-water features nearest to the point of withdrawal. Withdrawals from the Qc aquifer would likely cause more regional (spread out) head reduction. This may affect local streams but would also influence discharge to major river reaches and to Puget Sound. Withdrawals from the TQu aquifer more likely would have less nearby influence, and, therefore, more effect on large regional drainages (Deschutes and/or Nisqually Rivers) and on discharge to Puget Sound.

The distribution of effects associated with a specific ground-water withdrawal also depends on the geographic location of the well. Deep wells completed near the Sound will almost entirely reduce ground-water discharge to the Sound (saltwater intrusion is a potential consequence). Deep wells located near Tumwater, however, could have an effect on local surface water. Within the Deschutes River valley near Tumwater, wells completed in the Qc and TQu aquifers flow at land surface. These conditions indicate the potential for upward flow from deeper to shallower zones. Other locations with potentially highly conductive connections with the Deschutes River valley (because of proximity), include the Qal/Qvr and Qva aquifers in the river's vicinity, and unconsolidated sediments that lie north of the Deschutes River in the central and southern parts of the WRIA.

In general, there is a lack of published data that reveals the details of hydraulic continuity between surface-water bodies and adjacent aquifers in the WRIA. However, the USGS conducted seepage studies along the Deschutes River as part of the study (pers. comm. Bill Lum, USGS, 1995b). The results of the study suggest that the Deschutes is a gaining river (flow is from the aquifer to the river) below the confluence of the Deschutes River and Silver Creek (T16N, R1W, Section 02).

6.1.4 Ground-Water Flow

Ground-water-flow patterns within the WRIA reflect a continuum from local to regional flow systems. Local flow systems typically occur within shallower aquifers, and flow directions tend to correspond to local topography. Regional flow systems occur within deeper aquifers, with flow directions influenced only by major topographic features such as Puget Sound and the principal river valleys. Flow in the shallow Qal and Qvr aquifers is mostly local, whereas flow in the Qva aquifer is partly local and partly regional. Flow systems in aquifers of increasing depth tend toward an increased regional component of flow (the Qc and TQu aquifers). The more regional the flow system, the longer the flowpath between points of recharge and points of discharge.

Recharge

Recharge occurs throughout the WRIA and is characterized by infiltration of precipitation through the soil surface followed by downward movement to unconfined aquifers. The amount of recharge that occurs over a particular area is primarily controlled by the amount of precipitation, the local topographic features, and the permeability of the soil. Other factors include the vegetation cover and evapotranspiration potential. The largest amount of recharge occurs in areas characterized by high precipitation, relatively flat slopes with minimal vegetation cover, and very permeable soils.

The USGS (1994) estimated the amount of recharge from precipitation in the northern part of the WRIA. These estimates are based on recharge models and calculations using the soil, precipitation, and other physical parameters throughout the northern part of the WRIA. Estimated recharge rates typically range from 20 to 35 inches/year for the northern part of the WRIA. The central and south parts of the WRIA (i.e. south of the Deschutes River) are characterized by moderate to steep slopes and substantial outcrops of Tertiary bedrock (Figure 6-1). These surface conditions typically have limited recharge potential compared to unlithified sediments. Given these slope and soil conditions in the central and southern parts of the WRIA, and the increased precipitation in this region because of orographic effects, recharge probably ranges from 15 to 30 inches/year. Based on these recharge estimates, an average recharge rate for the entire WRIA would be approximately 25 inches/year.

Ground-Water Movement - Central and Southern WRIA

Data necessary for estimating the direction of ground-water movement includes spatially distributed ground-water levels in wells, springs, or surface-water bodies known to be representative of the aquifer system. These data are generally lacking for the central and southern of the WRIA. However, Noble and Wallace (1966) published ground-water contours for unconsolidated sediments north of the Deschutes River in a limited portion of the central and southern parts of the WRIA . These contours suggest that horizontal ground-water movement occurs northward away from the Deschutes River, parallel to the River, and southward toward the River in the area southeast and near the Town of Rainier. Ground-water movement in the bedrock areas of the WRIA (south of the River) would be controlled by fracture and joint patterns in the rock and as well as recharge and discharge locations. It is reasonable to assume that relatively shallow ground-water movement in bedrock areas would follow the topography and tend to flow toward the nearest surface-water features.

Ground-Water Movement - Northern WRIA

The conceptual model for ground-water movement in the northern WRIA of includes downward movement of ground water to the Qvr aquifer, through permeable portions of the Qvt, and into the underlying Qva aquifer. Ground-water movement in the Qva aquifer includes both horizontal and vertical components. Horizontal components of flow predominate in areas where the low permeability Qk unit forms the base of the Qva aquifer. Vertical components of flow predominate in areas where there is a substantial decrease of head with increasing depth and where the Qk unit has higher permeability, or is thin or absent. Ground-water movement in the Qc aquifer is generally horizontal. Locally, vertical gradients and flow may occur between the Qc and TQu aquifers.

Ground-water movement based on water-level data from wells and springs in the northern WRIA has been extensively characterized by the USGS during the 1988-89 GWMA study and in subsequent wellhead protection studies for the City of Lacey and McAllister Springs (PGG 1994a,b). Ground-water level contour maps for the Qva and Qc aquifers in the northern WRIA are shown in Figures 6-4 and 6-5, respectively. These maps provide an estimate of the direction of horizontal ground-water movement, and locally indicate the potential for downward movement of ground water from the Qva aquifer (higher head) to the Qc aquifer (lower head). Head differences between the Qva and Qc is largest in the peninsular areas and smallest in the general vicinity of Spurgeon Creek. In the lower reaches of the Deschutes River, several flowing wells completed in both the Qc and TQu aquifers indicate the potential for upward ground-water movement from the Qc and TQu aquifers to the shallower Qal/Qvr aquifer (PGG, 1995).

The key features which influence the ground-water contours and thus the horizontal flow pattern in both the Qva and Qc aquifers are 1) the relatively flat elevated areas that extend throughout the northern WRIA, and 2) the locations of discharge points such as the Deschutes River, the Nisqually River, Woodland Creek, Woodward Creek, and Puget Sound. Both the Qva and Qc systems are influenced by the geometric characteristics of the area, however, the movement of ground water in Qva is more strongly controlled by local topographic features than is ground water in the Qc.

A prominent feature of both the Qva and Qc contour maps is the presence of a ground-water divide in the northeastern part of the WRIA (Figures 6-4 and 6-5). This divide represents a subsurface boundary that separates two major ground-water basins; west of the divide ground water moves toward the Deschutes River basin, and east of the divide ground water moves toward the Nisqually River basin. Ground water withdrawn, for example, from the Qva and Qc aquifers south and east of Lacey represents water that would have moved toward, and discharged to, locations in the Nisqually WRIA (the Nisqually River, McAllister Springs/Creek, and/or Puget Sound). Wells located south and east of Lacey include, municipal wells operated by the City of Lacey, irrigation wells along Yelm Highway, and numerous private wells.

In addition to the divide that separates the Nisqually and Deschutes ground-water basins, the convergent ground-water-flow conditions indicated by the Qva and Qc contours further define the Deschutes ground-water basin. This pattern suggests that ground-water flow is influenced by the river and that some ground water in this sub-basin discharges to the river. Groundwater withdrawn from the Qal/Qvr, Qva, and Qc aquifers in the Deschutes ground-water basin (Figures 6-2, 6-4 and 6-5) represents water that would have moved toward the Deschutes River and discharged either to the Deschutes River or Budd Inlet in Puget Sound. The three main areas of ground-water withdrawals in the Deschutes ground-water basin include wells located south and west of Lacey (operated by the Cities of Lacey and Olympia), wells located in the Deschutes River valley and near the Olympia airport (operated by the City of Tumwater), and wells located in the lower reaches of the Deschutes River valley (operated by a single manufacturer). Numerous private wells and small water systems are distributed throughout the Deschutes ground-water basin.

Other significant features that define ground-water sub-basins within the Deschutes WRIA include the convergent ground-water-flow conditions indicated by Qva and Qc contours along Woodland Creek, Woodward Creek, and to a lesser extent Percival Creek (Qva contours on Figure 6-4). This pattern indicates that these streams influence ground-water movement, and along some reaches the streams serve as discharge locations for the Qva and/or Qc aquifers. Ground water withdrawn from these areas represents water that would have discharged to these creeks or Puget Sound (Budd or Henderson Inlets). Much of the ground water withdrawn in these areas is from private wells and small water systems, although the City of Lacey operates two wells completed in an area that contributes flow to the ground-water sub-basin in the Woodland Creek vicinity.

The pattern of contours in the peninsular areas bounded by saltwater indicate ground-water movement is both downward from the Qva to the Qc, and toward Puget Sound. Ground water withdrawn in these areas represents water that would have either discharged to small local streams and/or Puget Sound. Most of the withdrawals in the peninsular areas are from private and small-water system wells. An exception to this is the Allison Springs area along the shoreline of Eld Inlet. City of Olympia operates two large capacity wells that yield water from the Qc aquifer. Ground water pumped from these wells represents water that would discharge to Eld Inlet on Puget Sound and, possibly, to nearby Allison Springs (T18N, R2W, Section 18).

Ground-Water Discharge

Ground water in the WRIA discharges locally to springs, creeks, and streams; regionally as subflow across the WRIA boundaries and to Puget Sound; and as withdrawals from wells. As described in the sections on ground-water movement and hydraulic continuity, ground water discharges to many reaches of the principal streams in the WRIA. During low-flow conditions, some stream reaches may lose water to the adjacent aquifers. McAllister Springs (in the Nisqually WRIA) is a discharge point for ground water that flows from the part of the Deschutes WRIA south and east of Lacey. The USGS (1994) reports that ground-water discharge sustains the late-summer flow in numerous streams in the northern part of the WRIA, and that the lower reaches of Percival, Woodland, and Woodward Creeks are generally considered to be gaining reaches.

6.2 Quantification of Water Budget Components

Water-budget analysis is a useful tool for relating natural components of the hydrologic system to existing withdrawals and/or allocations. Balancing the water budget may allow estimation of system components which could otherwise not be quantified. Water budgets, however, cannot be rigorously used to assess resource availability, because they do not allow prediction of system response to additional withdrawals. It cannot be necessarily assumed that a fixed percentage of water estimated to discharge from the WRIA is available for further development.

Water budgets are balanced based on the assumption of dynamic equilibrium - that is, over the long-term hydrologic systems are in steady state. In steady state, inflows are equivalent to outflows with negligible changes in system storage. It is beyond the scope of this study to attempt to balance the ground-water budget. Many water-budget components within the Deschutes WRIA are not estimated in the available literature. However presentation of the water budget framework augments conceptual understanding of the basin hydrology.

This section presents estimates of water budget components, as available, for the climatic and ground-water portions of the hydrologic cycle. Data were insufficient to prepare a water budget for the surface-water portion of the hydrologic cycle. The following table describes system components, presents annual inflow/outflow volumes, and provides data references as needed:

Component	Inflow (af/yr)	Outflow (af/yr)	Comments
Climatic:			
Precipitation	736,291	----	51 in/yr areal average (USGS, 1994)
Evapotranspiration	----	245,430	17 in/yr areal average (USGS, 1994)
Runoff	----	129,933	9 in/yr areal average (USGS, 1994)
Ground-Water Recharge	----	360,927	25 in/yr areal average (USGS, 1994)
Ground Water:			
Recharge	360,927	----	25 in/yr areal average (USGS, 1994)
Subflow	not estimated	not estimated	see ground-water flow in Section 6.1.4
Stream Interaction	not estimated	not estimated	see hydraulic continuity in Section 6.1.3
Saltwater Discharge	not estimated	not estimated	see ground- water flow in Section 6.1.4
Well Withdrawals	----	22,460	1988 estimate, see section 3.3
Spring Discharge	----	7,980	likely Silver Springs, confirm w/ USGS
Miscellaneous	not estimated	not estimated	lake seepage, direct evapotranspiration

The climatic water budget presents estimates prepared by the USGS (1994) for the North Thurston County GWMA. Because the GWMA study area roughly corresponds to the Deschutes WRIA (see discussion in Section 3.3), areal averages presented by the USGS were applied over the 270 square mile WRIA. Areal averages are often used for water budgets, however it should be noted that rainfall, soil type and plant cover vary over the WRIA and cause non-uniform distributions of evapotranspiration, runoff, and recharge. Almost half the basin-averaged precipitation is estimated to recharge the ground-water system, while one third was lost to evapotranspiration and one sixth became surface runoff. The distribution of recharge is discussed in Section 6.1.4. Surface runoff becomes streamflow in the various major streams and tributaries throughout the WRIA.

The ground-water budget suggests that only a small portion (6.2%) of recharge is withdrawn by wells. Portions of these withdrawals are likely non-consumptive, and total ground-water consumption is likely a smaller value. The remainder of recharge leaves the watershed as subflow to the Nisqually watershed (McAllister Springs and others), discharge to adjacent saltwater bodies, and discharge to gaining reaches of rivers and streams. Estimates of the relative proportions of these components were not available. Ground-water-level contour maps show that subflow occurs both into and out of the basin (Figures 6-4 and 6-5). Subflow out of the basin largely occurs along its northeastern boundary towards McAllister Springs and the Nisqually WRIA. Subflow into the basin occurs southwest of Tumwater. Based on knowledge of the hydrogeology, subflow out of the basin likely exceeds subflow into the basin by a significant amount. Direct ground-water discharge to saltwater bodies occurs along Eld, Budd, and Henderson Inlets. Ground-water discharge and recharge occurs from the Deschutes River (Section 6.1.3), however actual measurements of seepage losses and gains are sparse.

A water budget of the surface-water system was not prepared due to lack of data. Estimated surface runoff of 129,933 af/yr provides flow to the Deschutes River and other smaller drainages within the WRIA. Based on sub-basin areas, the majority of this runoff (60 percent) is likely delivered to the Deschutes River. Seepage losses/gains, as well as actual surface-water diversions (or their consumptive components) have not been estimated.

6.3 Ground-Water Level Trends - Critical Indicators

Long-term records of ground-water level from numerous locations in a ground-water basin are useful in assessing how and where ground-water inputs and withdrawals affect water levels in an aquifer. Evaluation of the trends in ground-water levels, together with the precipitation and ground-water use data, provide the information necessary for efficient management of ground-water resources. Specifically, these data that can be used to make resource management decisions that 1) ensure a reliable source of supply, and 2) maintain adequate streamflow where aquifers discharge to streams.

Both USGS's and Ecology's ground-water-level data were reviewed. Records of four wells having data for 10 years or more are shown on Figure 6-6 with departure from average precipitation. The data represent water levels from one well completed in the Qva aquifer and three wells completed in the Qc aquifer. The location of these monitoring wells are shown on Figure 3-1. In addition, the trend of precipitation near Olympia is shown at the top of Figure 6-6. The precipitation data is presented as departure from the mean annual value for the period 1970 through 1993. Small fluctuations (from year to year) are observed in the precipitation data. Longer-term trends indicate decreasing precipitation from about 1970 to 1978, followed by relatively constant precipitation from 1978 to 1993. However, precipitation was below the average from 1985 to 1993, with the exceptions of 1986 and 1990.

Although, seasonal variation is observed in the water-level data for well 18N/02W-07R01 (a Qva aquifer well), the data also indicate a slight decrease from 1972 to 1980. This may be related to declines in precipitation. From about 1980 through 1988 no data were recorded. From 1988 to

1991, the record indicates a slight increase in water level, followed by a slight decrease from 1991 to 1994. This corresponds to a similar pattern of precipitation from 1988 to 1993 (Figure 6-6). Compared to the water levels for the 1970's, the water levels in the 1990's indicate a decline of at least five feet. A proportion of this decline may be related to pumping Olympia wells near Allison Springs.

Year-to-year water-level variations are also observed for the three Qc aquifer wells shown on Figure 6-6. However, the data for well 18N/02W-35B02 indicate a trend of decreasing water levels for the period from 1973 to 1978. The record for this same period for well 18N/02W-35F08 indicates relatively stable water levels. After 1978, there is an apparent trend toward rising water levels in the three Qc wells, although the increase is not as large for well 18N/02W-35F08 as it is for the other two. The aquifer in the vicinity of these wells is the major source of supply for a local industry and water levels near these wells are likely affected by local water demand requirements. Production data are currently not available, but could possibly be provided upon formal request (pers. comm. Pabst Brewey, 12/9/94).

Without sufficiently detailed long-term records of ground-water withdrawals in the vicinity of these four monitoring wells, the relationship between trends in ground-water levels and the trends in ground-water withdrawals cannot be ascertained. In addition, the period of record for the four wells, and the number and spatial distribution of the monitoring wells is not adequate to reliably characterize water-level trends throughout the Deschutes WRIA. In one monitoring well, water-level declines may be related to nearby pumping. Water-level declines near other large-volume withdrawals would be expected, but are not evident. Pumping ground-water *always* causes some water-level decline, but if pumping is steady and less than recharge, then the water levels will eventually stabilize.

6.4 Ground-Water Quality - Environmental Health Consideration

The quality of ground water in the northern part of the Deschutes WRIA is generally good. However, localized and elevated concentrations of certain anthropogenic (man-made or caused) or naturally occurring chemicals in ground-water has limited, or would limit potable water supply development in some areas. The most widespread anthropogenic water-quality problem is seawater intrusion which has been documented by the USGS (1994) in the peninsular areas of the northern part of the WRIA. Seawater intrusion (as indicated by elevated chloride concentrations) has occurred in localized areas of ground-water withdrawals where freshwater aquifers are hydraulic connected with seawater from Puget Sound. The specific areas of elevated chloride concentrations occur within the northernmost third of the three peninsulas, and near McClane Creek where it discharges to Mudd Bay (Figure 6-7). Other isolated areas of elevated chloride occur where wells may be affected by septic systems or by ground water that moves through Tertiary marine rocks. Many of the wells affected by chloride are private or small water-system wells that are located near the interface between freshwater and seawater. This type of water quality problem can be mitigated or avoided by locating wells further from shorelines, and by minimizing production rates.

Other areas of anthropogenic contamination are related to spills, leaks, septic discharge, or application of chemicals to agricultural lands. Volatile organic compounds have contaminated ground water in the lower Deschutes River valley and in the commercial area of Lacey. Petroleum compounds have contaminated ground water in the Airdustrial area northwest of the Olympia airport and numerous other sites in the northern part of the WRIA where petroleum products are bought and sold. Agricultural pesticides have contaminated ground water in two areas along Yelm highway; one south of Pattison Lake and the other south of Lake St. Clair (the Nisqually WRIA). A complete list of contaminated sites throughout the WRIA is provided in the WDOE Confirmed and Suspected Contaminated Sites List and the Leaking Underground Storage Tank (LUST) List.

Nitrate is a common anthropogenic ground-water constituent throughout the WRIA. Nitrogen sources include fertilizers applied on both domestic and agricultural lands, and septic tank discharges in unsewered residential areas. Nearly all ground water in the northern part of the WRIA contains nitrate concentrations well below in the drinking water regulation of 10 mg/L as nitrogen, and most concentrations are less than 5 mg/L. Figure 6-7 shows the locations of wells that have nitrate concentrations greater than 3 mg/L. Most of these elevated concentrations occur in the northeastern part of the WRIA (in the tri-Lakes vicinity) were land use is a mix of agriculture, small hobby farms, and single family homes that use septic systems. Activities associated with each of these land uses can contribute nitrate to ground water.

Areas with elevated concentrations of naturally occurring iron and manganese are located throughout the WRIA. Ground water affected by these constituents is generally pumped from the relatively deep TQu aquifers and locally in the Qal/Qvr, Qva, and Qc aquifers. Although these constituents are currently not considered to affect human health, they are an aesthetic problem because of their staining characteristics. The USGS reports (1994) that dissolved concentrations of iron and manganese in the TQu unit and locally in shallower aquifers are facilitated by low dissolved oxygen concentrations occurring in these units. In addition, the TQu unit may contain abundant fine-grained, iron- and manganese-rich minerals that more easily dissolve, given the geochemical conditions that exist in deep aquifers compared to shallow aquifers.

Radon is an element that the U.S. EPA has proposed for drinking water regulation in 1996. A proposed MCL for radon is 300 picoCuries/liter (pCi/L). The USGS reports that concentrations of radon in 47 wells in the GWMA ranges from <80 to 660 pCi/L and the median value is 410 pCi/L (USGS, 1994).

7 Stream Water Quality and Fisheries Habitat

7.1 Stream-Water Quality

A stream-water-quality assessment of the WRIA was completed to summarize existing water quality data and to provide an overview of water-quality conditions. Data sources used to complete this assessment include the Washington Department of Fish and Wildlife's Washington Rivers Information System (WARIS) database system, the U.S. Environmental Protection Agency (EPA) STORET database, water-quality data from the U.S. Geological Survey (USGS, 1995a) and the Washington Streams catalog. Information was also used from a report completed by the Thurston County Environmental Health Division to identify and discuss non-point source water quality problems in the Deschutes River watershed (Davis et al. 1993). Surface-water quality classifications and water bodies listed on Ecology's "303d" list are also indicated.

7.1.1 Water-Quality Classification

Surface waters in the WRIA are classified in chapter 173-210A WAC for the purposes of establishing water-quality standards for various parameters. All lakes in the WRIA are designated as Lake Class, all feeder streams to lakes are designated Class AA and all other waters in the WRIA are designated as Class A, except for the following segments:

- Henderson Inlet south of Johnson Point: Estuary Class AA
- Budd Inlet South of Priest Point Park: Estuary Class B
- Woodland Creek from the mouth to river mile 11.0: Class AA

7.1.2 Water-Quality-Limited Water Bodies

Ecology periodically submits a list of "water-quality-limited" water bodies of the state to EPA as required by Section 303(d) of the federal Clean Water Act. This 303(d) list contains water body segments that are not expected to meet water quality standards after implementation of technology-based pollution controls (Table 7-1). Fecal coliform and temperature violations caused the greatest number of listings for streams in 1994, while fecal coliform and pH violations were the most common causes for listing of estuaries. Total phosphorus was the most common reason for listing lakes. Water body segments contained in Ecology's May 13, 1994 303(d) list submitted to the EPA are included in this report (Table 7-1).

7.1.3 Water-Quality Assessment

Basin-Wide Conditions

A search of the EPA STORET database was conducted for this report. Search results included a summary of all available water-quality data recorded at stations throughout the Deschutes basin and reported to EPA. The STORET results show that over the periods of record, water-quality violations have occurred with respect to water temperature, dissolved oxygen, pH, copper, cadmium and fecal coliform in the WRIA. These results, along with the state's water-quality criteria, are shown in Table 7-2.

Mainstem Deschutes River

Generally, the mainstem Deschutes River met temperature standards at all stations except two near the communities of Rainier and Vail. Maximum temperatures recorded at these stations were 19° C and 19.2°C, respectively, exceeding the maximum Class A temperature standard of 18°C (Table 7-3). The river is wider and slower than adjacent reaches in this segment, which may reduce canopy cover and allow increased solar heating (Davis et al., 1993). The STORET database indicated a maximum temperature of 22.5°C in the basin between 1959 and 1993.

Dissolved oxygen levels recorded in the mainstem Deschutes River were generally very good. Minimum concentrations recorded were above Class A water quality standards of 8 mg/l at all stations except the station located at river mile (RM) 1.75, near Tumwater Falls (Table 7-3).

Fecal-coliform levels were low in the upper reaches of the watershed and increased in the lower reaches. Three of the seven stations violated Class A fecal coliform standards of 100 colonies/100ml (Davis et al., 1993). The greatest fecal coliform increases were recorded between RM 20.75 and 28.5 and between RM 1.75 and RM 2.0, near the Pabst brewery (Table 7-3). Data collected on the mainstem Deschutes River near the City of Olympia by the USGS indicated maximum fecal coliform level of 1,500 colonies/100ml (U.S. Geological Survey, 1995a).

The state's water-quality standard for turbidity is based on limiting the increase caused by human activity. Because average turbidity values recorded at all stations were well below 50 NTU, the amount of change allowed is less than 5 NTU (Table 7-3). While increases above 5 NTU were recorded, the cause of this change was undetermined due to the limited amount of data (Davis et al., 1993).

Tributaries

In the Thurston County study, water-quality data was collected at 10 tributary stations (see Davis et al. 1993). Results showed that only one tributary, Reichel Creek, located in the mid-reaches of the Deschutes, had a maximum temperature exceeding Class A state standards (Table 7-4). This creek flows through open pasture land where canopy cover has been removed. However, because only two measurements were taken at this station during the warm weather period, these readings may not accurately reflect prevailing conditions.

Average dissolved oxygen concentrations met state standards at all tributary locations. Three tributaries to the Deschutes; Moxlie, Percival and Chambers Creeks; violated state Class A fecal coliform standards (Table 7-4). This was particularly true in the first two creeks, which exceeded state standards both in both dry and wet seasons. The data suggest that continuous sources of bacteria are present in these drainages. All stations are located in the lower one-third of the watershed and receive runoff from urban and agricultural land uses.

Measured turbidity values were highest in Chambers and Reichel Creeks and lowest in the upper watershed. Due to the limited amount of data, the significance of this data was undetermined (Davis et al., 1993). Chambers Creek, with mixed agricultural and urban land uses in its watershed, had the highest nitrate concentrations in the WRIA, with an average of 1.3 mg/l (Table7-4). The Thurston County study suggested that this may have been due to contaminated ground water in the area (Davis et al., 1993).

Overall, creeks flowing through urban areas of the basin showed the greatest degree of contamination, both in routine ambient and in intensive storm-water monitoring. The five tributaries located in the upper portions of the basin had lower pollutant levels than those in the lower watershed.

Estuarine Areas

Fecal coliform bacteria counts were violated at three of the six Budd Inlet stations measured. Dissolved oxygen measurements at many stations on the inlet indicated supersaturated conditions which is indicative of a highly productive system. Sediment samples in the Inlet met all state standards for metals (Davis et al., 1993).

7.2 Fisheries Assessment

This fisheries assessment of the Deschutes WRIA summarizes existing information on fish abundance and distribution and fish-habitat conditions. Data sources used to complete this assessment include the State Salmon and Steelhead Stock Inventory (SASSI, 1994), the Washington Streams catalog (Washington Department of Fisheries, 1975) and the WARIS database.

7.2.1 Salmon Distribution, Abundance and Stock Status

The SASSI is part of a statewide effort to identify distinct salmon and steelhead stocks and determine their status. A review of the SASSI was made to determine the abundance and distribution of genetically distinct salmon stocks in the Deschutes WRIA (SASSI, 1994). Stocks identified as depressed or critical are close to or below the population size where permanent loss of distinct genetic material is a risk. The SASSI report defines a stock by the following criteria:

- distinct spawning distribution
- distinct run-timing distribution
- distinct biological characteristics (genetics, size, age structure, etc.)

Chinook Salmon

One distinct chinook stock, the South Sound Summer/Fall stock, is known to spawn in the Deschutes WRIA. This stock is composed of a mixture of Green River hatchery stock and natural chinook stock spawning in a number of south Puget Sound tributaries, including the Deschutes River. Chinook from south Puget Sound tributaries were aggregated into a single stock because natural stocks in these streams are all supplemented by regular releases of hatchery stock. Although sustained natural production occurs in some streams, the status of this stock depends largely on hatchery production. The status of this stock is healthy. Escapement levels have ranged from 9,600 to 19,700 fish per year with an average of 19,700 natural spawners (SASSI, 1994).

Spawning chinook are known to use suitable stretches throughout the accessible length of the Deschutes River, with concentrated spawning occurring in reaches between the communities of Tumwater and Vail. Of the tributaries, only Percival Creek is known to support significant numbers of spawning chinook. Use of other drainages in the WRIA by chinook is minimal since each of these streams exhibits very low flows during normal chinook migration and spawning periods. Juvenile chinook rear along the total length of the mainstem Deschutes and in the tributary streams inhabited by spawning adults. Extensive rearing also takes place in Capitol Lake (Washington Department of Fisheries, 1975).

Adult chinook spawning migration begins in late July and is usually terminated by mid-November. Actual spawning begins in mid-September and is completed by late November. The majority of fry rear in the system for about three months prior to seaward migration. Major outmigration occurs in the high spring runoff between March and June (Washington Department of Fisheries, 1975).

Coho Salmon

South Sound coho use streams draining into the inlets and passages throughout south Puget Sound, including Henderson and Eld Inlet. There have been substantial hatchery releases of coho in the area. As a result of uncertainties regarding the distinctions between the temporal or physical spawning distributions of native and introduced stocks, the stock in this area has been designated as a probable mixture of native and non-native stocks. Distinction of multiple stocks in South Sound coho are dependent on geographic spawning separation and the result of subjective judgements regarding the probability of spawner interchange between drainages (SASSI, 1994).

The "south Puget Sound tributaries" coho stock is defined only on the basis of geographic distribution and does not exhibit any documented distinct biological characteristics. This area has been heavily planted with hatchery coho, and fingerling and/or fry releases have been made in almost every year since the 1950s. The stock is considered healthy. The stock is being affected by increasing timber harvesting, agriculture, and urban development, and there is evidence of widespread habitat degradation. Because of development pressures in the region, future coho production will depend on successful maintenance of natural habitat-forming processes and restoration of habitat affected by past land use (SASSI, 1994).

The Deschutes coho stock does not exhibit any distinct biological characteristics. This stock is an introduced non-native stock, and fingerlings and yearlings have been released since the late 1940s. The Deschutes River above Tumwater Falls was inaccessible until construction of a fish passage facility in 1954. The stock status is considered healthy. As with the south Puget Sound tributaries coho, habitat used by the Deschutes coho is being affected by rapid development in the Deschutes River basin (SASSI, 1994).

Coho spawning occurs in almost every stream where suitable conditions permit. Spurgeon and Percival Creeks are of particular importance. Rearing takes place throughout the watershed as well as in Capitol Lake and estuarine areas. Adults enter the watershed from early to mid-September and spawn beginning in mid-October. Spawning is usually completed by late December. Juveniles generally remain in the watershed for more than a year, outmigrating from late February to mid-April (Washington Department of Fisheries, 1975).

Chum Salmon

Chum salmon using the South Sound region have been divided into nine distinct stocks based on geographic separation and run timing differences. Two of these stocks, the Henderson Inlet and Eld Inlet stocks, use streams in the Deschutes WRIA. The Eld Inlet stock was identified with a high level of certainty as a separate stock through electrophoretic analysis and because spawning grounds are geographically separated. The Henderson Inlet stock was identified with moderate certainty because separation was based only on geographic distribution of spawning grounds (SASSI, 1994).

The primary spawning tributaries to Eld Inlet in the WRIA are McLane and Swift Creeks. Spawning occurs in late November to early January. Hatchery plants were made in McLane Creek using Hood Canal chum from 1976 through 1983, but it is not known whether these plants were successful. Because hatchery plants were not made in Swift Creek, this stock should be considered native. The stock status is healthy. Escapement estimates since 1968 have ranged from 4,300 to 37,400 fish. Stock abundance is stable and shows signs of increasing (SASSI, 1994).

Woodland and Woodward creeks are the primary spawning tributaries on Henderson Inlet. Elson and Minter Creek hatchery chum stocks have been planted in both creeks, resulting in a mixed stock from a composite production. However, Woodland Creek may still support a native run. The stock status in unknown. Habitat degradation from development in this basin has occurred, and escapement began to decline in the 1970s. Only a few spawner surveys have been conducted since 1980 (SASSI, 1994).

Chum salmon do not readily ascend fishways and therefore do not often reach spawning grounds on the Deschutes River. Adult chum enter the basin in October through November. Spawning occurs from mid-November through most of December. Following incubation and fry emergence juveniles outmigrate from mid- to late February into May (Washington Department of Fisheries, 1975).

Steelhead

Six winter steelhead stocks have been identified in south Puget Sound. Two of these stocks, the Deschutes and the Eld Inlet, use habitat in the WRIA. There is little or no information whether South Puget Sound stocks are genetically distinct. The stocks are identified separately due to the geographical isolation of spawning populations (SASSI, 1994).

Winter steelhead runs in the Deschutes River developed from early-returning stock from Chambers Creek near Steilacoom. The stock status is healthy, and the stock is managed primarily to provide a recreational harvest since the stock originated from hatchery stocks. Harvest data from steelhead permit cards is showing a short-term decline in harvest levels from a high of 81 in 1987 when the cards were first used (SASSI, 1994).

Wild winter steelhead in Eld Inlet are native to the drainages and are a distinct stock based on geographical distribution. Spawning populations in the WRIA are found only in McLane Creek. The stock is comprised of a historically small number of steelhead, and the stock status is unknown. Spawning escapement is not monitored, and sport harvest data are not available.

Resident Fish

In addition to fresh-water fish species typically inhabiting western Washington streams, species of concern found in the WRIA include Dolly Varden/bull trout, Olympic mudminnow, pygmy whitefish, and sea-run cutthroat. These species are present in suitable habitat in stream systems throughout the basin. Major tributaries where these species are not reported present include Spurgeon Creek, Indian Creek, Pipeline Creek, Fall Creek, and Lincoln Creek (Washington Department of Fish and Wildlife, 1994).

Critical Spawning Habitat

Critical spawning habitat has been identified by the WDFW in Percival Creek and upper Spurgeon Creeks. Critical reaches are areas which provide habitat necessary for the perpetuation of regional fish populations (Washington Department of Fish and Wildlife, 1994).

7.2.2 General Habitat Description and Limiting Factors

The upper 11 miles of the Deschutes River contain numerous cascades with a moderately steep gradient and few good quality pool-riffle sections. The remainder of the river contains considerable excellent quality pool-riffle habitat interspersed with occasional rapid sections. The majority of this lower river area is highly suitable for anadromous fish. Much of the land use along this area is farmland, but is undergoing rapid urbanization. A few short tributaries enter the Deschutes River along this stretch, providing some additional fish habitat (Washington Department of Fisheries, 1975).

The Deschutes flows over a series of falls at river mile 2.0 near Tumwater. These falls were laddered by the Washington Department of Fisheries in 1954, opening the river to anadromous fish. Immediately below the falls the river runs through the 333-acre Capitol Lake, an artificial impoundment. Entering the Lake from the southwest is Percival Creek, one of the WRIA's more significant spawning and rearing tributaries (Washington Department of Fisheries, 1975).

Woodland and Woodward Creeks present gentle to moderate gradients throughout their lengths, with stream widths averaging 2 to 5 yards. These streams have good pool to riffle ratios with gravel beds. They also have considerable fine material and sand and take on slough-like conditions as they approach the sound. McLane Creek is also one of the more significant salmon production streams in south Puget Sound.

Limiting Factors

Within the Deschutes WRIA, limiting factors include occasional flooding, low summer flows, intermittent debris or beaver dams and water-quality problems. Flooding problems are mainly limited to the mainstem Deschutes, where floods occasionally destroy salmon spawning or rearing habitat. Logging activities in the upper basin may intensify intermittent runoff, increasing the magnitude of short-duration floods. Seasonal low flows are a limiting factor throughout the watershed, especially where land clearing has occurred. The diversion of water from streams, for municipal, agricultural, or industrial purposes aggravates low flow conditions in virtually all streams in the basin. There is also concern that Capitol Lake is rapidly silting in, which could reduce rearing capacity (Washington Department of Fisheries, 1975).

8 References

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Table 2-1 Land-Cover Statistics for the Deschutes WRIA

Class	Description	Acreage	Percent
0	Unclassified	414	0.24%
11	low density built-up and other developed	15,573	9.02%
12	high density built-up	374	0.22%
21	active agriculture	491	0.28%
24	other open agricultural land	462	0.27%
34	alpine cover	26	0.02%
35	other natural cover	75,599	43.78%
41	deciduous forest land	3,184	1.84%
42	coniferous forest land	65,268	37.80%
43	mixed forest land	7,255	4.20%
71	bare soil, gravel and sandy areas	4,024	2.33%
74	bare exposed rock	7	0.00%
90	perennial snow and ice	8	0.00%
	total for WRIA	172,685	100.00%

Notes:

1) Data source is satellite imagery, Puget Sound Regional Council, August 10, 1992.

Table 7-1 Water-Quality-Limited Water-Body Segments in the Deschutes WRIA

Waterbody Segment Number	Water Body	Parameter in Violation
WA-13-0010	Henderson Inlet	Fecal Coliform
WA-13-0020	Budd Inlet (Outer)	Fecal Coliform
		Dissolved Oxygen
		Total Nitrogen
WA-13-0030	Budd Inlet (Inner)	PAH
		Dioxin
		Petroleum Hydrocarbons
		Metals
		Phthalates
		Dibenzofuran
		PCBs
		Sediment Bioassay
		Benzo(a) Anthracene
		Benzo(b) Fluorene
		Benzo(k) Fluorene
		Chrysene
		Dissolved Oxygen
		Total Nitrogen
		Fecal Coliform
WA-13-1010	Deschutes River	Temperature
		Fecal Coliform
WA-13-1020	Deschutes River	Temperature
WA-13-1024	Huckleberry Creek	pH
WA-13-1500	Woodland Creek	Temperature
		Fecal Coliform
		Dissolved Oxygen
		Turbidity
WA-13-9200	Ward Lake	PCB-1260

Table 7-2 EPA STORET Water-Quality Database Search Results for the Deschutes River Watershed (HUC 17110016)

Parameter	Sample Size	Mean	Maximum	Minimum	Beginning/End Date Of Collection	WAC 246-290-310 Drinking Water Standards	WAC 173-201A Water Quality Standards	
							Class AA	Class A
Water Temp. (°C)	672	10.6	22.5	1.6	7/59 to 9/93	None	16	18
Turbidity (NTU)†	74	3.4	22	0.7	8/86 to 9/93	< 1 unit chg.	<5 unit chg.	<5 unit chg.
Diss. Oxygen (mg/l)	630	96.3	131	0	7/59 to 9/93	None	>9.5	> 8
pH	2	7.7	9.4	6.1	7/59 to 9/93	None	6.5-8.5	6.5-8.5
Fecal Coliform (/100ml)	297	44	600	0	10/74 to 9/93	0	50	100
NO_2 and NO_3 (mg/l)	340	0.3	0.8	0	10/74 to 9/93	0.1 (NO_2-N); 10.0 (NO_3-N)	None	None
Ammonia (mg/l)	583	0.1	3	0	10/71 to 9/93	None	24‡	
Copper (ug/l)	14	22.9	90	0	10/62	1300**	5.3*	
Lead (ug/l)	11	5.6	10	1	8/77 to 10/81	15**	13.6*	
Zinc(ug/l)	14	1.6	20	0	10/62 to 6/89	5000	40.5*	
Mercury (ug/l)	11	0.5	1	0.2	8/77 to 10/81	2	2.4	
Cadmium (ug/l)	11	1.7	5	1	8/77 to 10/81	5	.96*	
Chromium	16	3.8	10	0	6/67 to 10/81	100	696.9*	

†Nephelometric Turbidity Units
* Acute standards based on a recorded hardness of 32.8.
‡ Total ammonia criteria for 15 C and a pH of 7.0. For the same conditions, the unionized standard is 0.0066mg/l.
**Action Level based on monitoring throughout a water system.

Table 7-3 Water-Quality Measurements Taken on the Mainstem of the Deschutes River

	Location						
Parameter	**RM 1.75**	**RM 2.0**	**RM 5.0**	**RM 10.5**	**RM 20.75**	**RM 28.5**	**RM 36.5**
Temperature (°C, min/max)	4-16	4.6-17.1	4.5-14.2	4.9-17	3.9-19	3.5-19.2	2-14.9
Dissolved Oxygen (mg/l, min/max)	6.4-14.4	9.9-14	9.4-13.2	9.6-13.2	8.8-13.8	9.2-13.7	9.8-14.2
Fecal Coliform (/100ml, min/max) %>200	15-1300 40	14-310 14	0-290 10	0-260 20	0-125 0	5-215 10	0-85 0
Mean Turbidity (NTU)	15.8	20.1	15.8	14.2	16.8	14.0	7.7
Mean Nitrate+ Nitrite (mg/l)	.61	.62	.64	.48	.45	.35	.17
Mean Ammonia (mg/l)	.02	.02	.02	.02	.02	.03	.04

Source: Davis et al. 1993

Table 7-4 Water-Quality Measurements Taken on Deschutes River Tributaries

	Tributary									
Parameter	**Moxlie**	**Percival**	**Chambers**	**Spurgeon**	**Reichel**	**Huckleberry**	**Thurston**	**Little Deschutes**	**Lincoln**	**Hard**
Temperature (°C, min/max)	6-14	3.5-17	4.9-11	3-14.5	1.8-20	1.8-16.5	2.8-13	1.8-16	5-13.8	2.1-13.5
Dissolved Oxygen (mg/l, min/max)	8.1-12.5	8.8-14.6	9.0-12.8	8.8-14.1	8.7-12.6	7.6-14	10-13.8	9.5-14.5	9.7-12.6	9.7-14.7
Fecal Coliform (/100ml, min/max) %>200	5-9375 30	0-6875 20	0-1971 20	10-390 10	18-790 10	0-10 0	0-10 0	0-65 0	0-13 0	0-25 0
Mean Turbidity (NTU)	7.4	5.8	11.1	6.6	18.9	4.2	2.5	6.0	1.3	.4
Mean Nitrate+ Nitrite (mg/l)	.74	.30	1.3	.36	.38	.31	.08	.19	.02	.04
Mean Ammonia (mg/l)	.05	.03	.06	.07	.02	.04	.04	.03	.07	.05

Source: Davis et al. 1993

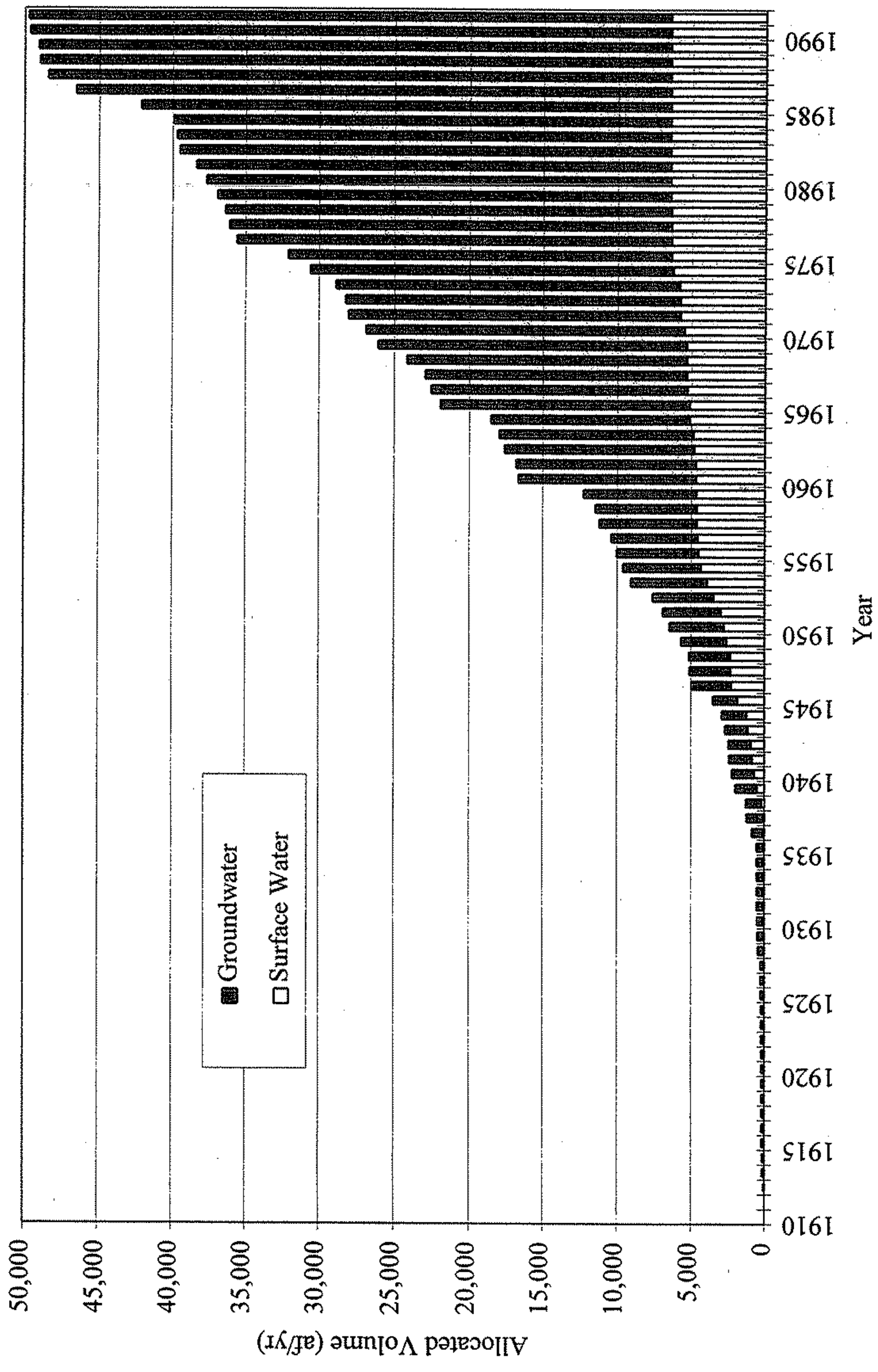


FIGURE 3-2

Water Rights Versus Time

Initial Watershed Assessment Program
Deschutes Basin

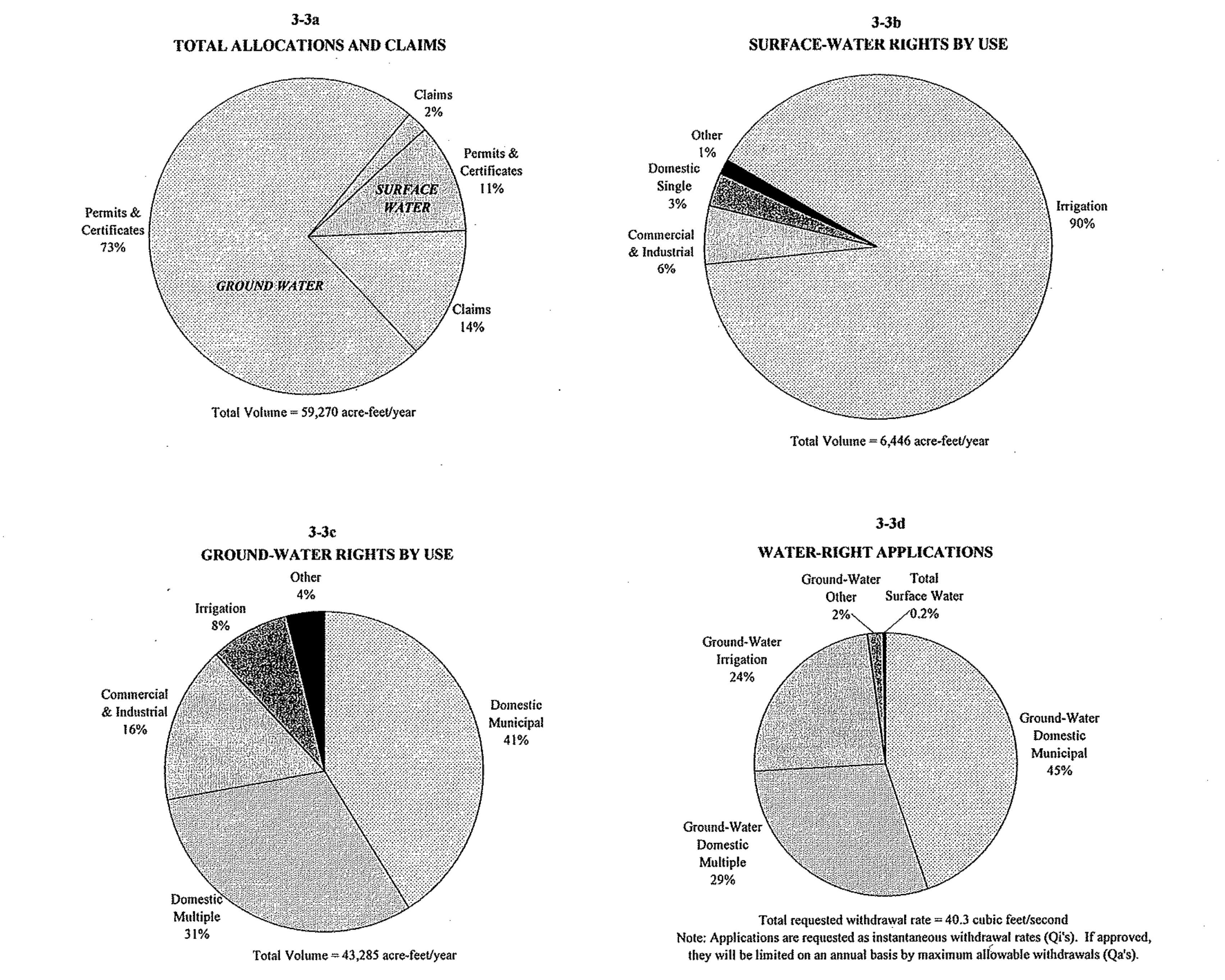


FIGURE 3-3(a-d)

Total Allocations and Claims, Surface-Water Rights, Ground-Water Rights, and Water-Right Applications

Initial Waterhed Assessment Program
Deschutes Basin

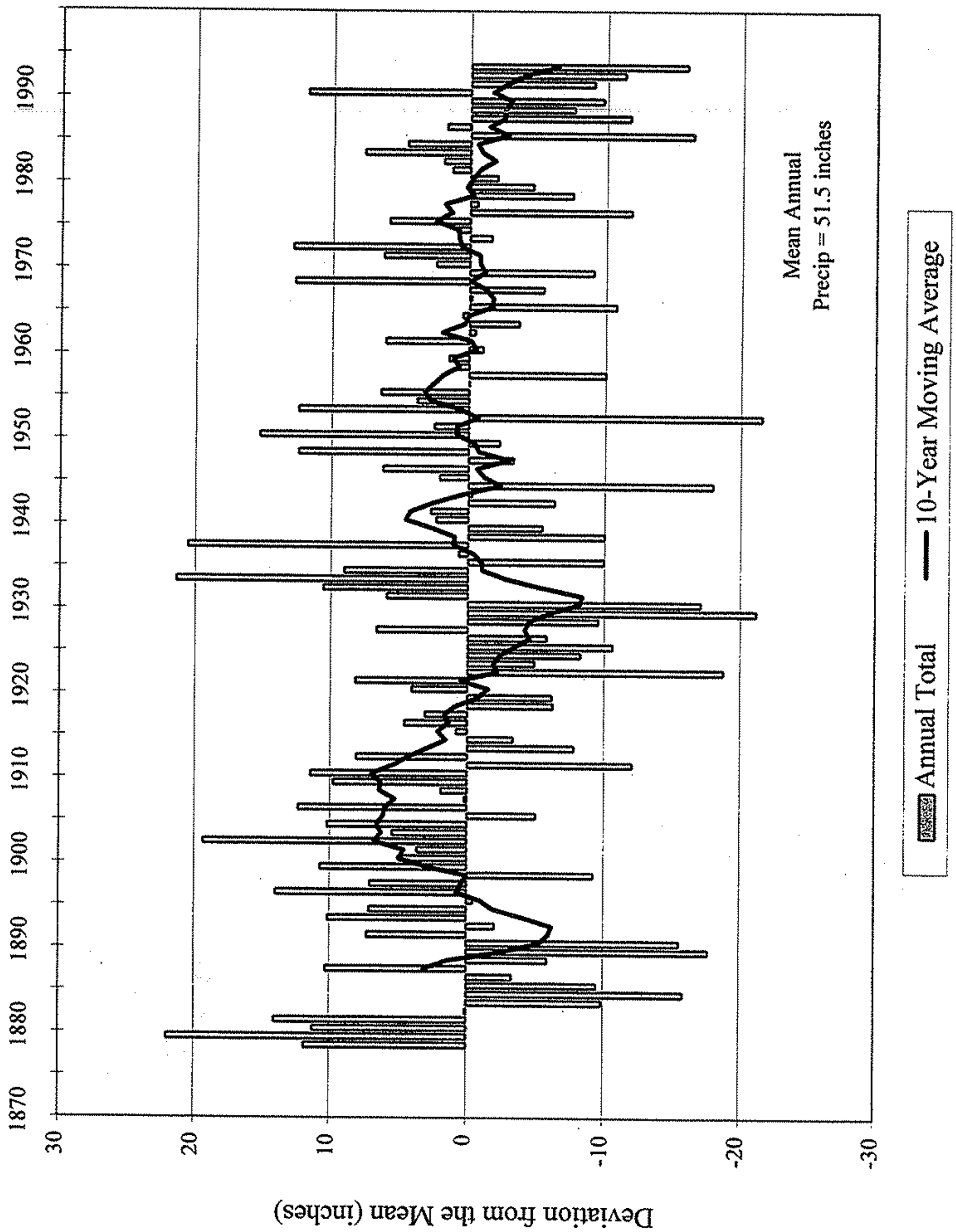


FIGURE4-2

Annual Precipitation at Olympia

Initial Watershed Assessment Program
Deschutes Basin

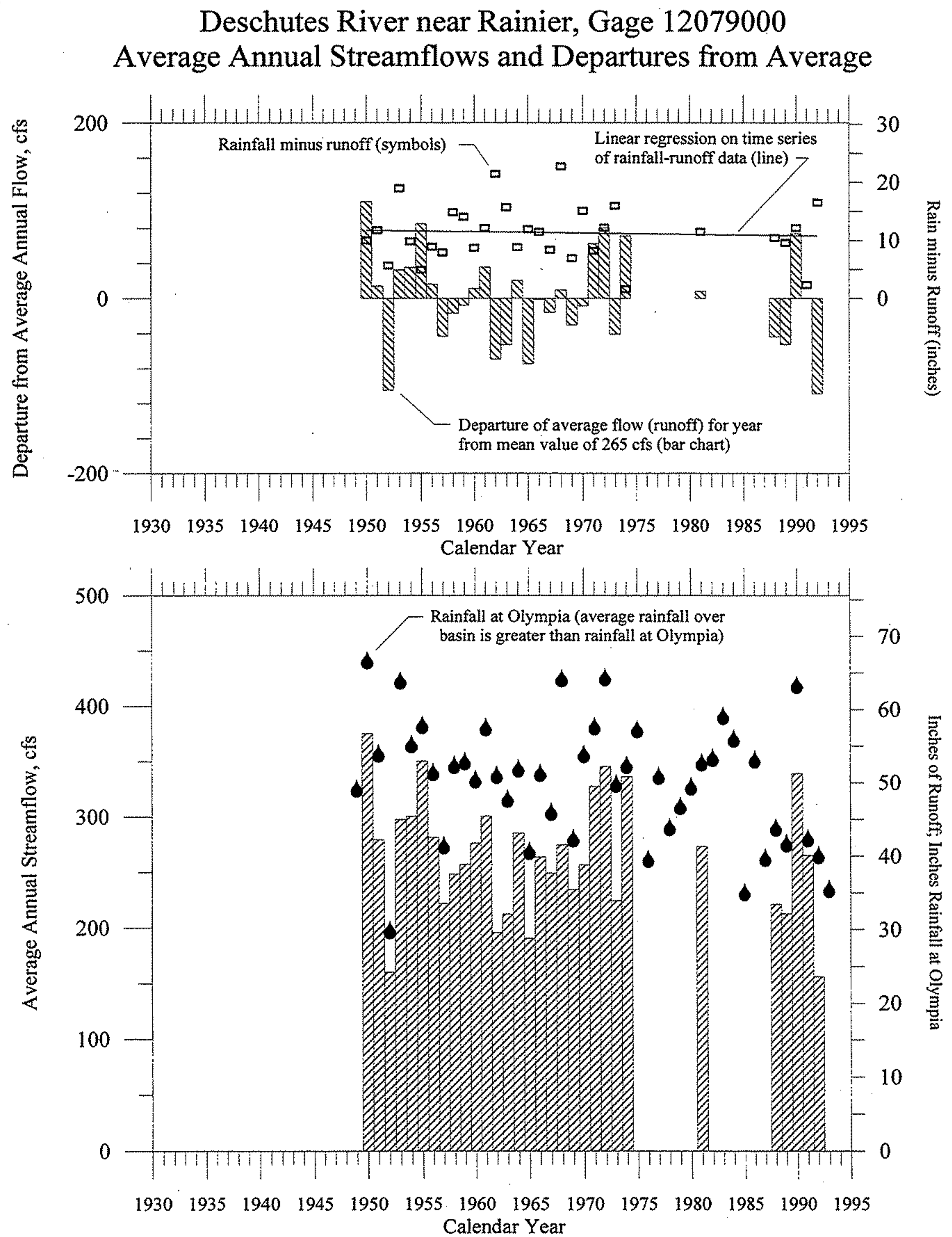


FIGURE 5-1
Average Flows and Trends Analysis
Deschutes River near Rainier
Basin Area 90 sq. mi.

Initial Watershed Assessment Program
Deschutes Basin

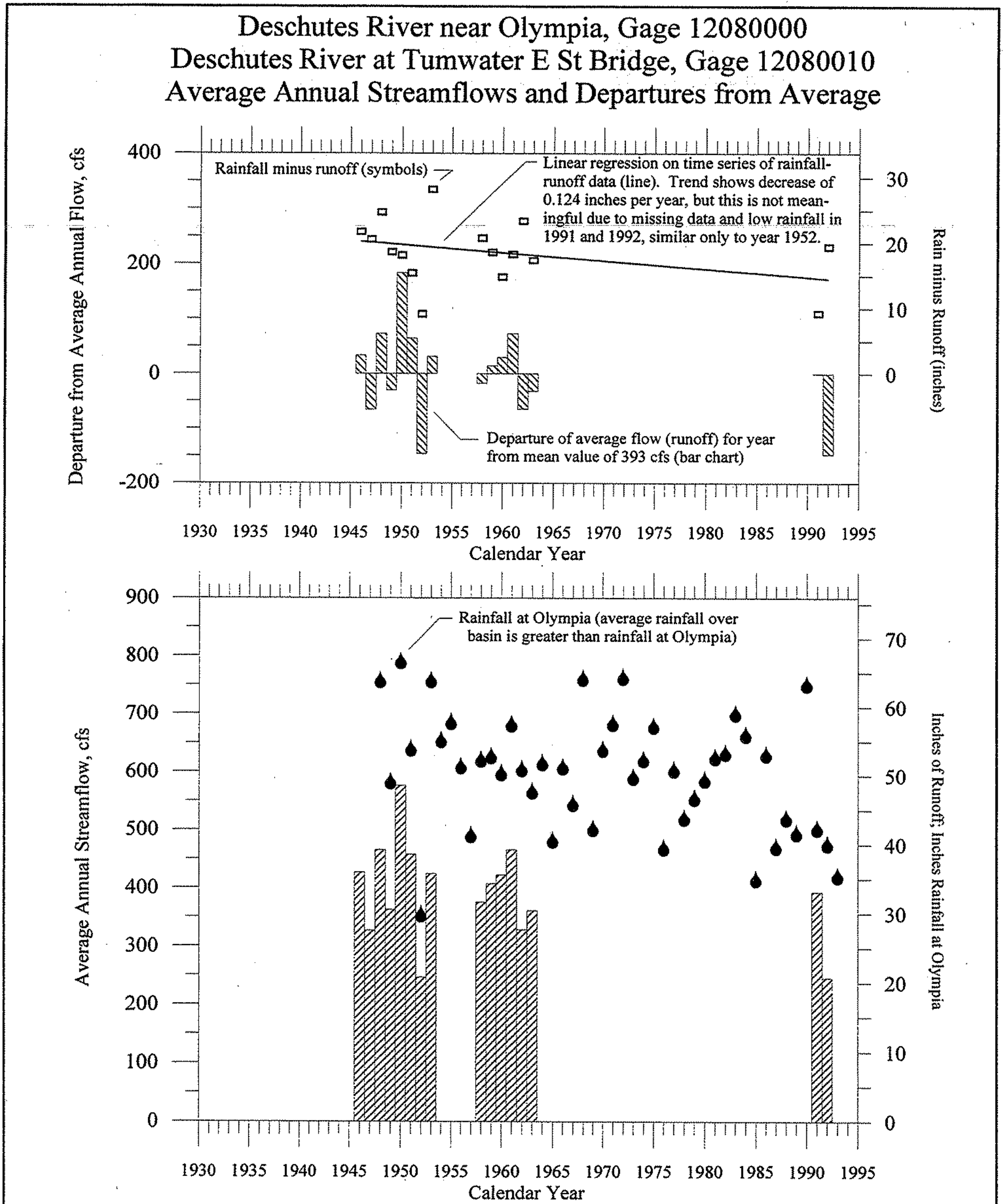


FIGURE 5-2
Average Flows and Trends Analysis
Deschutes River near Olympia
Basin Area 161 sq. mi.

Initial Watershed Assessment Program
Deschutes Basin

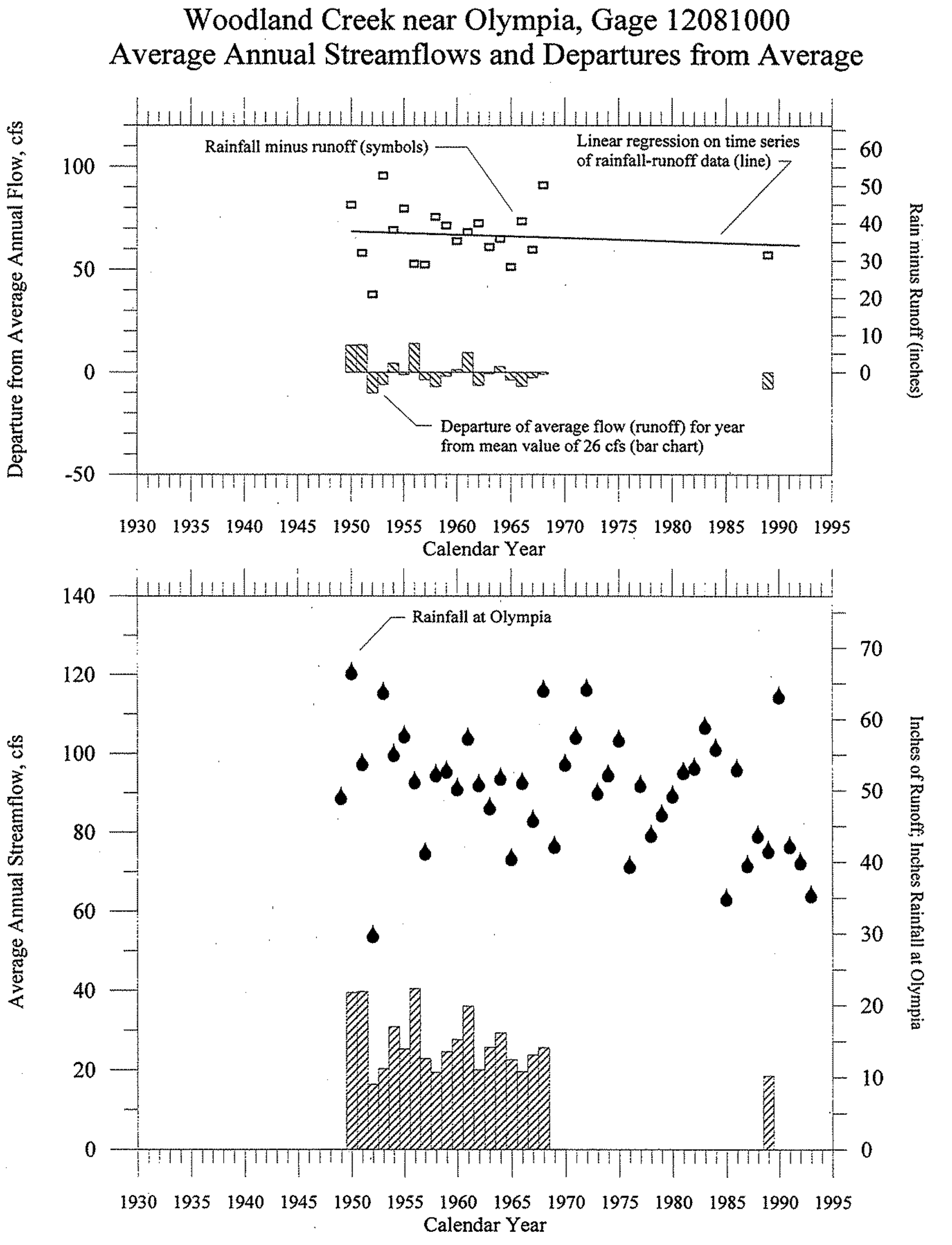


FIGURE 5-3
Average Flows and Trends Analysis
Woodland Creek near Olympia
Basin Area 25 sq. mi.

Initial Watershed Assessment Program
Deschutes Basin

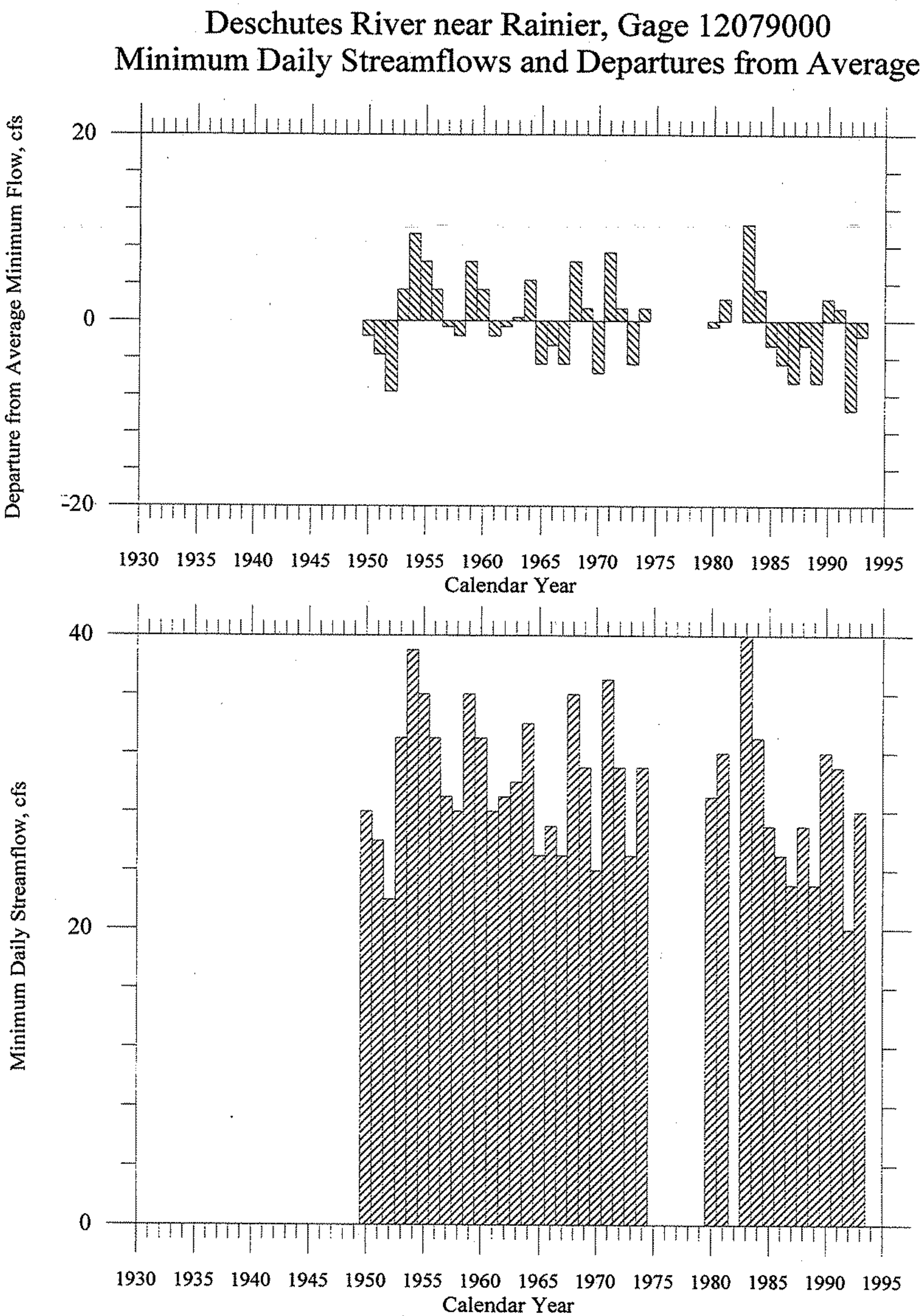


FIGURE 5-4
Minimum Flows and Trends Analysis
Deschutes River near Rainier
Basin Area 90 sq. mi.

Initial Watershed Assessment Program
Deschutes Basin

Deschutes River near Olympia, Gage 12080000 (to 1964)
Deschutes River @ Tumwater E Street, Gage 12080010 (from 1990)
Minimum Daily Streamflows and Departures from Average

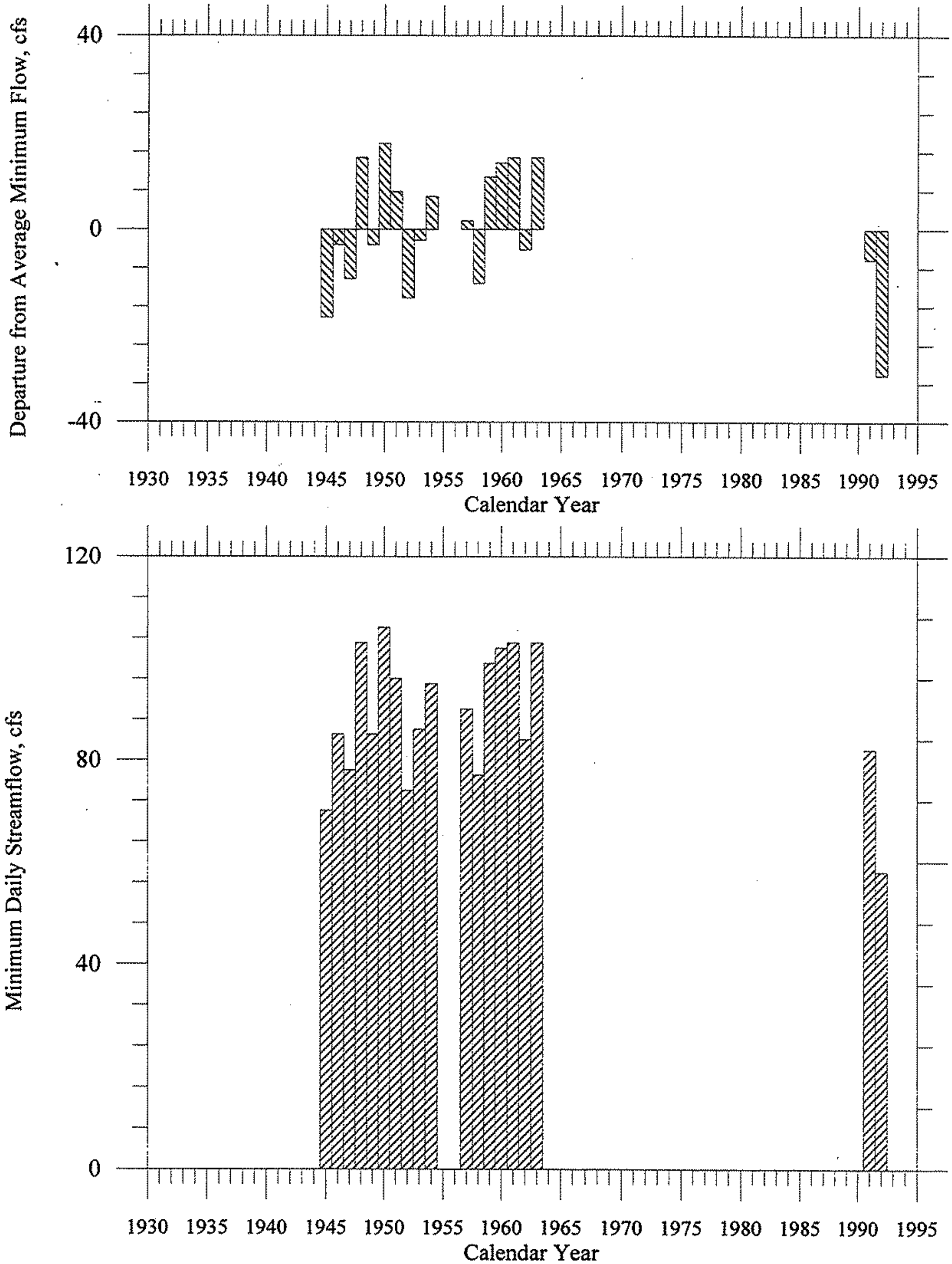


FIGURE 5-5
Minimum Flows and Trends Analysis
Deschutes River near Olympia
Basin Area 161 sq. mi.

Initial Watershed Assessment Program
Deschutes Basin

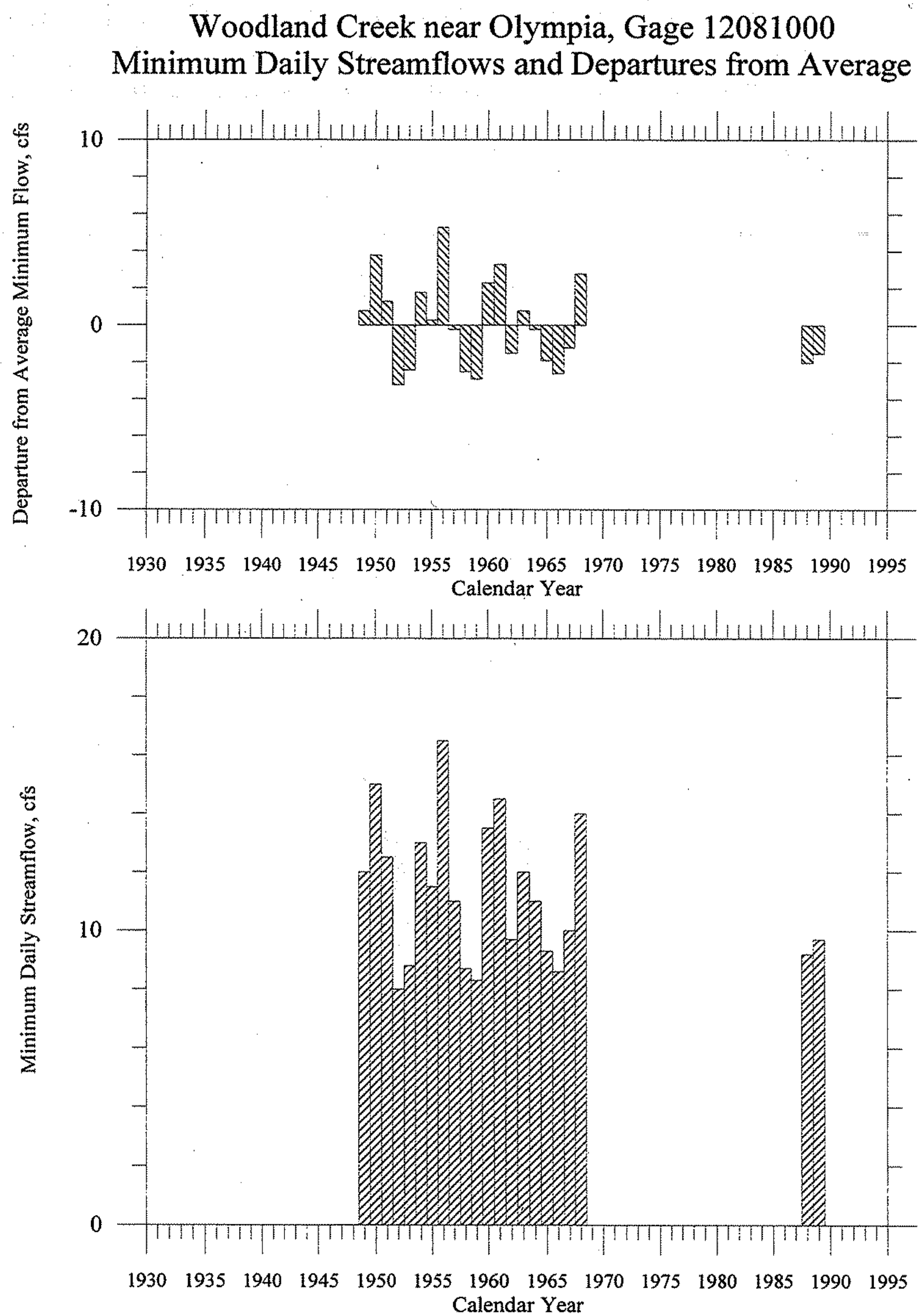


FIGURE 5-6
Minimum Flows and Trends Analysis
Woodland Creek near Olympia
Basin Area 25 sq. mi.

Initial Watershed Assessment Program
Deschutes Basin

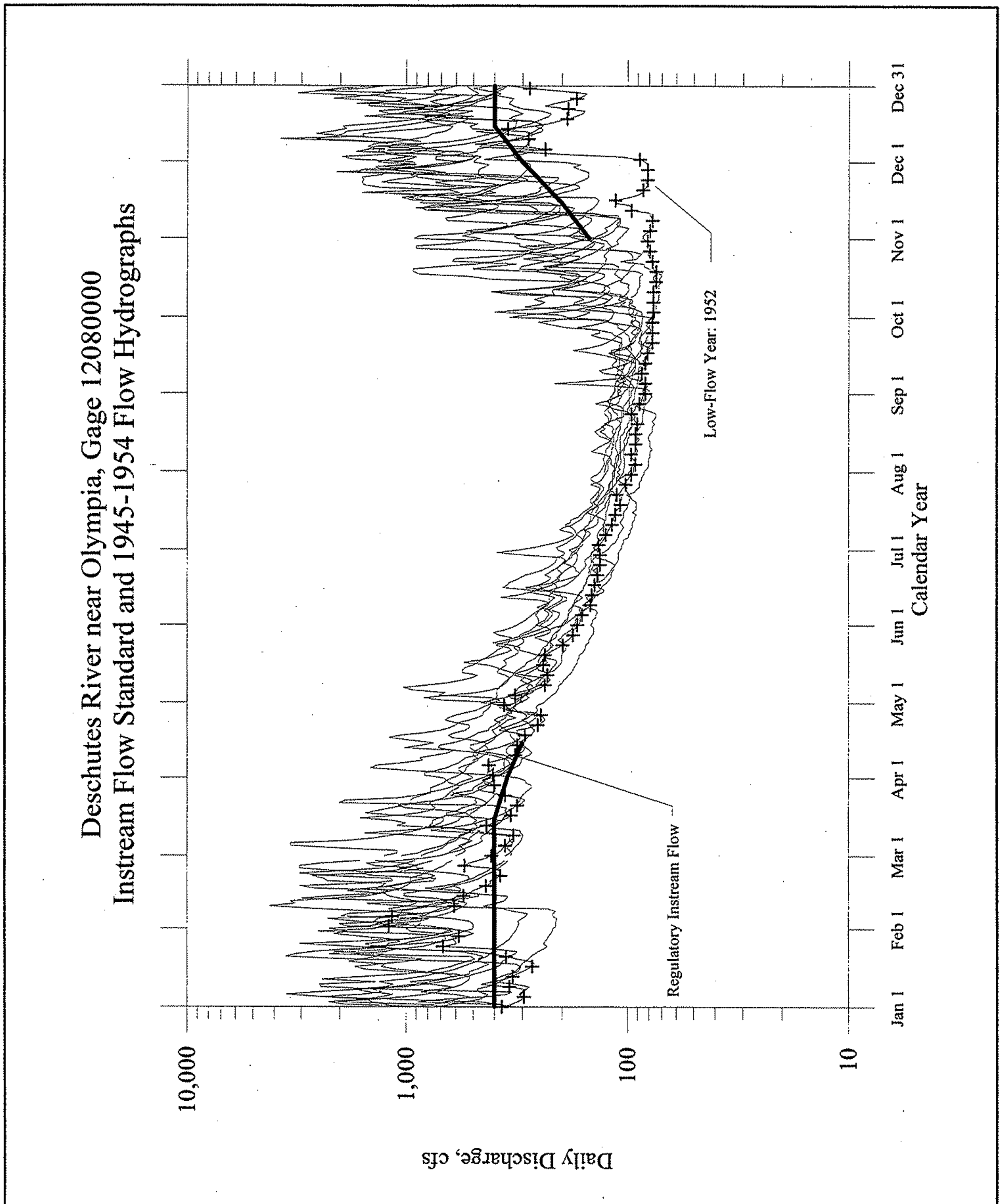


FIGURE 5-7
Instream Flows and Actual Flows
Deschutes River near Olympia
Early Flow Hydrographs

Initial Watershed Assessment Program
Deschutes Basin

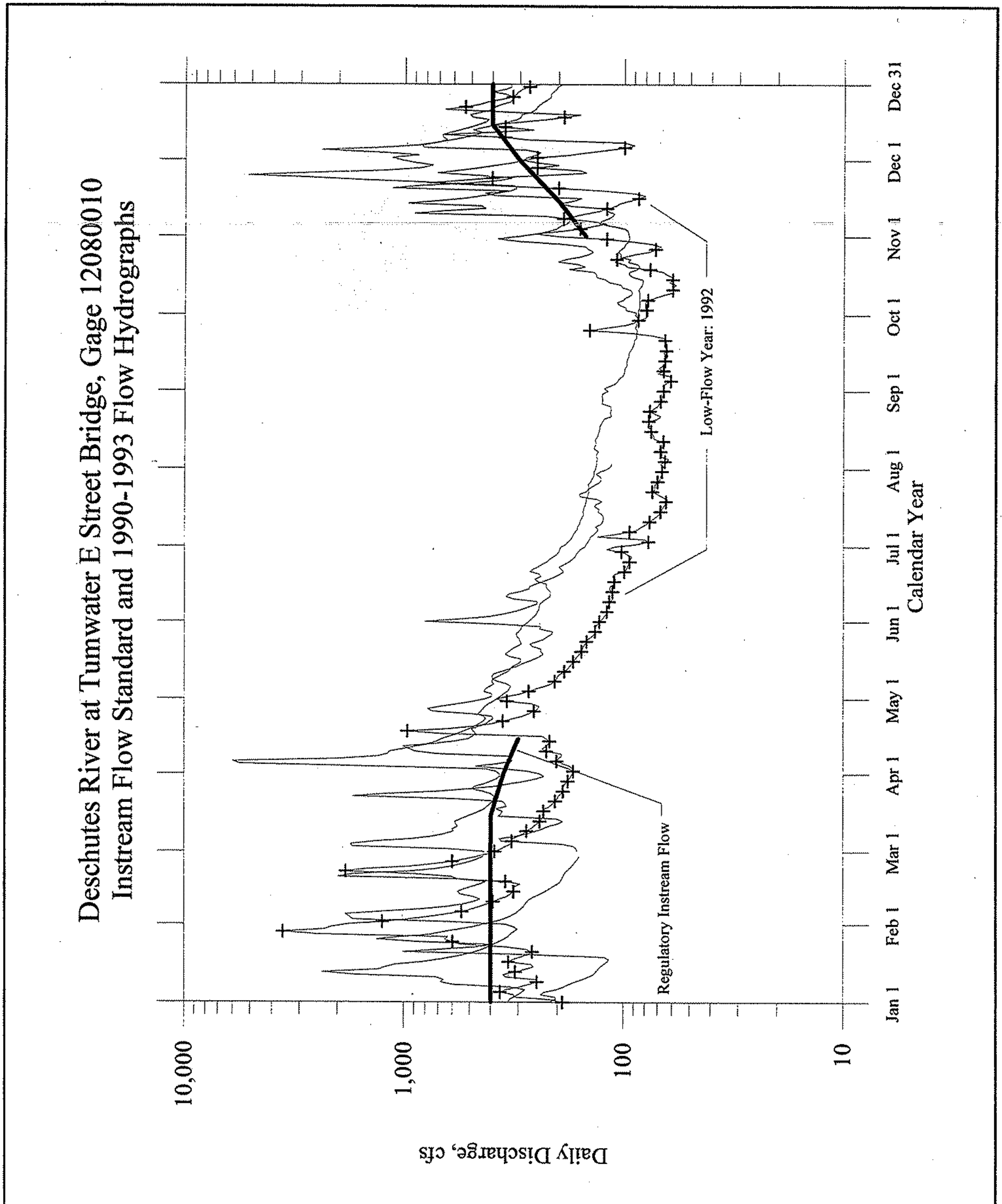


FIGURE 5-8
Instream Flows and Actual Flows
Deschutes River near Olympia (Tumwater)
Recent Flow Hydrographs

Initial Watershed Assessment Program
Deschutes Basin

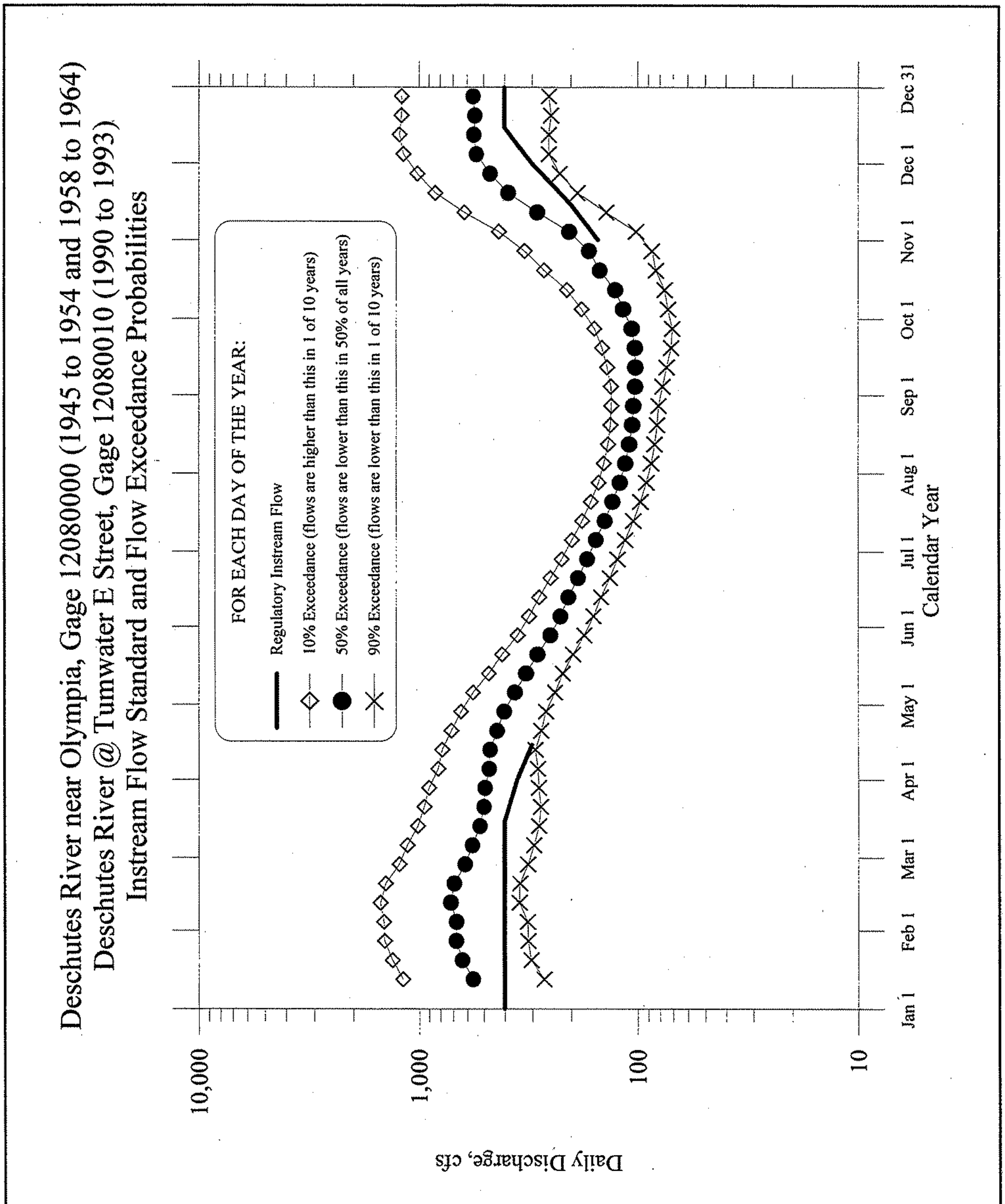
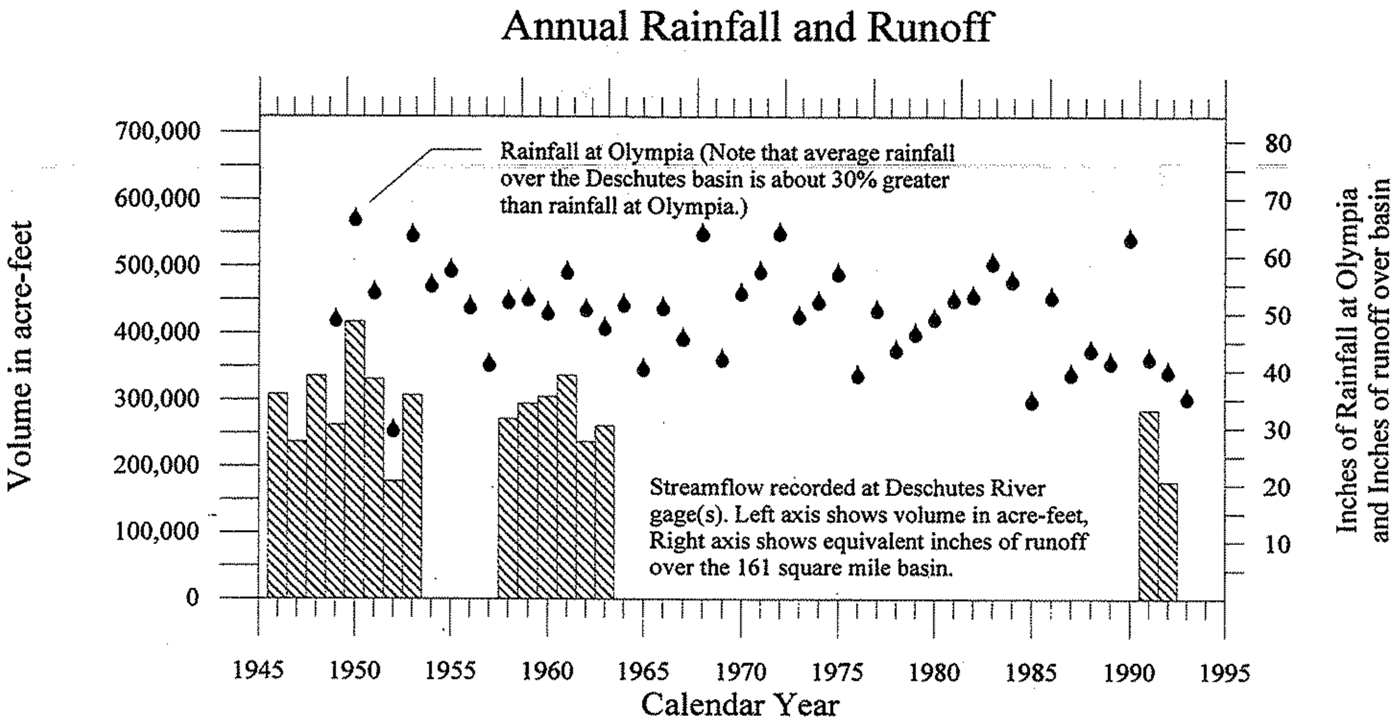


FIGURE 5-9
Instream Flows and Flow Exceedance Probabilities Deschutes River near Olympia (Tumwater)

Initial Watershed Assessment Program
Deschutes Basin

Annual Rainfall, Runoff, Flows and Summer Allocations
Deschutes River near Olympia



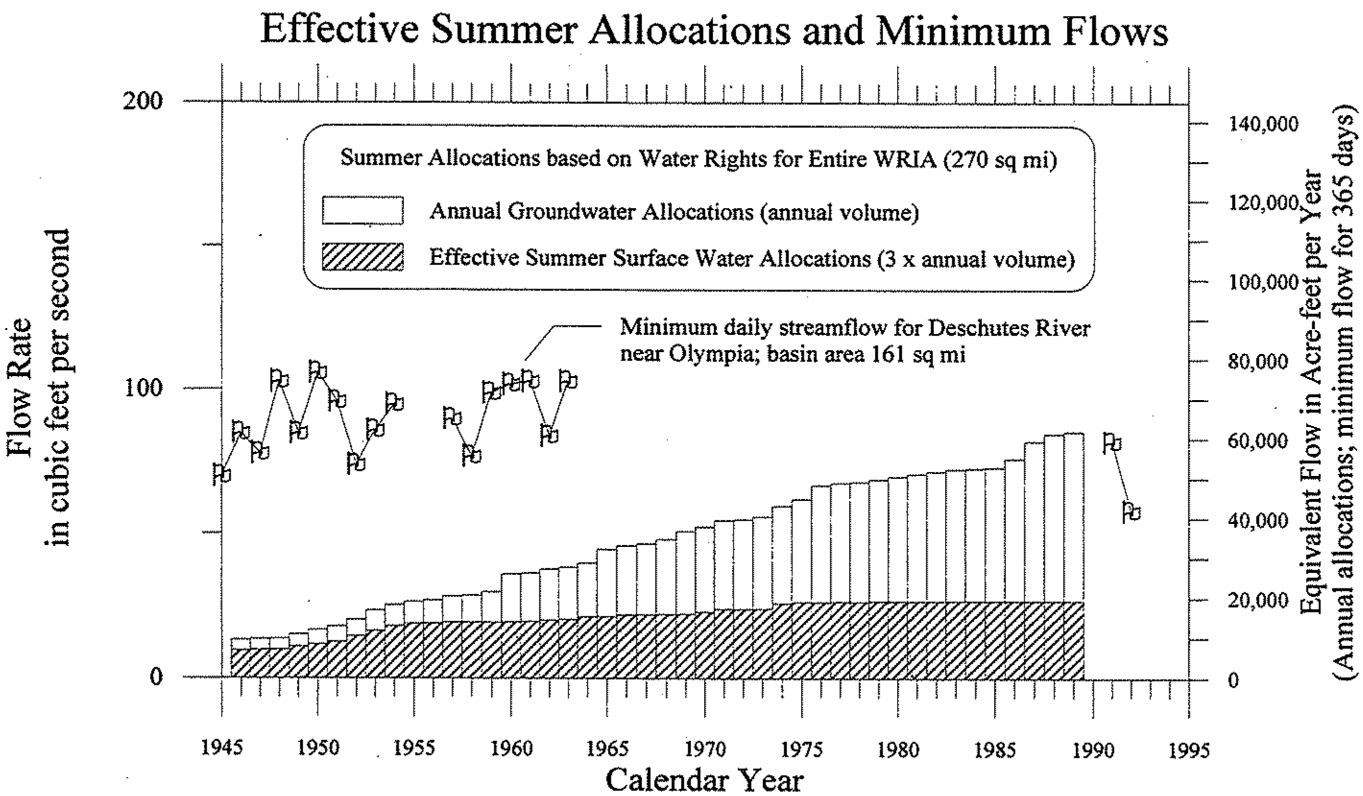


FIGURE 5-10
Rainfall, Flows, and Water Rights
Deschutes River near Olympia
Deschutes Basin WRIA

Initial Watershed Assessment Program
Deschutes Basin

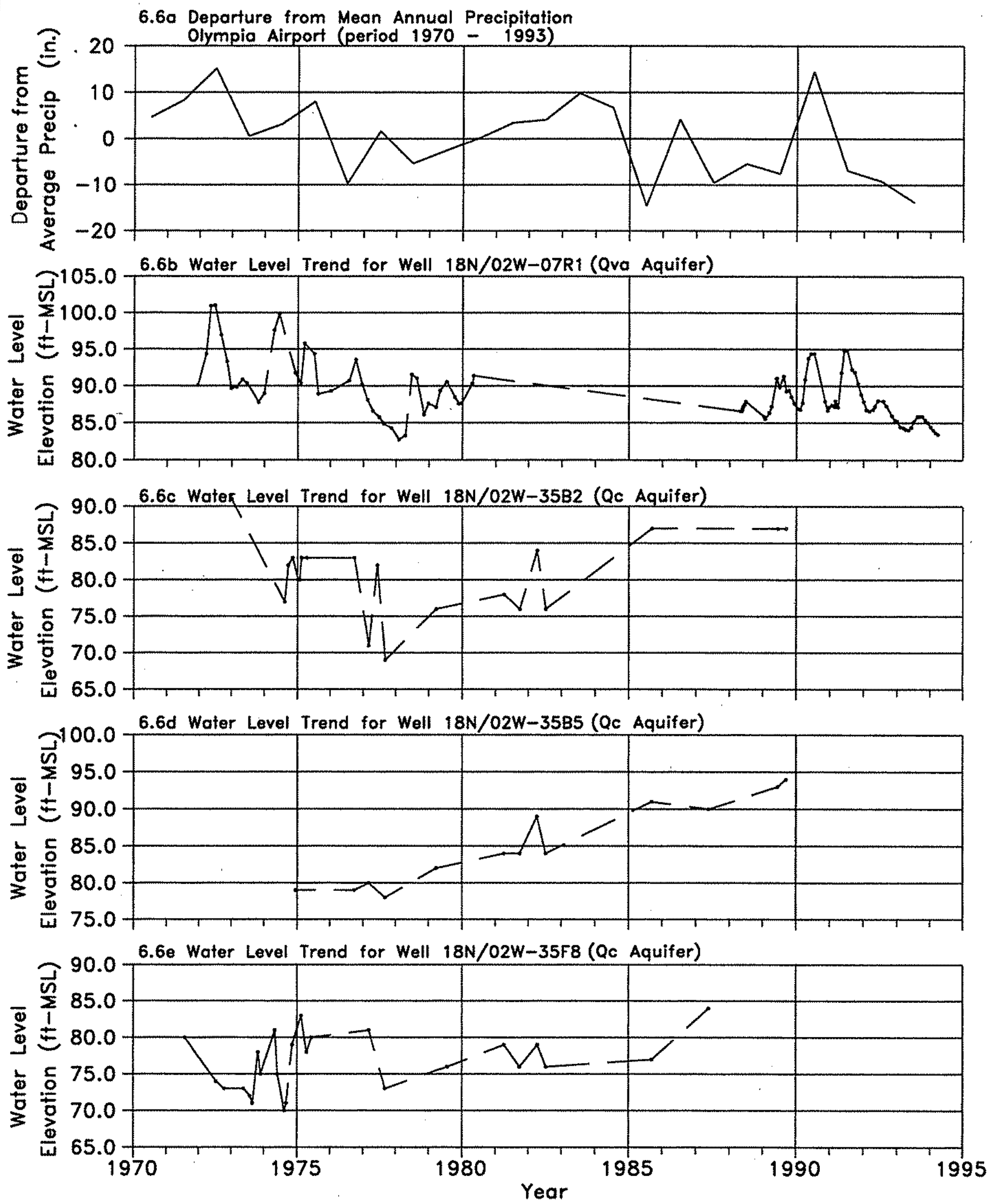


FIGURE 6.6
WATER LEVEL AND PRECIPITATION TREND DATA

Pacific Groundwater Group

Initial Watershed Assessment Program
Deschutes Basin

APPENDIX A
RESOURCE PROTECTION AND MANAGEMENT REGULATIONS

Chapter 173–513 WAC
INSTREAM RESOURCES PROTECTION PROGRAM— DESCHUTES RIVER BASIN, WATER RESOURCES INVENTORY AREA (WRIA) 13

WAC 173-513-010 General provision. These rules apply to waters within the Deschutes River Basin, WRIA 13, as defined in WAC 173-500-040. This chapter is promulgated pursuant to chapter 90.54 RCW (Water Resources Act of 1971), chapter 90.22 RCW (Minimum Water Flows and Levels), and in accordance with chapter 173-500 WAC (Water Resources Management Program). [Statutory Authority: Chapters 90-.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-010, filed 6/24/80.]

WAC 173-513-020 Purpose. The purpose of this chapter is to retain perennial rivers, streams, and lakes in the Deschutes River Basin with instream flows and levels necessary to provide protection for wildlife, fish, scenic, aesthetic, environmental values, recreation, navigation, and water quality. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-020, filed 6/24/80.]

WAC 173-513-030 Establishment of instream flows. (1) Stream management units and associated control stations are established as follows:

Stream Management Unit Information

Control Station No. Stream Management Unit Name	Control Station Location, River Mile and Section, Township and Range	Affected Stream Reach
12.0800-00 Deschutes River	3.4 Sec. 35-18N-2W	From the confluence of the Deschutes River with Capitol Lake upstream to the Deschutes Falls at river mile 41.

(2) Instream flows established for the stream management unit described in WAC 173-513-030(1) are as follows:

INSTREAM FLOWS IN THE DESCHUTES RIVER BASIN
(in Cubic Feet per Second)

Month	Day	USGS Gage 12-0800-00 Deschutes River
Jan.	1	400
	15	400
Feb.	1	400
	15	400
Mar.	1	400
	15	400
Apr.	1	350
	15	(Closed)
May	1	(Closed)
	15	(Closed)
June	1	(Closed)
	15	(Closed)
July	1	(Closed)
	15	(Closed)
Aug.	1	(Closed)
	15	(Closed)
Sept.	1	(Closed)
	15	(Closed)
Oct.	1	(Closed)
	15	(Closed)
Nov.	1	150
	15	200
Dec.	1	300
	15	400

(3) Instream flow hydrograph, as represented in the document entitled "Deschutes River Basin Instream Resource Protection Program," shall be used for identification of instream flows on those days not specifically identified in WAC 173-513-030(2). [Statutory Authority: Chapters 90.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-030, filed 6/24/80.]

WAC 173-513-040 Surface water source limitations to further consumptive appropriations. (1) The department of ecology, having determined that further consumptive appropriations would harmfully impact instream values, closes the following streams and lakes to further consumptive appropriation for the periods indicated.

New Surface Water Closures

Stream or Lake Section, Township and Range of Mouth or Outlet	Tributary to	Period of Closure
Deschutes River below Deschutes Falls (river mile 41) NW1/4SW1/4 Sec. 26, T. 18N., R. 2W.	Puget Sound (Budd Inlet)	Apr. 15 to Nov. 1
Deschutes River above Deschutes Falls (river mile 41) and all tributaries of Deschutes River		All year

Stream or Lake Section, Township and Range of Mouth or Outlet	Tributary to	Period of Closure
E1/2NE1/4 Sec. 10, T. 15N., R. 3E. (Deschutes Falls)		
McLane Creek and all tributaries SW1/4NW1/4 Sec. 33, T. 18N., R. 2W.	Puget Sound (Eld Inlet)	All year
Woodland Creek and all tributaries SW1/4NW1/4 Sec. 19, T. 19N., R. 1W.	Puget Sound (Henderson Inlet)	All year
Long Lake SE1/4NE1/4 Sec. 22, T. 18N., R. 1W.	Woodland Creek	All year
Patterson Lake SE1/4SW1/4 Sec. 35, T. 18N., R. 1W.	Woodland Creek	All year
Hicks Lake NE1/4SW1/4 Sec. 27, T. 18N., R. 1W.	Woodland Creek	All year

(2) The following stream and lake low flows and closures are adopted confirming surface water source limitations previously established administratively under the authority of chapter 90.03 RCW and RCW 75.20.050.

Existing Low Flow Limitations and Closures

Stream Section, Township and Range of Mouth	Tributary to	Action
Percival Creek SW1/4NE1/4 Sec. 22, T. 18N., R. 2W.	Capital Lake	Closure
Unnamed Stream NW1/4NW1/4 Sec. 33, T. 19N., R. 2W.	Puget Sound (Eld Inlet)	Low Flow (1.5 cfs)
Unnamed Stream NW1/4NW1/4 Sec. 25, T. 19N., R. 2W.	Gull Harbor	Low Flow (1.0 cfs)
Woodward Creek SW1/4NW1/4 Sec. 19, T. 19N., R. 1W.	Woodward Bay	Closure

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-040, filed 6/24/80.]

WAC 173-513-050 Groundwater. Future groundwater withdrawal proposals will not be affected by this chapter unless it is verified that such withdrawal would clearly have an adverse impact upon the surface water system contrary to the intent and objectives of this chapter. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-050, filed 6/24/80.]

WAC 173-513-060 Lakes. In future permitting actions relating to withdrawal of lake waters, lakes and ponds shall be retained substantially in their natural condition. Withdrawals of water which would conflict therewith shall be authorized only in those situations where it is clear that overriding considerations of the public interest will be served. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-060, filed 6/24/80.]

WAC 173-513-070 Exemptions. (1) Nothing in this chapter shall affect water rights, riparian, appropriative, or otherwise existing on the effective date of this chapter, nor shall it affect existing rights relating to the operation of any navigation, hydroelectric, or water storage reservoir or related facilities.

(2) Domestic use for a single residence and stock watering, except that use related to feedlots, shall be exempt from the provisions of this chapter if no alternative source is available. If the cumulative effects of numerous single domestic diversions would seriously affect the quantity of water available for instream uses, then only domestic in-house use shall be exempt. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-070, filed 6/24/80.]

WAC 173-513-080 Future rights. No rights to divert or store public surface waters of the Deschutes River Basin, WRIA 13, shall hereafter be granted which shall conflict with the purpose of this chapter as stated in WAC 173-513-020. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-080, filed 6/24/80.]

WAC 173-513-090 Enforcement. In enforcement of this chapter, the department of ecology may impose such sanctions as appropriate under authorities vested in it, including but not limited to the issuance of regulatory orders under RCW 43.27A.190 and civil penalties under RCW 43.83B.335. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-090, filed 6/24/80.]

WAC 173-513-100 Regulation review. The rules in this chapter shall be reviewed by the department of ecology at least once in every five years. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 80-08-019 (Order DE 80-11), § 173-513-100, filed 6/24/80.]

8-13-86
Priority date

Chapter 173-591 WAC
RESERVATION OF FUTURE PUBLIC WATER SUPPLY FOR THURSTON COUNTY

WAC 173-591-010 Purpose. The purpose of this chapter is to reserve ground waters within Thurston County for future public water supply. [Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-010, filed 7/14/86.]

WAC 173-591-020 Authority. This regulation is adopted pursuant to the Water Resources Act of 1971, chapter 90.54 RCW and chapter 173-590 WAC. [Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-020, filed 7/14/86.]

WAC 173-591-030 General. (1) These rules shall apply to ground waters in Thurston County, as defined in WAC 173-591-040 and 173-591-070(4), as specified in Figure II-2 of the coordinated water system plan for Thurston County, dated May 1982, as approved by the department of social and health services for the purposes of reserving ground waters for future public supply, and as shown as the reservation source of supply subareas on the Thurston County reservation source of supply subarea boundary map in WAC 173-591-130, Illus. 2.

(2) The reservation adopted under this chapter will be for the specific geographical area so named the "reservation boundaries" as shown in Figure II-1 of the coordinated water supply plan for Thurston County, dated May 1982, as approved by the department of social and health services for the purposes of reserving ground waters for future public water supply, and shown on the Thurston County reservation area boundary map in WAC 173-591-130, Illus. 1.

(3) Appropriation of reserved waters under this chapter shall be in accordance with the intent and procedures set forth in chapters 90.03 and 90.44 RCW and chapter 173-513 WAC Instream resources protection program—Deschutes River Basin, Water Resource Inventory Area (WRIA) 13 (adopted 6/24/80) and chapter 173-511 WAC Instream resources protection program—Nisqually River Basin, Water Resource Inventory Area (WRIA) 11 (adopted 2/2/81) and chapter 173-514 WAC Instream resources protection program—Kennedy-Goldsborough Water Resource Inventory Area (WRIA 14) (adopted 1/23/84). [Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-030, filed 7/14/86.]

WAC 173-591-040 Reservation area defined. "Thurston County reservation area" and "Thurston County reservation source of supply area" shall mean those lands lying within Thurston County described as follows:

Location	Township	Range	Sections
Reservation Area	16N	3W	1-3, 10-12
	16N	2W	1-12
	16N	1W	4-9
	17N	3W	1, 2, 3 (portion), 10-15, 22-27, 34-36
	17N	2W	1-36
	17N	1W	1-21, 27 (portion), 28-33
	17N	1E	6, 7, portions of 3, 8, 18
	18N	3W	1-4, 9-16, 21 (portion), 22 (portion), 23-25, 36
	18N	1W	1-36
	18N	1E	6, 7, 17-20, 29-32, portions of 5, 8, 16, 28
	19N	3W	12, 13, 23-28, 33-36, (portions in Thurston County)
	19N	2W	portion in Thurston County
	19N	1W	portion in Thurston County
	19N	1E	portion in Thurston County
Reservation Source of Supply Area			
Airport	17N	2W	3, 10-15, 22-24 & portions of 9, 16, 21 east of Interstate 5
	18N	2W	34
Allison Springs	18N	2W	18
Black Lake	17N	2W	4-8, 17-20, 29-31 & portions of 9, 16, 21, 18 & 33 west of Interstate 5
	18N	2W	31-33
Deschutes Valley	17N	2W	12
	18N	2W	25, 26, 35, 36
Hawks Prairie	18N	1W	1-8 & portions of 9-12 north of Interstate 5
	19N	1W	25-36
	18N	1E	portion of 6 west of Nisqually River

Location	Township	Range	Sections
	19N	1E	portions of 30 & 31 west of Nisqually River
McAllister Springs	18N	1E	19
Mottman Industrial Park	18N	2W	27–29
Southeast	17N	1W	2–11, 14–23
	18N	1W	19–21, 28–34

[Statutory Authority: RCW 90.54.050(1). 86–15–029 (Order DE–86–16), § 173–591–040, filed 7/14/86.]

WAC 173–591–050 Definitions. For the purpose of this chapter the following definitions shall be used:

(1) "Community water use" means use of water associated with needs of a community including street cleaning, parks, public buildings, public swimming pools, fire fighting, and attendant commercial, industrial and irrigation uses.

(2) "Director" means the director of the state of Washington department of ecology or the director's authorized representative.

(3) "Department" means the department of ecology unless otherwise specified.

(4) "Domestic water use" means use of water associated with human health and welfare requirements, including water used for drinking, bathing, sanitary purposes, cooking, laundering, irrigation of not over one–half acre of lawn or garden per dwelling, and other incidental household uses.

(5) "Commercial and/or industrial use" means use of water associated with commercial and/or industrial requirements such as service, processing, cooling and conveying.

(6) "Public water supply" means any water supply intended or used for human consumption and community uses for more than one single–family residence.

(7) "Public water supply system" means a set of facilities including source, treatment, storage, transmission and distribution facilities whereby water is furnished to any municipality, community, collection, or number of individuals for human consumption and community uses.

(8) "Coordinated water system plan" means a plan adopted by utilities covering one or more public water supply system(s), which identifies present and future needs of participating water systems and sets forth means for meeting those needs in the most efficient manner possible.

(9) "Reservation" means an allocation of water for a future beneficial use with the priority established as of the date when the reservation becomes effective.

(10) "Appropriation" means the process of legally acquiring the right to specific amounts of the public water resource for application to beneficial uses pursuant to RCW 90.03.250 through 90.03.340 and 90.44.060.

(11) "Person" means any individual, municipal, public, or private corporation, or other entity, including a federal or state agency or county which operates a public water supply system or who contemplates such an operation. [Statutory Authority: RCW 90.54.050(1). 86–15–029 (Order DE–86–16), § 173–591–050, filed 7/14/86.]

WAC 173–591–060 Petition received—Notice. A petition requesting the reservation of ground waters in Thurston County pursuant to chapter 173–590 WAC, and a coordinated water system plan approved by the secretary of the department of social and health services were received and accepted by the department. Notice of the receipt of proper petition was published in a newspaper of general circulation in Thurston County for two consecutive weeks, and the director sent notice thereof to the directors of the departments of fisheries, wildlife, and social and health services for the purpose of soliciting their comments. [Statutory Authority: Chapters 43.21B, 43.27A, 90.22 and 90.54 RCW. 88–13–037 (Order 88–11), § 173–591–060, filed 6/9/88. Statutory Authority: RCW 90.54.050(1). 86–15–029 (Order DE–86–16), § 173–591–060, filed 7/14/86.]

WAC 173–591–070 Reservation. (1) The department, having received a final environmental impact statement dated January 16, 1985, and having conducted an investigation of the surrounding impacts of the proposed reservation and having heard comments solicited through the notice of receipt of petition and having found ground waters to be generally available for the purposes of the reservation and that the proposed use of the ground waters will result in the maximum net benefit for the people of the state, does hereby reserve portions of those ground waters for future public water supplies in Thurston County.

(2) The department finds that to provide peaking capacity on a daily basis the appropriate amount of the reservation shall be 40,589 gallons per minute, limited to a maximum annual withdrawal of 22,931 acre–feet/year, provided that the total annual withdrawal and diversion from all sources shall not exceed 48,225 acre–feet/year. This is intended to serve the estimated population of 288,092 in fifty years. The amount of this reservation shall be reviewed by the department whenever new information, changing conditions, or statutory modifications make it necessary to consider revisions.

(3) A map showing the reservation area boundary is shown in Figure II–1 of the coordinated water system plan for Thurston County, dated May 1982, as approved by the department of social and health services for the purposes of reserving water for future public water supply purposes, and shown as the reservation area boundary map in WAC 173–591–130, Illus. 1.

(4) Due to the nature of the geographic distribution of the ground waters to be reserved and the development patterns that are anticipated in Thurston County, the reserved ground waters are intended to be beneficially utilized from the unconsolidated materials overlying bedrock, and are prorated to the subareas designated in Figure V–1 of the coordinated water system plan for Thurston County, dated May 1982, as approved by the department of social and health services for the purpose of reserving water for future public water supply purposes, and shown as the reservation source of supply subareas map in WAC 173–591–130, Illus. 2. The reserved ground waters are generally prorated to the

reservation source of supply subareas as follows, with the totaled reserved quantity to be obtained from within the boundary area.

Source Location	Reservation Quantities Instantaneous (GPM)	Annual (Af/Yr)
Airport	2,500	1,486
Allison Springs	2,000	1,888
Black Lake	2,000	1,888
Deschutes Valley	1,969	1,170
Hawks Prairie	7,000	4,160
McAllister Springs	2,000	—
Mottman Indust. Park	2,000	1,888
Southeast	14,426	8,573
Total	40,589	22,931

(5) The priority date of any permit issued pursuant to RCW 90.03.290 and 90.44.070 which authorizes withdrawal and use of public water for public water supply pursuant to the reservation provided in subsection (2) of this section shall be the effective date of this regulation.

(6) A record of all ground water permits issued pursuant to the reservation provided in subsection (2) of this section shall be maintained by the department in a manner that will readily show the quantities that have been allocated from the reserved ground waters for each subarea identified in subsection (4) of this section and the quantities of unappropriated ground waters that may remain in the reserved status available for appropriation.

(7) No permit issued as described in subsection (5) of this section shall authorize a withdrawal that causes a lowering of the water levels below a reasonable or feasible pumping lift in any withdrawal facilities of a senior ground water right holder. [Statutory Authority: Chapters 43.21B, 43.27A, 90.22 and 90.54 RCW. 88-13-037 (Order 88-11), § 173-591-070, filed 6/9/88. Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-070, filed 7/14/86.]

WAC 173-591-080 Future nonpublic water supply—Policy uses. If applications are made for the use of the ground water reserved in WAC 173-591-070(2) for purposes other than public water supplies, as defined in WAC 173-591-050 (6) and (7), the director may issue a permit allowing such uses but these uses shall be junior in priority to all rights issued pursuant to WAC 173-591-070. Interim uses authorized in this section may be reduced or curtailed in right when necessary to allow to full utilization of higher priority rights established in WAC 173-591-070. The department may limit or otherwise condition junior water rights permits as necessary to ensure availability of the reserved ground waters for public water supply purposes consistent with this chapter. [Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-080, filed 7/14/86.]

WAC 173-591-090 Monitoring program. (1) The department, in cooperation with local government agencies, shall implement a comprehensive monitoring program, the purpose of which is to maintain accurate information on the quality and quantity of ground water reserved in WAC 173-591-070(2).

(2) Under this monitoring program surface and ground water levels will be periodically recorded as well as the levels of any lakes that are maintained by ground waters. [Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-090, filed 7/14/86.]

WAC 173-591-100 Water quality. As a general rule, an element of a ground water right is the right to use waters of quality appropriate to the beneficial use. In addition to the protection of the availability of ground water to the water withdrawal facilities of ground water right holders, it shall be the policy of the department to protect the quality of the ground waters of the state and in relation thereto to discourage any withdrawal facilities, construction methods, water use, or disposal practices which would contaminate or otherwise reduce the quality of the ground waters or impair the beneficial uses of ground waters of the state. Local governments with land use authority are urged to exercise their authorities in such a manner as to protect the quality of the public ground waters reserved for future public water supply by this chapter. [Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-100, filed 7/14/86.]

WAC 173-591-110 Exemptions. Wells for single family domestic, stock watering, or other purposes for which the withdrawal is less than 5,000 gallons per day, with priority dates subsequent to the effective date of this regulation, shall be junior to rights issued pursuant to WAC 173-591-070. The quantities of water withdrawn by such wells will not be subtracted from the waters reserved by this regulation. [Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-110, filed 7/14/86.]

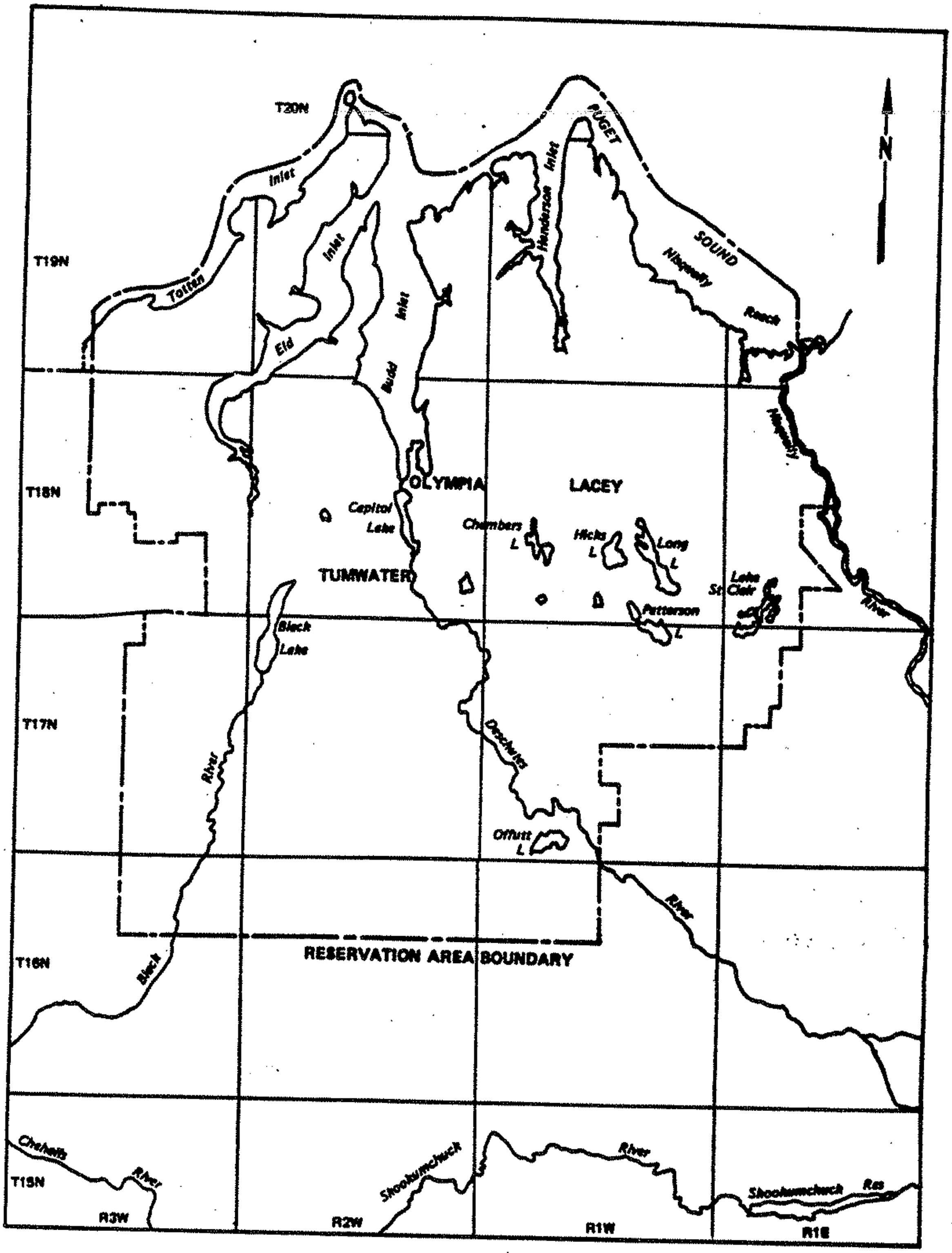
WAC 173-591-115 Appeals. All final written decisions of the department of ecology pertaining to permits, regulatory orders, and related decisions made pursuant to this chapter shall be subject to review by the pollution control hearings board in accordance with chapter 43-.21B RCW. [Statutory Authority: Chapters 43.21B, 43-.27A, 90.22 and 90.54 RCW. 88-13-037 (Order 88-11), § 173-591-115, filed 6/9/88.]

WAC 173-591-120 Regulation review. The department of ecology shall initiate a review of the rules established in this chapter whenever new information, changing conditions, or statutory modifications make it necessary to consider revisions. [Statutory Authority: Chapters 43.21B, 43.27A, 90.22 and 90.54 RCW. 88-13-037 (Order 88-11), § 173-591-120, filed 6/9/88. Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-120, filed 7/14/86.]

WAC 173-591-130 Reservation boundary maps. Thurston County reservation area and reservation source of supply subareas shall include those lands that lie within the heavy outline on the following maps:

THURSTON COUNTY RESERVATION AREA BOUNDARY MAP

SEE ILLUSTRATION
(WAC 173-591-130, Illus. 1)

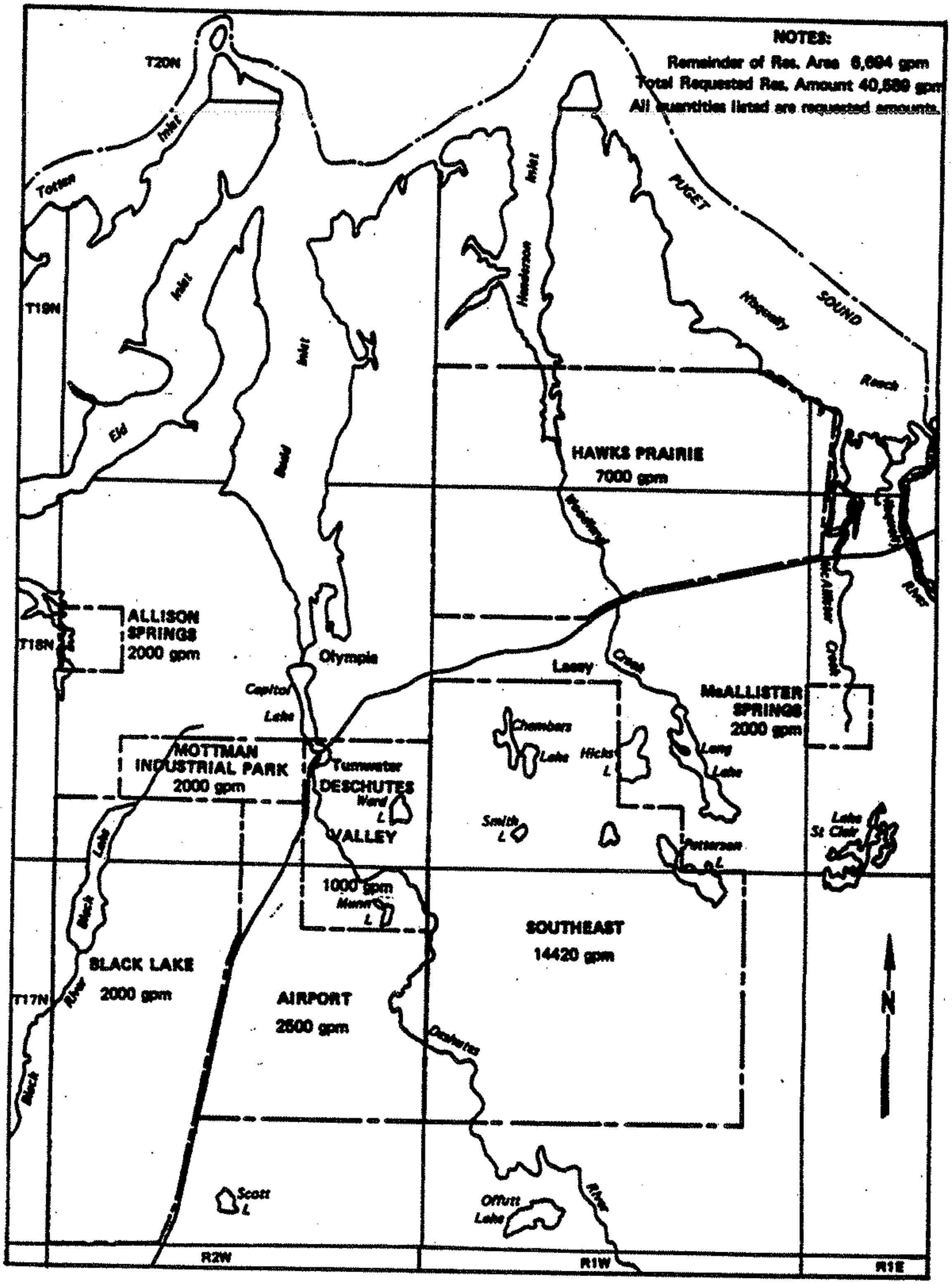


THURSTON COUNTY RESERVATION AREA BOUNDARY MAP
WAC 173-591-130
ILLUSTRATION 1

THURSTON COUNTY RESERVATION SOURCE OF SUPPLY SUBAREAS BOUNDARY MAP

SEE ILLUSTRATION
(WAC 173-591-130, Illus. 2)

[Statutory Authority: RCW 90.54.050(1). 86-15-029 (Order DE-86-16), § 173-591-130, filed 7/14/86.]



THURSTON COUNTY RESERVATION SOURCE OF SUPPLY SUBAREAS BOUNDARY MAP
WAC 173-591-130
ILLUSTRATION 2

APPENDIX B
PRECIPITATION AND STREAMFLOW DATA

Rainfall At Olympia

Monthly and Annual Totals in Inches

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	Departure From Mean
1948						1.35	1.10	2.27	3.92	4.35	10.19	12.11		
1949	0.69	9.96	3.75	1.52	1.54	0.72	0.51	0.82	1.39	5.24	12.33	10.73	49.20	-1.1
1950	9.31	9.66	10.13	3.10	0.79	0.86	1.35	1.47	2.19	9.20	9.49	9.16	66.71	16.5
1951	10.59	11.28	5.89	0.54	1.91	0.05	0.28	0.54	2.83	6.95	7.32	5.80	53.98	3.7
1952	5.65	3.96	3.13	2.25	0.85	1.22	0.10	0.74	0.43	1.55	1.39	8.65	29.92	-20.3
1953	19.84	5.12	3.55	2.58	2.72	1.50	0.27	1.63	2.68	6.85	7.79	9.42	63.95	13.7
1954	11.96	8.40	3.13	4.07	1.63	3.36	0.82	1.74	1.89	3.38	7.87	6.99	55.24	5.0
1955	3.01	5.23	4.76	4.19	1.35	0.71	2.68	0.02	1.84	9.31	12.18	12.59	57.87	7.6
1956	10.75	3.93	8.27	0.37	0.30	2.57	0.38	0.88	2.30	9.52	2.81	9.36	51.44	1.2
1957	3.02	5.88	7.43	1.72	1.42	1.78	0.97	0.87	0.66	4.74	4.05	8.91	41.45	-8.8
1958	7.87	6.40	2.29	4.39	1.47	1.65	0.00	0.62	1.52	5.41	12.35	8.43	52.40	2.1
1959	8.91	4.53	4.63	4.51	1.45	1.85	0.30	0.70	4.26	3.92	10.36	7.50	52.92	2.7
1960	6.35	5.93	6.12	4.53	3.50	0.59	0.00	1.16	1.21	5.84	11.33	3.89	50.45	0.2
1961	8.69	13.18	6.26	3.29	2.93	1.05	0.80	1.01	0.33	4.97	6.78	8.25	57.54	7.3
1962	3.22	3.72	3.82	4.50	1.81	0.89	0.14	3.17	2.45	6.00	15.51	5.81	51.04	0.8
1963	3.47	6.42	5.10	4.13	1.76	0.63	1.48	0.79	2.16	5.98	10.32	5.55	47.79	-2.5
1964	15.13	2.54	4.47	1.58	0.98	2.35	1.07	1.47	2.26	1.79	9.18	9.11	51.93	1.7
1965	9.37	4.93	0.48	3.61	1.89	0.33	0.48	2.05	0.60	3.30	5.84	7.81	40.69	-9.6
1966	7.89	3.38	7.28	1.71	1.30	1.28	1.34	0.68	1.95	4.83	8.16	11.53	51.33	1.1
1967	12.21	3.58	4.31	2.88	0.25	1.49	0.02	0.00	1.36	10.08	3.90	5.94	46.02	-4.2
1968	9.04	7.83	6.53	3.02	2.57	2.43	0.89	5.45	2.51	6.07	7.96	9.95	64.25	14.0
1969	9.45	3.41	2.90	3.44	2.07	1.68	0.50	0.18	5.23	2.69	3.60	7.24	42.39	-7.9
1970	12.48	4.30	3.07	4.76	1.21	0.14	0.16	0.15	3.20	2.71	7.40	14.32	53.90	3.6
1971	11.15	4.41	9.11	2.78	1.50	3.00	0.78	0.71	3.06	4.43	7.59	9.18	57.70	7.4
1972	12.43	11.06	10.01	5.87	0.83	1.07	1.72	0.70	5.04	0.85	4.17	10.66	64.41	14.2
1973	5.66	1.71	3.02	2.23	2.66	2.60	0.05	0.59	2.18	4.60	12.95	11.61	49.86	-0.4
1974	10.57	5.68	6.65	4.77	2.65	1.57	2.29	0.07	0.50	1.38	7.44	8.86	52.43	2.2
1975	9.70	5.61	4.32	1.88	1.51	0.72	0.25	3.97	0.00	8.38	9.54	11.42	57.30	7.0
1976	9.40	7.25	4.24	2.79	2.66	1.07	1.26	2.71	1.22	2.64	1.37	3.00	39.61	-10.6
1977	1.55	3.70	4.44	1.27	5.21	0.64	0.32	4.17	4.58	3.40	9.30	12.36	50.94	0.7
1978	6.61	4.39	3.45	3.97	2.90	1.54	1.49	1.47	7.59	0.78	6.81	2.95	43.95	-6.3
1979	2.67	9.25	2.73	2.21	1.40	1.11	1.58	1.56	2.72	6.20	2.38	13.01	46.82	-3.4
1980	6.27	6.18	3.98	4.14	0.93	2.46	0.41	0.36	2.21	1.84	9.77	10.92	49.47	-0.8
1981	2.54	9.19	3.86	4.77	1.81	2.96	0.36	0.85	2.44	8.17	7.22	8.60	52.77	2.5
1982	7.79	9.91	4.67	3.89	0.51	1.15	0.54	0.55	1.89	6.12	5.74	10.64	53.40	3.1
1983	9.99	7.09	6.63	2.26	1.51	2.80	3.00	2.18	1.89	1.66	12.84	7.28	59.13	8.9
1984	6.97	5.49	6.42	3.67	5.48	3.74	0.00	0.21	1.76	5.13	12.19	4.97	56.03	5.8
1985	0.29	3.54	4.10	2.65	0.94	2.48	0.37	0.70	2.65	9.86	4.99	2.50	35.07	-15.2
1986	12.14	6.84	2.29	2.87	3.20	0.92	1.11	0.01	3.38	4.12	11.09	5.20	53.17	2.9
1987	8.38	3.55	7.14	3.11	2.71	0.32	0.84	0.24	0.29	0.39	3.65	9.14	39.76	-10.5
1988	5.18	2.35	5.66	4.94	3.36	2.06	0.42	0.43	1.93	2.26	10.14	5.16	43.89	-6.4
1989	5.41	4.19	7.88	2.49	1.99	1.47	0.70	0.55	0.49	2.42	8.50	5.66	41.75	-8.5
1990	14.53	8.52	3.54	3.29	2.06	2.86	0.32	1.79	0.03	6.34	15.06	5.05	63.39	13.1
1991	5.35	5.85	4.32	7.80	1.69	1.30	0.33	2.31	0.00	2.20	7.00	4.28	42.43	-7.8
1992	9.45	4.19	1.50	5.15	0.19	1.15	0.36	0.82	2.44	2.80	6.82	5.28	40.15	-10.1
1993	5.36	0.22	4.95	6.67	4.57	1.77	1.35	0.15	0.00	1.63	2.86	6.02	35.55	-14.7
Min	0.29	0.22	0.48	0.37	0.19	0.05	0.00	0.00	0.00	0.39	1.37	2.50	29.92	-20.3
Avg	7.96	5.86	4.94	3.38	1.95	1.55	0.77	1.21	2.12	4.61	7.99	8.10	50.25	0.0
Max	19.84	13.18	10.13	7.80	5.48	3.74	3.00	5.45	7.59	10.08	15.51	14.32	66.71	16.5

Rainfall At Longmire Rainier

Monthly and Annual Totals in Inches

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	Departure From Mean
1931	7.17	5.20	11.75	4.20	3.21	7.26	0.00	0.44	4.06	10.67	10.56	9.33	73.85	-8.5
1932	10.57	11.79	16.91	7.24	3.16	0.87	3.86	1.57	1.61	9.83	21.99	15.66	105.06	22.7
1933	16.93	9.26	9.38	2.67	4.16	3.41	0.28	2.75	7.89	12.43	8.35	36.09	113.60	31.2
1934	17.69	2.46	13.07	2.84	4.01	1.61	0.69	0.85	5.06	11.66	19.09	15.41	94.44	12.0
1935	12.14	3.75	11.13	3.19	1.05	3.26	2.07	1.05	2.23	4.18	5.81	7.44	57.30	-25.1
1936	16.01	11.49	7.92	2.20	9.21	5.63	1.81	0.87	2.43	2.62	0.78	14.96	75.93	-6.5
1937	4.51	12.81	5.39	11.65	2.25	7.43	0.73	4.50	1.86	7.05	19.38	16.58	94.14	11.7
1938	7.33	3.52	8.44	5.70	3.46	0.61	0.35	0.88	1.25	6.16	11.50	14.57	63.77	-18.6
1939	11.68	10.91	4.35	1.30	3.16	3.47	1.57	1.30	2.29	5.58	5.52	14.83	65.96	-16.4
1940	4.26	14.39	7.14	6.59	2.56	0.69	2.21	0.84	3.53	7.49	8.04	6.61	64.35	-18.0
1941	6.25	2.29	2.48	4.11	7.20	2.84	0.23	4.68	7.85	8.80	9.00	13.72	69.45	-12.9
1942	5.27	5.63	4.57	5.47	5.19	6.85	3.43	1.26	0.08	6.29	17.12	13.62	74.78	-7.6
1943	6.41	7.91	10.35	5.03	4.86	3.84	1.20	1.48	0.97	9.42	3.90	8.94	64.31	-18.1
1944	7.11	7.70	5.59	3.75	5.73	1.55	0.04	0.54	7.40	2.41	8.90	5.26	55.98	-26.4
1945	11.46	12.20	10.15	7.82	4.49	1.34	0.39	1.20	7.73	5.79		13.01		
1946	15.41	9.37	8.16	2.99	1.79	6.06	1.73	0.54	2.34	12.91	11.22	18.63	91.15	8.8
1947	13.89	6.16	5.07	7.36	1.26	5.86	1.62	0.99	4.75	15.14	14.53	10.39	87.02	4.6
1948	9.17	12.61	6.98	7.13	7.39	4.12	2.86	3.14	4.92	6.01	17.86	15.47	97.66	15.3
1949	2.81	17.17	4.96	2.94	3.09	2.21	1.54	1.43	2.75	8.70	13.04	17.30	77.94	-4.5
1950	16.42	11.67	11.41	6.11	2.96	2.87	2.71	2.19	3.32	11.78	15.32	14.18	100.94	18.5
1951	12.94	12.15	9.70	0.97	5.18	0.49	0.29	1.41	5.27	14.41	11.55	9.72	84.08	1.7
1952	6.89	6.07	6.49	3.34	2.78	3.48	0.04	0.84	0.91	1.93	1.42	9.03	43.22	-39.2
1953	26.83	6.79	5.68	4.91	5.45	5.00	1.11	2.90	3.04	5.33	10.24	23.57	100.85	18.5
1954	16.84	10.14	4.22	5.86	3.67	6.26	2.30	2.74	2.67	5.22	11.00	11.25	82.17	-0.2
1955	6.60	10.38	12.80	7.76	4.30	2.78	4.13	0.09	4.82	17.20	18.66	14.41	103.93	21.5
1956	13.34	10.33	13.84	1.75	1.90	4.75	0.86	2.23	3.89	10.55	5.35	15.85	84.64	2.2
1957	6.29	11.38	9.71	4.92	3.62	3.98	1.19	1.59	1.48	7.48	8.64	16.59	76.87	-5.5
1958	10.52	9.12	2.93	9.08	2.21	3.65	0.04	1.03	4.72	9.17	21.22	13.11	86.80	4.4
1959	16.78	5.23	9.33	6.54	4.00	3.87	1.21	2.04	13.36	13.73	17.32	8.89	102.30	19.9
1960	6.51	8.84	9.56	7.24	10.36	2.99	0.07	4.99	3.11	8.98	16.71	7.64	87.00	4.6
1961	11.88	19.29	8.51	8.96	3.94	1.46	1.59	1.56	3.58	9.56	8.74	14.82	93.89	11.5
1962	8.86	3.32	8.14	8.01	4.91	2.79	1.06	3.13	4.35	7.01	18.50	7.70	77.78	-4.6
1963	3.80	11.26	8.19	5.72	2.73	3.95	2.79	2.21	2.78	6.33	11.43	7.64	68.83	-13.6
1964	21.33	5.13	10.52	7.07	3.52	4.92	2.29	5.29	4.49	4.31	10.05	18.07	96.99	14.6
1965	19.39	10.80	1.35	4.76	3.51	0.50	0.75	3.84	3.10	4.26	8.79	7.20	68.25	-14.1
1966	10.66	7.05	8.53	3.82	2.99	4.71	2.23	0.94	2.10	7.79	10.85	11.73	73.40	-9.0
1967	21.92	9.69	7.42	3.06	1.55	2.62	0.22	0.08	2.09	17.49	6.53	11.76	84.43	2.0
1968	10.07	12.81	7.17	6.57	3.62	7.43	1.14	8.36	6.77	9.71	13.96	13.00	100.61	18.2
1969	14.90	4.57	4.24	5.47	4.00	3.34	0.48	0.65	8.38	4.38	5.89	10.02	66.32	-16.1
1970	21.95	5.85	6.16	6.44	2.97	1.55	0.62	0.33	6.19	7.13	10.59	13.23	83.01	0.6
1971	25.74	11.08	10.49	2.59	4.10	4.17	1.79	0.55	5.42	5.48	8.78	17.08	97.27	14.9
1972	23.76	17.27	14.11	9.93	2.82	5.27	2.20	1.21	8.25	1.52	8.61			
1973	7.04	2.72	4.22	2.10	3.67	4.86	0.02	0.21	4.74	8.00	15.01	15.33	67.92	-14.5
1974	24.61	8.72	10.66	7.96	5.02	5.01	2.35	0.41	0.74	1.86	7.67	17.79	92.80	10.4
1975	19.82	8.77	5.44	2.83	3.32	3.19	0.79	6.49	0.46	12.51	12.97	24.96	101.55	19.2
1976	15.25	9.12	6.51	3.48	4.08	3.43	3.06	6.12	1.43	4.86	4.68	5.52	67.54	-14.9
1977	2.35	4.80	10.56	3.58	6.02	1.04	0.78	5.88	7.28	5.41	17.35	22.78	87.83	5.4
1978	7.26	5.60	4.75	5.52	5.66	3.51	1.42	5.03	5.93	1.89	10.14			
Min	2.35	2.29	1.35	0.97	1.05	0.49	0.00	0.08	0.08	1.52	0.78	5.26	43.22	-39.2
Avg	12.43	8.89	8.05	5.22	4.00	3.60	1.38	2.18	4.08	7.88	11.37	13.71	82.40	0.0
Max	26.83	19.29	16.91	11.65	10.36	7.43	4.13	8.36	13.36	17.49	21.99	36.09	113.60	31.2

Rainfall At Rainier Ohanapecosh

Monthly and Annual Totals in Inches

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	Departure From Mean
1948							2.18	1.51	4.16	6.21	16.37	22.52		
1949	2.54	18.36	3.49	2.00	0.75	0.85	0.37	1.01	2.29	5.94	12.94	13.11	63.65	-12.3
1950	20.25	10.83	12.73	3.57	1.06	1.71	1.34	2.18	1.88	13.09	15.30	14.32	98.26	22.3
1951	17.35	8.73		1.41	3.97	0.54	0.12	0.90	3.77	13.10	12.56	11.88		
1952	8.45	6.39	5.88	1.91	2.10	2.49	0.05	0.30	0.63	1.18	1.22	12.19	42.79	-33.1
1953	31.59	7.85	5.14	5.31	4.25	2.55	0.38	1.64	2.30	3.77	10.70	22.09	97.57	21.6
1954	20.92	12.13	4.01	6.01	2.41	4.23	1.11	1.71	1.67	5.54	10.91	7.67	78.32	2.4
1955	6.73	10.63	10.18	7.62	2.13	1.52	2.39	0.00	4.09	16.09	18.77	18.24	98.39	22.5
1956	18.67	8.28	14.25	0.69	1.05	2.01	0.55	1.85	3.22	6.48	5.57	16.93	79.55	3.6
1957	4.70	12.84	10.53	4.50	2.62	2.50	1.03	1.97	0.88	6.06	6.91			
1958		8.57	3.29	9.82	1.55	2.23	0.07		3.11	7.58	25.69	14.06		
1959	16.99	6.23	9.08	5.63	2.09	3.27	0.46	1.28	8.96	11.77	16.62	10.25	92.63	16.7
1960	6.32	8.98	6.45	7.42	7.09	2.58	0.17	2.10	1.98	7.46	15.39	4.43	70.37	-5.6
1961	9.25	15.98	6.87	5.49	3.52	1.56	0.83	1.51	3.19	6.50	8.83	13.83	77.36	1.4
1962	6.24	2.32	4.38	8.69	4.56	1.18	0.61	2.54	3.66	5.41	20.45	5.35	65.39	-10.5
1963		7.34	7.57		3.53	1.23	1.63	2.39	1.57	6.12	12.18	8.55		
1964	29.63	2.36	6.48	4.24	2.15	3.32	1.73	2.75	2.58	4.68	10.93	19.90	90.75	14.8
1965	19.44	9.27	1.23	5.80	2.90	0.85	0.83	3.38	1.90	3.42	7.85	10.61	67.48	-8.5
1966	13.94	6.39	8.63	1.73	2.13	2.52	2.01	0.41	1.69	6.61	11.12	13.12	70.30	-5.6
1967	22.18	10.01	6.14	3.69	0.65	2.11	0.01	0.07	1.25	15.67	6.97	12.64	81.39	5.5
1968	12.13	13.69	5.47	3.45	1.77	5.41	0.52	5.66	4.74	8.63	14.63	17.31	93.41	17.5
1969	17.58	5.53	4.80	4.15	4.31	0.98	0.25	0.26	10.95	4.39	4.69	10.62	68.51	-7.4
1970	20.86	7.01	5.33	6.80	1.97	0.99	0.51	0.16	4.60	5.60	12.63	17.31	83.77	7.8
1971	23.36	8.84	11.76	2.79	3.61	3.56	0.77	0.51	3.92	6.68	9.99	18.71	94.50	18.6
1972	25.45	18.53	13.43	7.44	1.95	2.22	0.96	1.28	6.74	1.24	6.58	15.87	101.69	25.8
1973	7.30	1.93	3.81	2.05	2.88	2.64	0.00	0.31	4.40		16.01	13.29		
1974	14.92	8.45	8.94	5.97	4.26	3.82	0.95	0.23	0.47	1.43	11.74	18.01	79.19	3.3
1975	20.40	9.53	6.72	1.95	2.49	2.48	0.86	4.66	0.11	12.45	12.80	22.11	96.56	20.6
1976	14.27	13.18	7.87	3.94	1.75	2.34	1.51	4.62	1.21	3.68	4.27	5.12	63.76	-12.2
1977	3.26	5.25	10.03	1.84	4.04	1.93	0.48	4.01	5.96	5.12	13.79	23.50	79.21	3.3
1978	6.47	5.52	3.20	5.49	5.13	1.49	2.49	5.55	3.87	1.44	8.52	8.54	57.71	-18.2
1979	4.01	12.40	5.80	3.89	2.15	1.23	2.60	2.23	2.44	6.28	3.90	17.00	63.93	-12.0
1980	12.92	10.77	6.13	2.70	1.26	3.89	0.28	1.56	3.22	1.01	15.75	18.69	78.18	2.2
1981	2.25	10.57	3.78	9.21	2.67	6.09	1.43	0.08	3.94	8.15	7.17	17.82	73.16	-2.8
1982	18.19	15.17	6.79	5.16	0.87	1.54	1.36	0.55	3.74	8.32	9.15	13.41	84.25	8.3
1983	13.57	8.67	9.85	2.31	3.08	2.82	3.13	1.87	3.55	2.80	18.78	9.62	80.05	4.1
1984	13.73	6.32	7.76	5.16	6.97	3.23	0.00	0.28	2.56	8.57	14.28	10.27	79.13	3.2
1985	0.79	7.98	5.44	4.73	1.24	4.70	0.06	1.03	3.54	9.97	9.51	2.74	51.73	-24.2
1986	11.51	12.89	5.18	3.31	4.22	1.26	1.15	0.38	3.82	4.47	16.48	5.98	70.65	-5.3
1987	7.57	6.05	8.96	4.02	4.52	0.69	1.76	0.28	0.88	0.10	5.94	14.12	54.89	-21.0
1988	7.88	5.47	10.14	6.85	3.92	1.71	0.82	0.20	3.54	6.16	18.90	6.89	72.48	-3.5
1989	12.97	5.45	8.62	2.91	3.14	1.27	0.53	1.52	0.68	3.18	12.17	6.30	58.74	-17.2
1990	22.86	12.09	4.04	6.11	3.17	3.87	0.78	2.61	0.19	13.52	13.90	9.65	92.79	16.9
1991	10.54	10.56	7.47	9.92	3.66	4.11	0.44	0.74	0.18	3.32	14.12	9.71	74.77	-1.2
1992	12.61	5.58	1.56	7.22	0.94	1.64	1.23	0.49	6.45	3.05	12.12	9.32	62.21	-13.7
1993	5.62	0.44	7.91	8.44	3.25	2.87	3.77	0.24	0.00	1.48	4.46	9.50	47.98	-28.0
Min	0.79	0.44	1.23	0.69	0.65	0.54	0.00	0.00	0.00	0.10	1.22	2.74	42.79	-33.1
Avg	13.45	8.92	6.98	4.85	2.88	2.40	1.01	1.57	3.05	6.30	11.73	12.96	75.94	-0.0
Max	31.59	18.53	14.25	9.92	7.09	6.09	3.77	5.66	10.95	16.09	25.69	23.50	101.69	25.8

Average Flows at Gage 12079000, Deschutes River near Rainier

Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From Mean
1949						61	44	36	35	60	325	537		
1950	671	855	755	421	193	109	53	42	37	191	570	639	375	110
1951	672	809	385	226	122	57	41	33	33	175	353	480	279	14
1952	353	510	248	232	166	71	46	31	25	25	36	189	160	-105
1953	1,071	478	273	182	173	119	64	45	41	135	280	709	297	33
1954	738	943	335	405	125	137	78	50	51	91	332	373	300	35
1955	327	381	355	517	248	141	80	47	52	274	719	1,063	350	85
1956	784	303	735	366	129	118	54	42	35	138	188	461	281	16
1957	162	614	576	267	139	80	47	40	32	58	149	522	222	-43
1958	552	566	232	345	106	67	40	30	31	69	536	435	248	-16
1959	752	306	328	297	191	116	53	39	89	172	391	351	257	-8
1960	246	551	415	455	287	103	53	50	44	109	725	290	276	11
1961	588	918	634	277	255	80	51	34	36	79	200	491	300	36
1962	260	169	235	254	192	86	45	39	41	113	512	404	196	-69
1963	224	450	243	373	189	68	61	42	44	95	501	284	212	-53
1964	902	361	373	227	156	133	64	51	40	59	314	725	285	20
1965	709	483	196	185	118	60	42	41	30	43	130	264	190	-75
1966	607	263	622	281	117	68	64	34	34	78	212	769	264	-1
1967	852	385	433	228	141	83	46	35	32	175	180	398	249	-16
1968	438	647	369	211	107	175	55	74	90	166	370	600	275	10
1969	495	497	352	310	168	92	65	40	63	119	171	458	235	-30
1970	756	457	243	232	138	63	38	29	39	81	209	798	257	-8
1971	1,056	433	642	413	206	130	79	43	57	107	313	446	327	62
1972	868	832	839	393	178	87	62	43	59	43	114	624	345	81
1973	425	160	218	118	107	86	51	32	42	85	606	753	224	-41
1974	1,004	618	628	401	216	161	110	53	38	37	306	473	336	71
1975	870	532	390	189	192	74	47	54	52					
1976														
1977														
1978														
1979														
1980						86	46	36	43	39	347	563		
1981	182	680	209	368	168	195	75	42	52	250	360	731	273	8
1982	585	874	439	408	142	69	48							
1983								55	68	47				
1984						149	73	42	39	85				
1985						105	40	34	42	211				
1986						64	48	31	35	60	560			
1987						96	42	30	26	23	65	536		
1988	370	238	369	393	198	144	55	35	36	57	505	254	221	-44
1989	412	276	602	336	114	68	45	33	27	55	250	334	213	-52
1990	875	835	419	244	146	233	55	44	37	124	634	463	339	74
1991	469	645	452	659	163	113	63	44	40	46	271	256	265	0
1992	486	444	116	181	89	43	38	24	32	37	164	226	156	-109
1993	267	131	253	372	183	160	71	47	32					
Min	162	131	116	118	89	43	38	24	25	23	36	189	156	-109
Avg	589	519	409	317	164	104	56	41	43	100	340	497	265	0
Max	1,071	943	839	659	287	233	110	74	90	274	725	1,063	375	110

Average Flows at Gage 12080000, Deschutes River near Olympia
and Gage 12080010, Deschutes River @ Tumwater E Street
Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From Mean
DESCHUTES RIVER NEAR OLYMPIA, WASH.; Basin Area 160 sq. mi.														
1945					327	139	95	79	91	83	482	626		
1946	846	875	636	390	227	197	163	105	98	144	511	952	426	34
1947	616	712	371	337	179	136	106	89	91	315	451	549	327	-66
1948	834	711	619	527	499	246	146	122	128	169	516	1,051	465	73
1949	352	1,027	613	359	333	165	119	100	93	119	392	728	362	-30
1950	1,002	1,215	1,176	664	346	221	149	127	116	263	742	934	576	183
1951	1,021	1,344	717	413	260	164	127	111	104	247	419	620	457	65
1952	466	713	376	328	244	146	115	92	81	77	86	242	246	-146
1953	1,308	794	424	305	277	211	136	106	94	196	357	893	424	31
1954	1,015	1,246	583	604	262	246	162	118	115	156				
1955														
1956														
1957						193	130	115	96	129	226	658		
1958	732	780	408	497	217	155	109	87	84	130	709	630	375	-17
1959	990	579	517	489	346	207	137	106	152	238	554	581	407	15
1960	419	799	626	676	423	212	148	127	116	170	919	451	422	30
1961	792	1,302	981	486	433	207	147	117	115	163	286	612	465	73
1962	423	303	377	382	309	177	116	101	98	195	709	743	328	-65
1963	465	707	404	616	333	182	147	123	125	177	651	436	361	-32
1964	1,305	741	581	379	274	230								
DESCHUTES R AT E ST BRIDGE AT TUMWATER, WASH; Basin Area 162 sq. mi.														
1990										142	812	641		
1991	618	801	609	1,034	324	233	156	128	97	91	310	358	393	0
1992	631	669	245	299	189	110	77	70	74	78	209	304	245	-147
1993	377	244	386	527	313	272	136							
Min	352	244	245	299	179	110	77	70	74	77	86	242	245	-147
Avg	748	819	561	490	306	193	131	106	104	164	492	632	393	0
Max	1,308	1,344	1,176	1,034	499	272	163	128	152	315	919	1,051	576	183

Average Flows at Gage 12081000, Woodland Creek near Olympia

Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From Mean
1949							17.1	15.0	13.0	13.1	17.0	24.2		
1950	50.8	61.3	84.1	59.9	40.0	30.6	24.7	20.5	17.4	17.5	23.6	44.6	39.5	13.1
1951	67.3	102.1	77.1	51.3	38.4	30.3	21.4	16.6	14.4	17.0	18.6	26.6	39.7	13.4
1952	26.8	30.5	24.2	20.0	17.9	15.9	12.8	10.2	9.4	9.3	9.4	9.6	16.3	-10.0
1953	26.2	40.9	26.4	21.7	18.2	15.8	12.5	11.1	10.9	11.3	18.8	31.4	20.3	-6.1
1954	52.0	58.9	50.3	39.4	30.3	25.6	21.4	18.3	15.6	14.6	20.7	24.6	30.8	4.4
1955	24.0	27.8	28.2	27.7	22.6	18.0	14.8	14.1	12.2	14.9	29.5	68.4	25.2	-1.1
1956	92.5	62.9	68.2	52.2	38.7	32.4	26.5	21.6	18.9	19.7	20.6	30.0	40.4	14.1
1957	26.2	31.2	44.7	35.0	26.0	20.1	18.2	15.7	13.7	13.4	12.9	16.6	22.8	-3.6
1958	25.5	31.5	30.1	26.5	20.4	15.6	11.6	9.1	9.2	9.7	18.2	25.9	19.4	-7.0
1959	37.9	41.4	34.9	30.6	24.0	20.0	16.0	14.0	13.0	21.0	15.5	26.8	24.5	-1.9
1960	27.3	44.2	38.8	39.5	32.0	24.1	18.7	17.1	15.3	15.1	27.5	31.8	27.6	1.3
1961	39.4	65.4	80.1	53.7	45.6	29.3	22.7	18.8	16.3	16.2	19.7	27.4	36.0	9.7
1962	28.7	24.9	26.4	24.4	20.2	15.4	12.0	11.5	11.2	11.6	22.2	31.6	20.0	-6.4
1963	30.7	41.6	35.3	38.9	28.7	22.0	16.9	14.6	13.1	14.3	24.9	28.1	25.6	-0.7
1964	56.4	57.7	47.9	35.8	28.3	23.3	18.0	15.1	12.7	12.7	14.4	28.5	29.2	2.9
1965	39.0	47.0	35.9	31.0	26.3	18.7	12.2	11.5	11.7	10.4	12.0	16.6	22.5	-3.8
1966	31.4	23.5	31.9	25.5	20.5	15.9	12.6	10.4	11.1	9.8	11.6	30.5	19.6	-6.8
1967	46.2	44.6	38.0	31.8	24.3	18.7	14.9	11.6	11.6	13.3	12.9	18.2	23.7	-2.6
1968	27.2	39.9	36.5	31.2	24.7	20.1	16.1	15.3	14.8	16.1	22.9	41.1	25.5	-0.8
1969	56.3	58.5	41.6	34.6	29.1	22.4	18.9	15.9	15.2					
1988			19.2	28.2	20.4	17.6	12.7	11.7	11.0	10.1	14.6	14.1		
1989	18.9	21.1	34.5	31.7	21.4	16.7	14.3	12.5	11.5	10.4	12.9	16.0	18.5	-7.9
1990	43.5	59.3												
Min	18.9	21.1	19.2	20.0	17.9	15.4	11.6	9.1	9.2	9.3	9.4	9.6	16.3	-10.0
Avg	39.7	46.2	42.5	35.0	27.2	21.3	16.8	14.5	13.2	13.7	18.2	27.8	26.4	-0.0
Max	92.5	102.1	84.1	59.9	45.6	32.4	26.5	21.6	18.9	21.0	29.5	68.4	40.4	14.1

Minimum Flows at Gage 12079000, Deschutes River near Rainier

Minimum Daily Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From Mean
1949						52	38	33	29	31	45	148		
1950	190	240	338	206	135	74	43	36	28	39	113	394	28	-2
1951	298	262	187	127	78	44	36	28	26	42	72	206	26	-4
1952	152	206	173	148	93	56	34	28	22	24	27	34	22	-8
1953	255	172	128	144	107	85	47	37	33	65	87	247	33	3
1954	261	397	180	150	98	95	53	46	40	39	57	152	39	9
1955	208	156	165	246	176	98	55	38	36	44	169	388	36	6
1956	311	233	271	220	109	76	43	36	33	35	92	83	33	3
1957	70	150	265	163	92	53	40	33	29	31	42	133	29	-1
1958	218	273	165	131	76	49	34	28	28	28	46	229	28	-2
1959	239	242	190	123	101	78	42	36	36	58	64	139	36	6
1960	93	172	152	211	178	71	44	36	33	33	84	161	33	3
1961	152	506	320	200	120	60	41	28	28	31	59	118	28	-2
1962	103	104	106	110	110	54	35	32	29	49	50	157	29	-1
1963	88	163	128	180	82	55	44	33	30	32	136	149	30	0
1964	368	188	195	180	128	84	50	38	34	41	49	192	34	4
1965	290	221	107	95	84	46	35	31	26	25	31	79	25	-5
1966	176	178	222	126	73	50	38	31	27	28	47	297	27	-3
1967	397	214	186	178	98	59	40	31	25	50	91	147	25	-5
1968	149	183	154	145	80	73	43	36	50	57	143	242	36	6
1969	150	150	182	207	107	64	45	34	31	57	56	76	31	1
1970	127	208	129	118	86	47	32	24	26	28	48	183	24	-6
1971	240	263	257	188	136	103	49	37	38	48	128	208	37	7
1972	178	224	239	218	109	70	47	34	31	35	47	59	31	1
1973	150	125	123	81	73	58	36	28	25	34	94	327	25	-5
1974	150	299	271	200	159	81	70	42	34	31	45	143	31	1
1975	310	220	199	136	105	56	38	32	34					
1976														
1977														
1978														
1979														
1980						62	33	29	33	32	107	190	29	-1
1981	110	100	122	212	119	104	53	36	32	73	96	223	32	2
1982	150	208	199	211	90	54	39							
1983								42	50	40			40	10
1984						98	52	36	33	33			33	3
1985						53	33	27	28	33			27	-3
1986						50	38	27	25	29	62		25	-5
1987						47	34	26	23	23	27	100	23	-7
1988	78	132	118	126	122	68	39	30	27	36	40	124	27	-3
1989	176	112	211	135	83	49	36	29	24	23	57	75	23	-7
1990	130	335	215	141	95	80	41	32	32	35	135	175	32	2
1991	148	199	223	196	134	90	47	35	33	31	62	95	31	1
1992	90	148	72	70	51	33	26	21	20	27	63	70	20	-10
1993	34	69	70	153	106	76	57	37	28				28	-2
Min	34	69	70	70	51	33	26	21	20	23	27	34	20	-10
Avg	184	207	184	161	106	66	42	33	31	38	73	169	30	-0
Max	397	506	338	246	178	104	70	46	50	73	169	394	40	10

Minimum Flows at Gage 12080000, Deschutes River near Olympia and Gage 12080010, Deschutes River @ Tumwater E Street

Minimum Daily Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From Mean
DESCHUTES RIVER NEAR OLYMPIA, WASH.; Basin Area 160 sq. mi.														
1945					216	110	84	74	79	70	99	224	70	-18
1946	338	520	480	320	179	161	117	98	88	85	136	352	85	-3
1947	279	348	273	256	143	114	96	84	78	78	278	272	78	-10
1948	323	284	352	428	336	171	127	117	103	119	136	473	103	15
1949	221	210	428	323	202	143	106	93	86	85	108	245	85	-3
1950	424	500	660	415	268	179	134	118	106	115	210	620	106	18
1951	520	620	465	260	208	138	115	104	96	121	147	319	96	8
1952	265	373	292	238	172	132	96	85	77	74	77	83	74	-14
1953	316	362	298	264	210	169	108	95	86	121	166	356	86	-2
1954	356	577	400	320	218	194	128	106	95	95				
1955														
1956														
1957						145	115	96	90	90	110	195	90	2
1958	354	449	307	246	170	129	94	77	78	80	112	363	77	-11
1959	415	483	352	249	210	167	112	99	102	121	127	310	99	11
1960	224	374	346	381	318	168	129	112	107	102	166	309	102	14
1961	286	781	581	398	272	168	126	106	103	104	152	220	103	15
1962	242	237	239	218	220	135	97	89	84	128	135	414	84	-4
1963	265	358	268	334	198	160	120	105	107	103	241	286	103	15
1964	620	488	377	330	236	178								
DESCHUTES R AT E ST BRIDGE AT TUMWATER, WASH; Basin Area 162 sq. mi.														
1990										88	179	318		
1991	280	345	364	366	280	196	137	114	87	82	95	194	82	-6
1992	190	294	174	170	132	92	63	62	61	58	80	90	58	-30
1993	116	160	163	240	210	158	124							
Min	116	160	163	170	132	92	63	62	61	58	77	83	58	-30
Avg	318	409	359	303	220	153	111	97	90	96	145	297	88	0
Max	620	781	660	428	336	196	137	118	107	128	278	620	106	18

Minimum Flows at Gage 12081000, Woodland Creek near Olympia

Minimum Daily Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From Mean
1949							15.5	14.0	12.0	12.0	12.5	13.5	12.0	0.8
1950	35.0	42.0	69.0	47.0	34.0	27.0	23.0	18.5	16.5	15.0	16.5	33.0	15.0	3.8
1951	45.0	67.0	63.0	45.0	31.0	25.0	19.0	15.0	12.5	15.0	14.5	19.5	12.5	1.3
1952	21.0	25.0	22.0	18.0	16.0	15.0	11.0	9.6	9.0	8.6	8.8	8.0	8.0	-3.2
1953	8.8	31.0	24.0	20.0	16.5	14.0	11.5	11.0	10.5	10.5	13.0	19.5	8.8	-2.4
1954	28.0	43.0	41.0	34.0	27.0	23.0	19.0	17.5	13.0	13.0	14.0	21.0	13.0	1.8
1955	22.0	22.0	26.0	25.0	21.0	16.0	13.5	12.5	11.5	12.0	17.0	39.0	11.5	0.3
1956	72.0	58.0	58.0	44.0	34.0	29.0	23.0	19.5	17.5	16.5	17.5	21.0	16.5	5.3
1957	25.0	25.0	36.0	30.0	22.0	19.5	16.0	14.0	12.5	12.0	11.0	11.0	11.0	-0.2
1958	17.5	23.0	26.0	24.0	17.5	14.0	9.8	8.7	8.7	8.7	9.4	18.0	8.7	-2.5
1959	26.0	37.0	32.0	25.0	24.0	20.0	16.0	14.0	13.0	21.0	8.3	16.0	8.3	-2.9
1960	20.0	34.0	34.0	35.0	29.0	20.0	18.0	16.0	14.0	13.5	15.0	26.0	13.5	2.3
1961	27.0	43.0	62.0	47.0	36.0	24.0	20.0	17.0	15.0	14.5	16.5	22.0	14.5	3.3
1962	25.0	23.0	24.0	20.0	18.0	12.5	10.5	10.5	10.5	9.7	9.7	28.0	9.7	-1.5
1963	26.0	36.0	32.0	33.0	19.0	16.0	14.0	13.0	12.0	12.0	16.0	24.0	12.0	0.8
1964	38.0	46.0	39.0	31.0	23.0	20.0	17.0	13.0	12.0	11.0	11.0	18.0	11.0	-0.2
1965	29.0	40.0	31.0	26.0	23.0	14.0	10.0	10.0	11.0	9.3	9.8	12.0	9.3	-1.9
1966	23.0	21.0	23.0	22.0	18.0	13.0	11.0	9.8	9.6	8.6	9.1	17.0	8.6	-2.6
1967	27.0	39.0	34.0	28.0	21.0	16.0	13.0	10.0	10.0	10.0	11.0	14.0	10.0	-1.2
1968	17.0	29.0	31.0	26.0	21.0	17.0	15.0	14.0	14.0	14.0	16.0	26.0	14.0	2.8
1969	43.0	46.0	36.0	31.0	26.0	20.0	17.0	15.0	13.0					
1988			14.0	22.0	18.0	14.0	12.0	11.0	10.0	9.2	9.8	11.0	9.2	-2.0
1989	14.0	16.0	22.0	24.0	19.0	15.0	13.0	12.0	11.0	9.7	9.7	10.0	9.7	-1.5
1990	13.0	49.0												
Min	8.8	16.0	14.0	18.0	16.0	12.5	9.8	8.7	8.7	8.6	8.3	8.0	8.0	-3.2
Avg	27.4	36.1	35.4	29.9	23.4	18.4	15.1	13.3	12.1	12.1	12.6	19.4	11.2	-0.0
Max	72.0	67.0	69.0	47.0	36.0	29.0	23.0	19.5	17.5	21.0	17.5	39.0	16.5	5.3

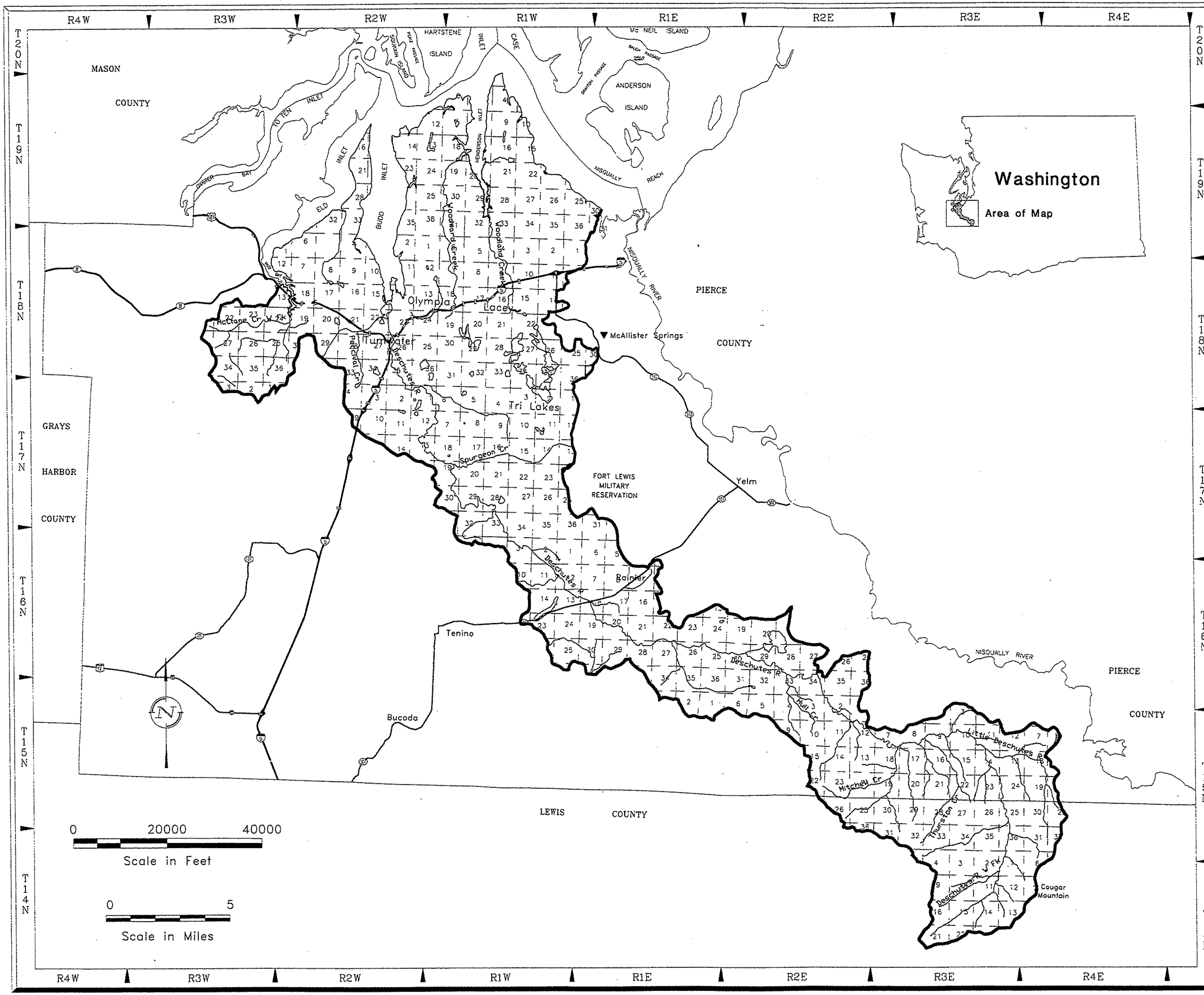


FIGURE 1-1

Location and Base Map of the Deschutes River Water Resources Inventory Area

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

EXPLANATION

- Deschutes WRIA Boundary
- Stream
- Section Lines
- Major Roads

DATA SOURCES

Washington State Department of Ecology, Water Resources Division

Thurston County Geo Data Center

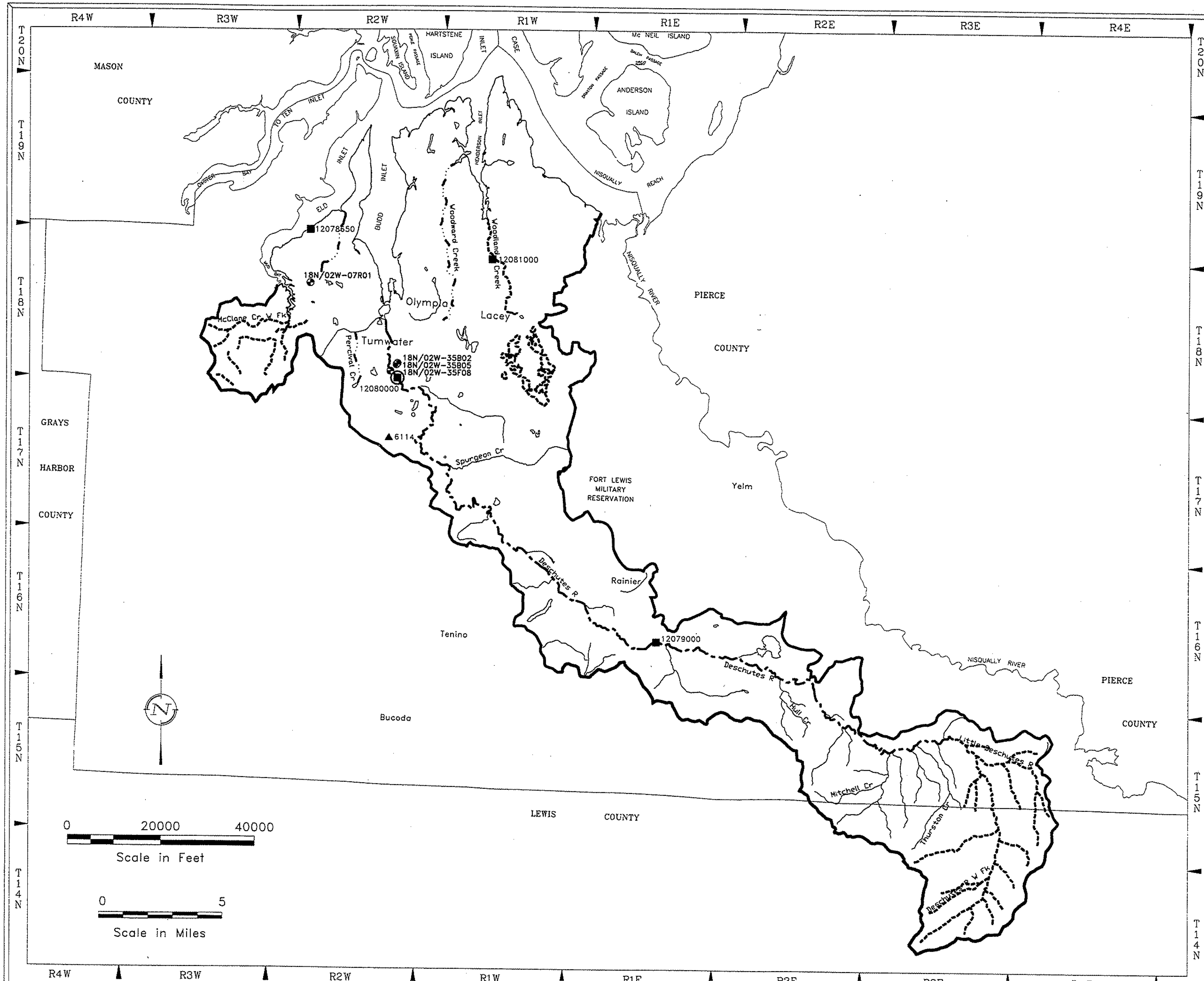


FIGURE 3-1

Monitoring Stations and Surface-Water Restrictions

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

EXPLANATION

18N/02W-07R01 ⊛	Monitoring Wells
12081000 ■	Stream Gages
12080000 ◙	Stream Gage, IRPP
6114 ▲	Weather Station

Stream Restrictions

- Stream - No Restrictions
- Instream Flow
- Surface Water Closure
- Low Flow Limitation
- Deschutes WRIA Boundary

DATA SOURCES

Washington State Department of Ecology, Water Resources Division

WAC 173-513

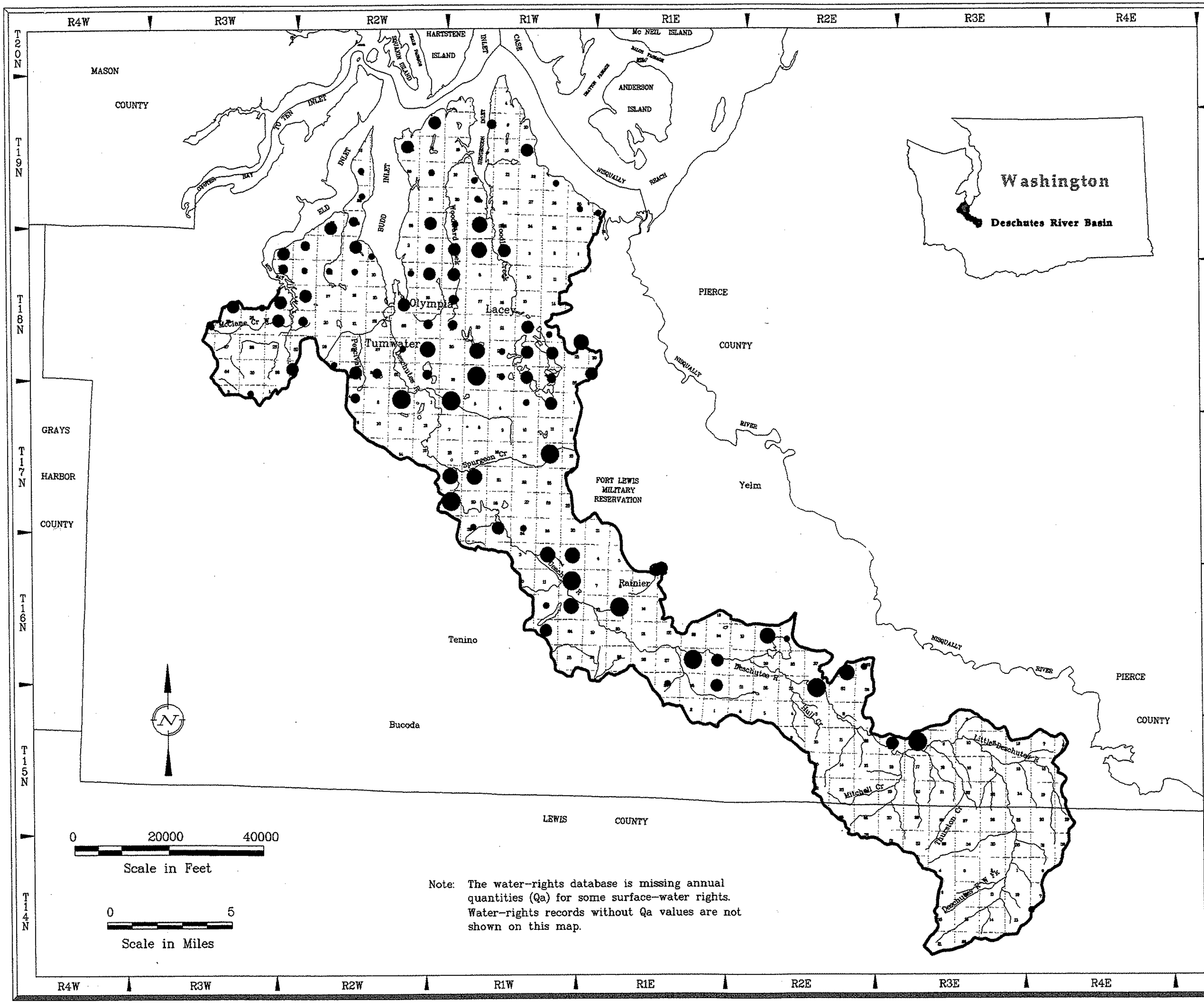


FIGURE 3-4

Distribution of Surface-Water Permits/Certificates

Initial Watershed Assessment Program
Deschutes Basin

EXPLANATION

Aggregate Surface-Water Permits/Certificates
Maximum Annual Quantities by Section

- 0 acre-ft/yr
- 0 to 5 acre-ft/yr
- 5 to 10 acre-ft/yr
- 10 to 50 acre-ft/yr
- 50 to 100 acre-ft/yr
- Greater Than 100 acre-ft/yr

- Stream, Larger
- Section Lines
- Deschutes Basin Boundary

DATA SOURCES

Washington State Department of Ecology, Water Resources Division

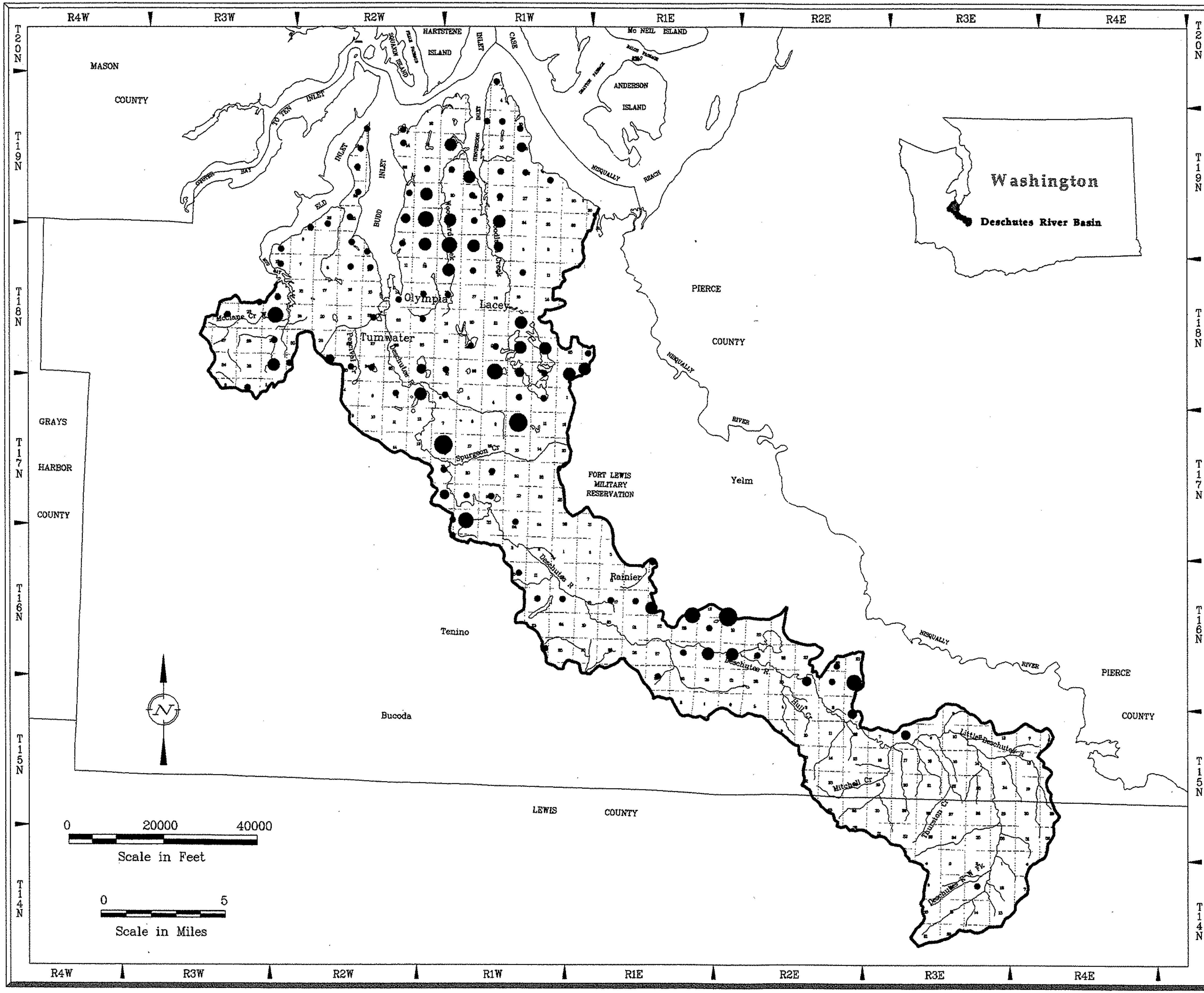


FIGURE 3-5

Distribution of Surface-Water Claims

Initial Watershed Assessment Program
Deschutes Basin

EXPLANATION

Aggregate Surface-Water Claims
Maximum Annual Quantities by Section

0 acre-ft/yr

0 to 5 acre-ft/yr

5 to 10 acre-ft/yr

10 to 50 acre-ft/yr

50 to 100 acre-ft/yr

Greater Than 100 acre-ft/yr

Stream, Larger

Section Lines

Deschutes Basin Boundary

DATA SOURCES

Washington State Department of Ecology,
Water Resources Division

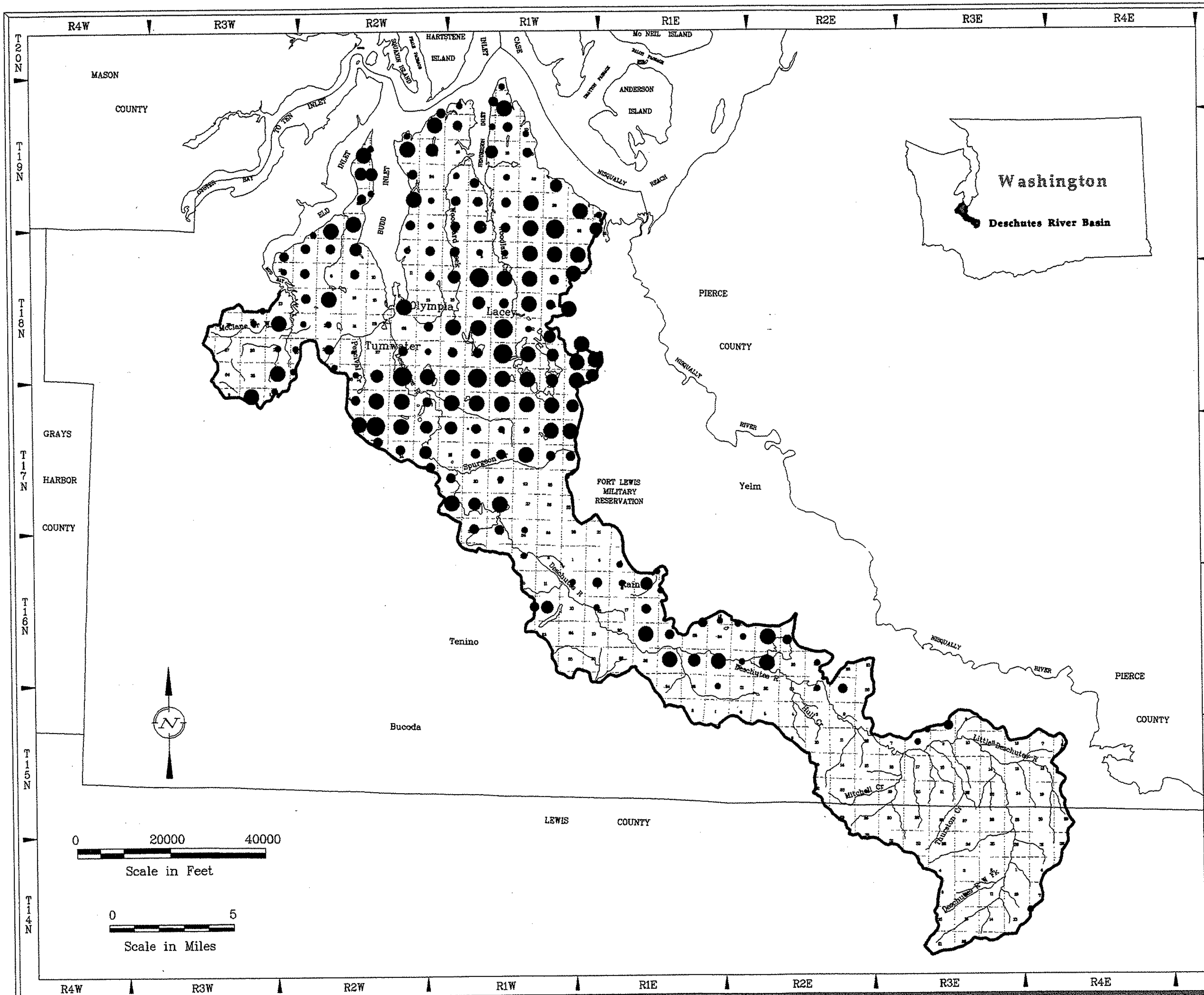


FIGURE 3-6

Distribution of Ground-Water Permits/Certificates

Initial Watershed Assessment Program
Deschutes Basin

EXPLANATION

Aggregate Ground-Water Permits/Certificates
Maximum Annual Quantities by Section

- 0 acre-ft/yr
- 0 to 10 acre-ft/yr
- 10 to 50 acre-ft/yr
- 50 to 100 acre-ft/yr
- 100 to 1000 acre-ft/yr
- Greater Than 1000 acre-ft/yr

- Stream, Larger
- Section Lines
- Deschutes Basin Boundary

DATA SOURCES

Washington State Department of Ecology, Water Resources Division

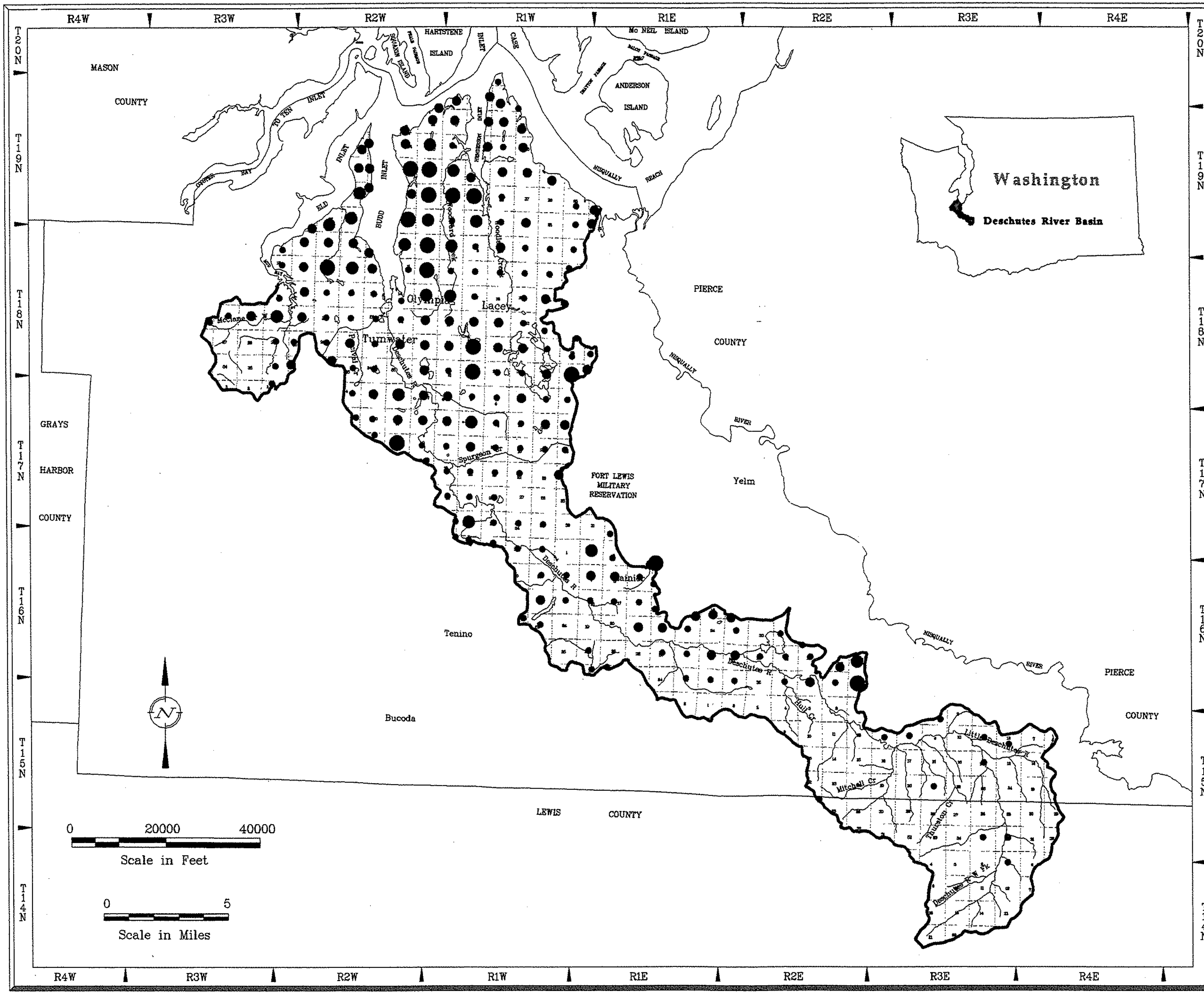


FIGURE 3-7

Distribution of Ground-Water Claims

Initial Watershed Assessment Program
Deschutes Basin

EXPLANATION

Aggregate Ground-Water Claims
Maximum Annual Quantities by Section

0 acre-ft/yr
0 to 10 acre-ft/yr
10 to 50 acre-ft/yr
50 to 100 acre-ft/yr
100 to 1000 acre-ft/yr
Greater Than 1000 acre-ft/yr

Stream, Larger
Section Lines
Deschutes Basin Boundary

DATA SOURCES

Washington State Department of Ecology, Water Resources Division

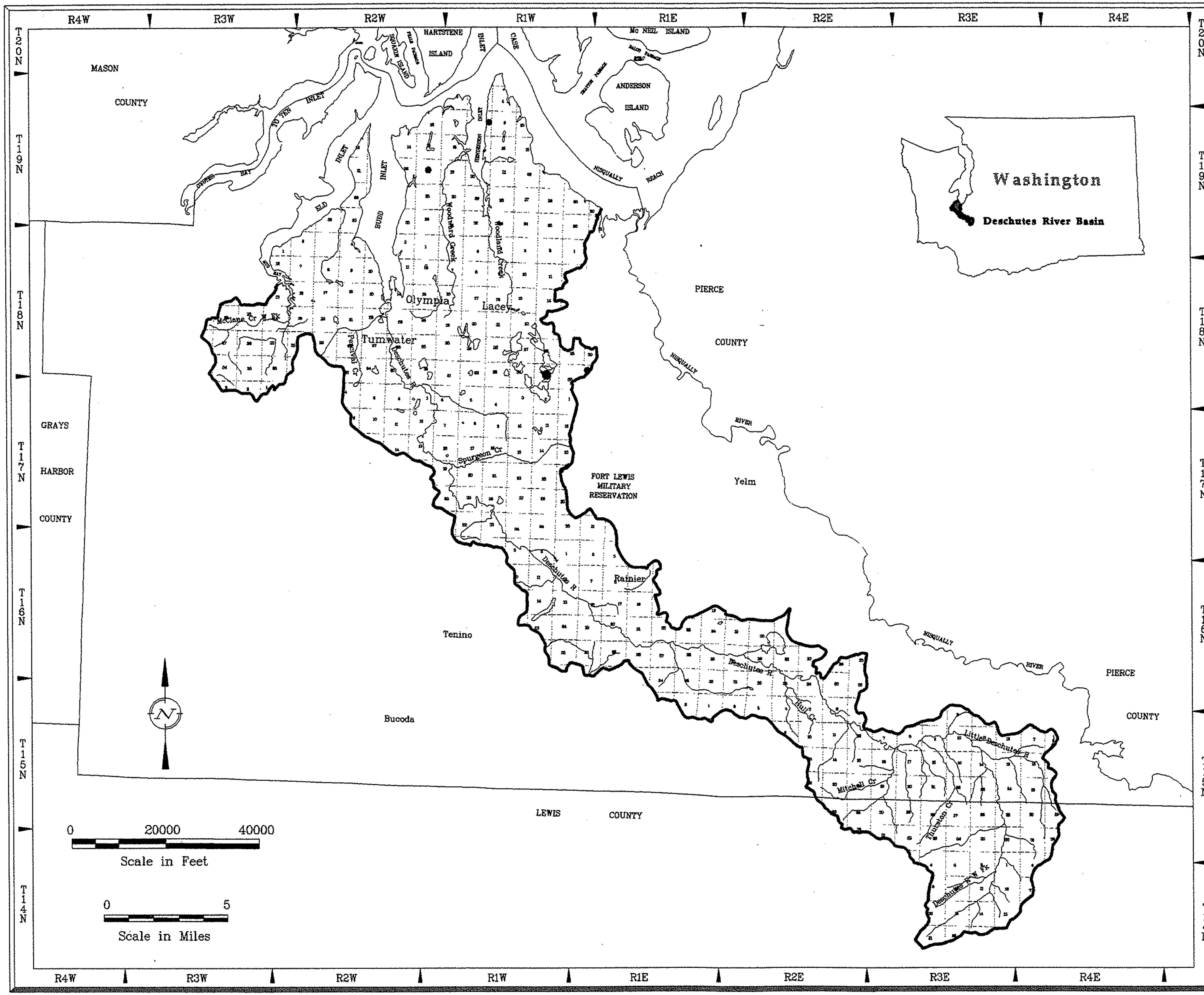


FIGURE 3-8

Distribution of Surface-Water Applications

Initial Watershed Assessment Program
Deschutes Basin

EXPLANATION

Aggregate Surface-Water Applications
Instantaneous Quantities by Section

0 cfs

0.02 cfs

0.03 cfs

Stream, Larger

Section Lines

Deschutes Basin Boundary

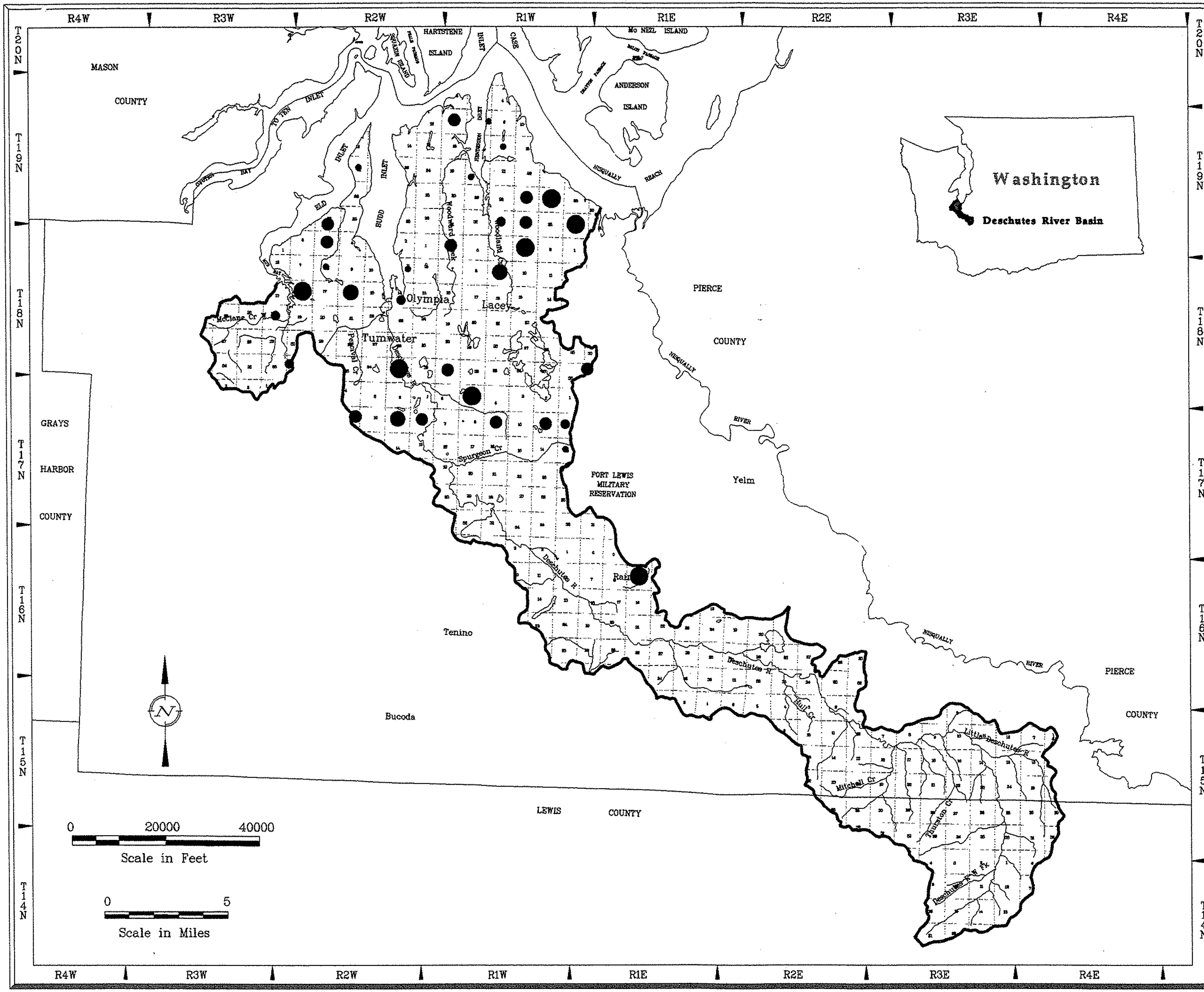
DATA SOURCES

Washington State Department of Ecology, Water Resources Division

FIGURE 3-9

Distribution of Ground-Water Applications

Initial Watershed Assessment Program
Deschutes Basin



EXPLANATION

Aggregate Ground-Water Applications
Instantaneous Quantities by Section

- 0 gpm
- 0 to 50 gpm
- 50 to 100 gpm
- 100 to 500 gpm
- 500 to 1000 gpm
- Greater Than 1000 gpm

- Stream, Larger
- Section Lines
- Deschutes Basin Boundary

DATA SOURCES

Washington State Department of Ecology, Water Resources Division

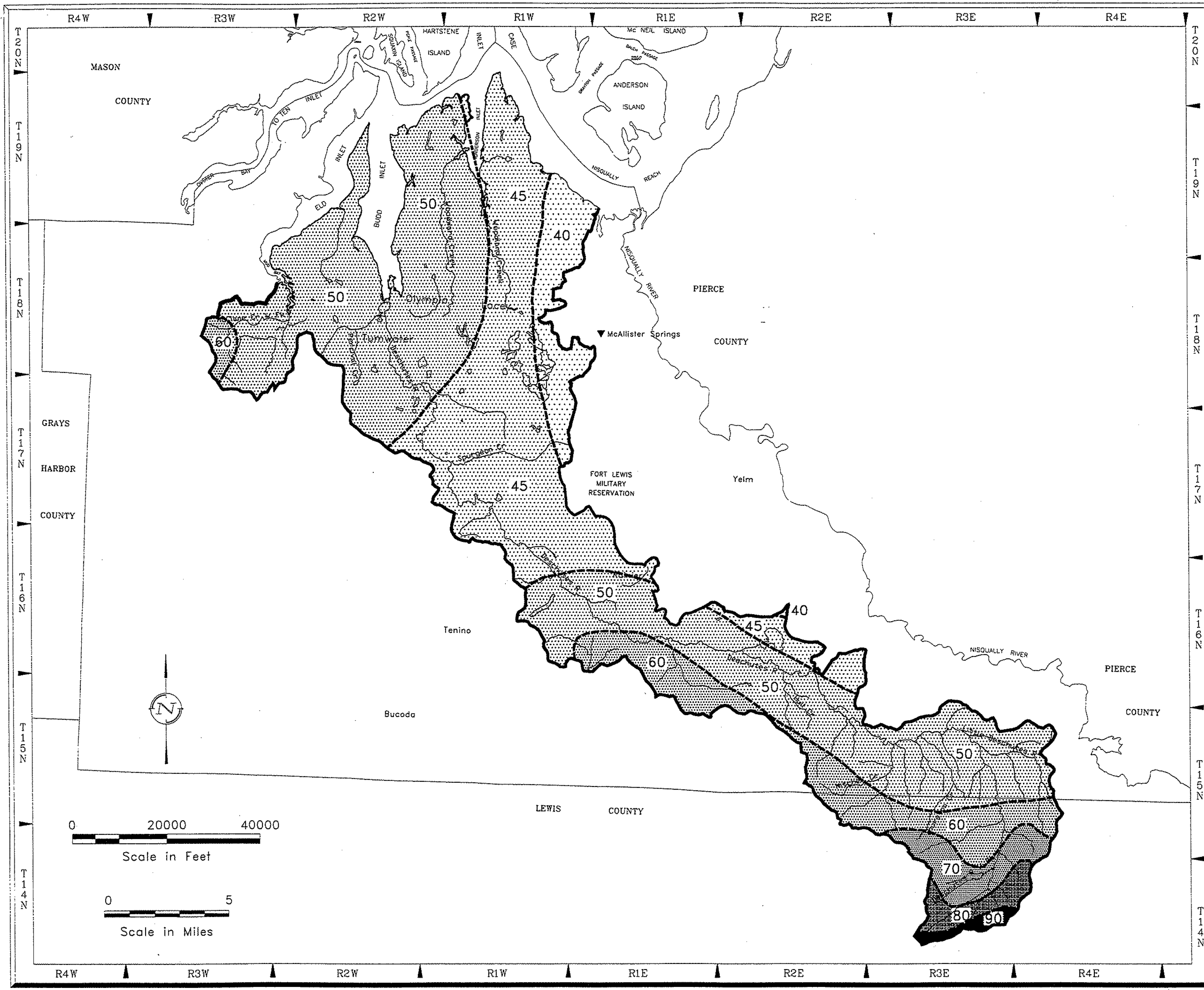


FIGURE 4-1

Spatial Distribution of Precipitation

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

EXPLANATION

Precipitation (Inches)

40
45
50
60
70
80
90

Stream

Deschutes WRIA Boundary

DATA SOURCES

Soil Conservation Service, USDA, March 1965, Map of Mean Annual Precipitation 1930 – 1957, State of Washington

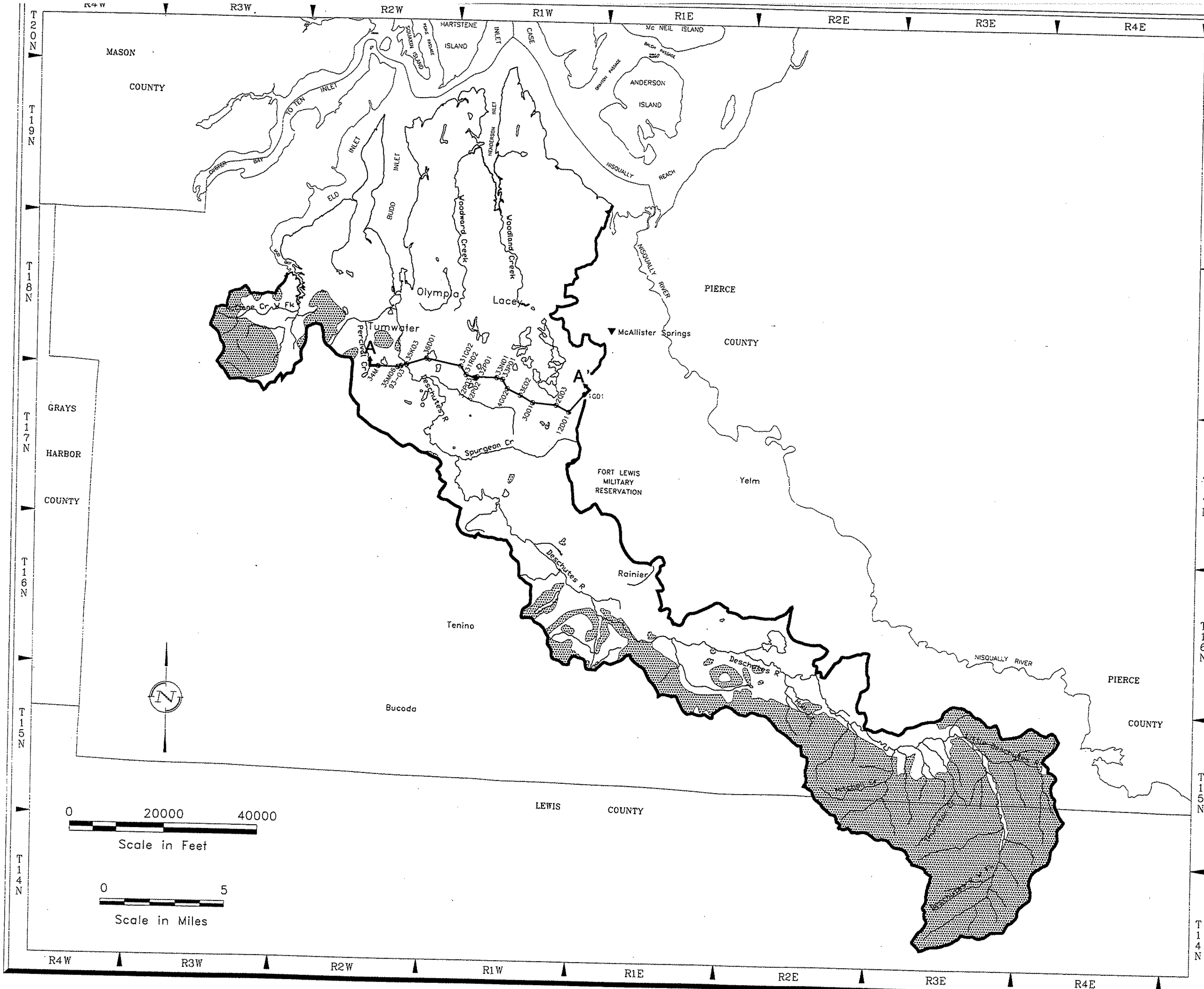


FIGURE 6-1

Generalized Surficial Geology and Cross-Section Alignment

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

EXPLANATION

Quaternary / Tertiary Sediments

Tertiary Bedrock

A — A' Cross-Section Trace

4G02 Well Location and ID

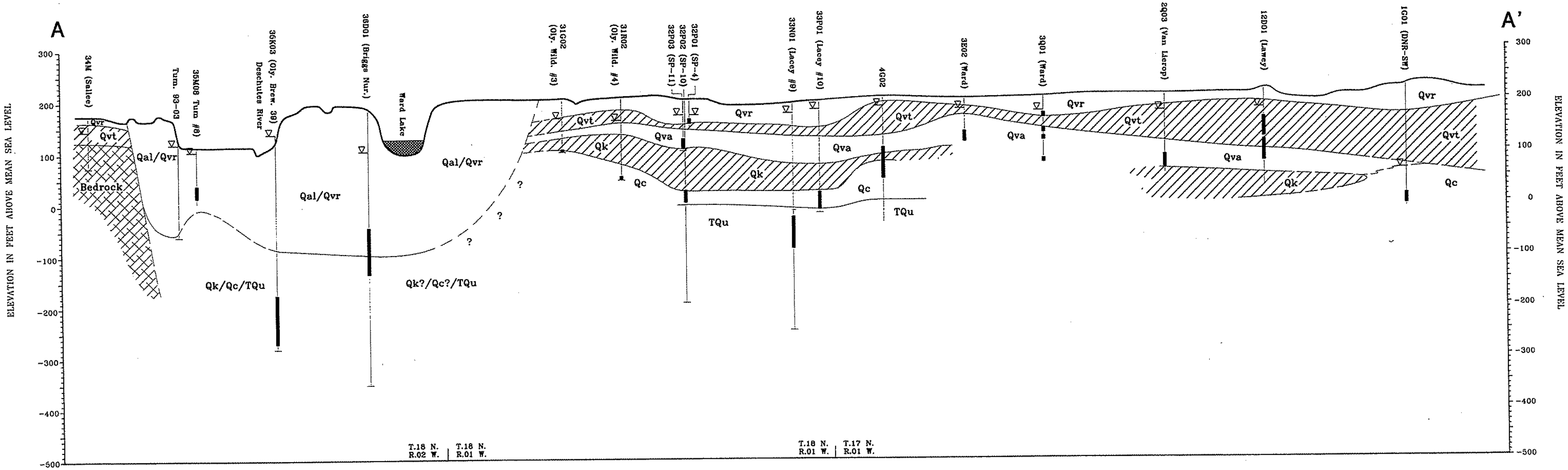
Stream

Deschutes WRIA Boundary

DATA SOURCES

Surficial Geology
Washington Department of Natural Resources, Geologic Map of Washington, Walsh, et al.

Geologic Cross-Section Trace
Pacific Groundwater Group



DATA SOURCES

EXPLANATION

Qal	Recent Alluvial Deposits
Qvr	Quaternary Vashon Recessional Outwash
Qvt	Quaternary Vashon Till
Qva	Quaternary Advance Outwash
Qk	Kitsap Formation
Qc	Sea-Level Glacial Deposits
TQu	Tertiary/Quaternary Undifferentiated Deposits

Low Permeability Deposits Consisting of Vashon Till and the Kitsap Formation

Tertiary Bedrock

Horizontal Scale in Feet
0 2000 4000 8000

0 100 200 400
Vertical Scale in Feet

33P01 (Well 10) — Well Number

Water Level

Completion Interval

FIGURE 6-2

Hydrogeologic Cross Section A - A'

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

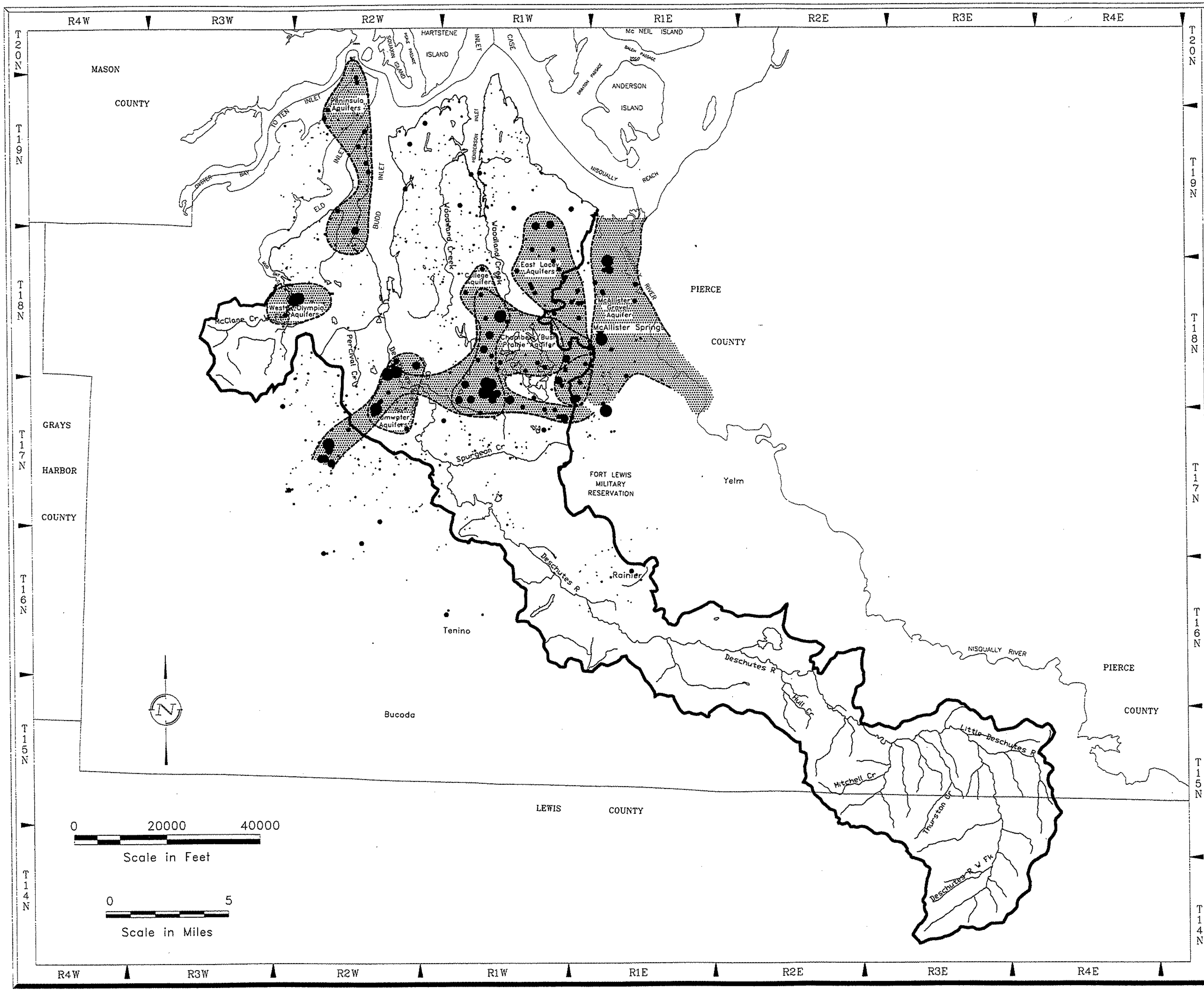


FIGURE 6-3

Distribution of Well Yield and Generalized Aquifer Areas in the Northern Part of WRIA 13

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

EXPLANATION

Well Yield (gpm)

- 0 - 30
- 30 - 100
- 100 - 500
- 500 - 1000
- > 1000

Generalized Aquifer Areas

Stream

Dechutes WRIA Boundary

DATA SOURCES

Olympia Water System Plan Update, Water Resource Assessment, Pacific Groundwater Group, 1993

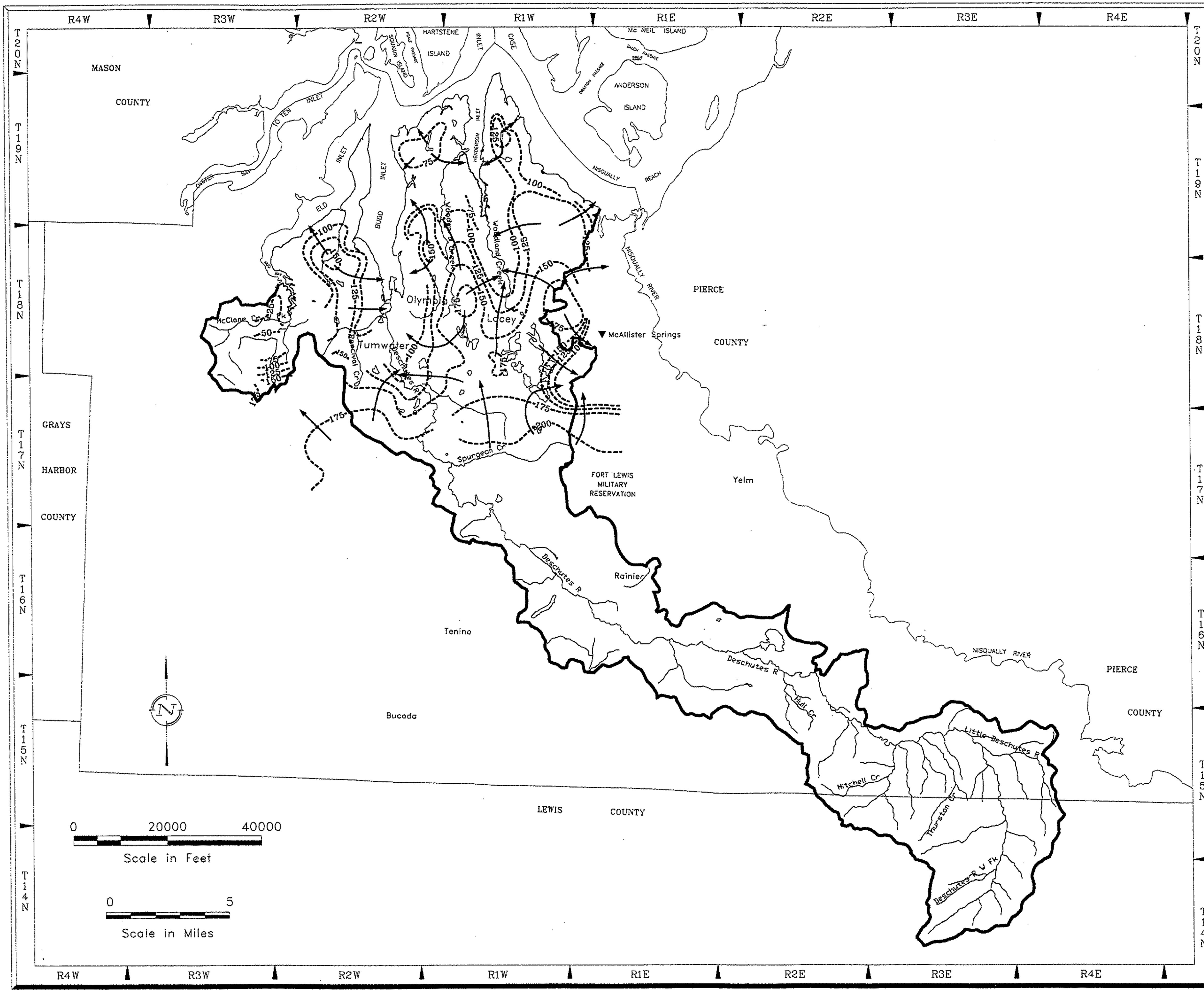


FIGURE 6-4

Ground-Water-Level Contours for the Qva Aquifer in the Northern Part of WRIA 13

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

EXPLANATION

Water Levels for Qva Aquifer (feet MSL)

Water Level Contour (interval - 25 feet)

Groundwater Flow Direction

Stream

Deschutes WRIA Boundary

DATA SOURCES

USGS Water Resources Investigations Report 92-4109

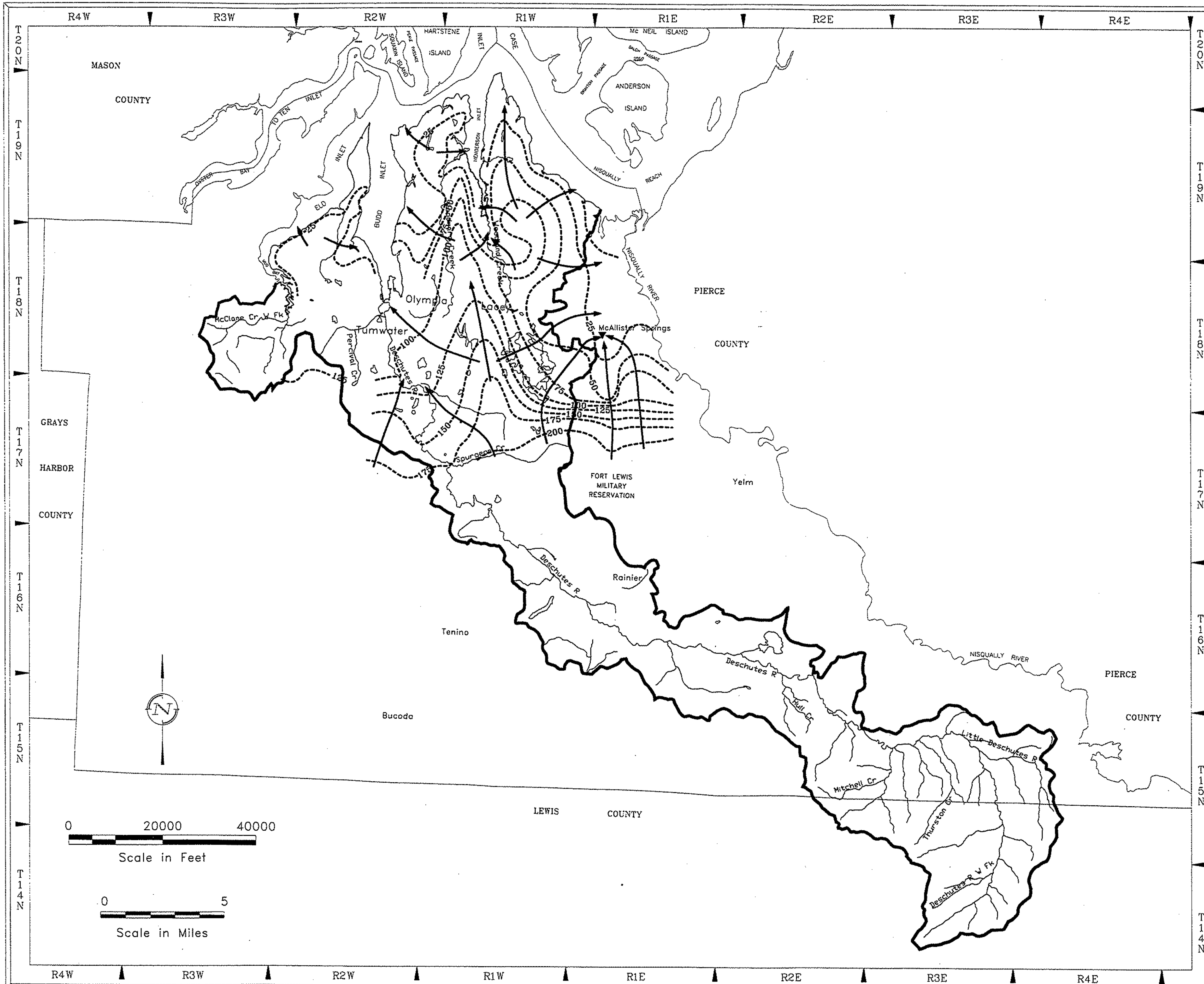


FIGURE 6-5

Ground-Water-Level Contours for the Qc Aquifer in the Northern Part of WRIA 13

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

EXPLANATION

Water Levels for Qc Aquifer (feet MSL)

- 25 — Water Level Contour (interval - 25 feet)
- Groundwater Flow Direction
- Stream
- Deschutes WRIA Boundary

DATA SOURCES

USGS, Water Resources Investigations Report 92-4109

FIGURE 6-7

Distribution of Elevated Chloride and Nitrate Values

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

EXPLANATION

- ● Wells with Chloride Concentrations > 10 mg/l
- Wells with Nitrate Concentrations > 3.0 mg/l
- Stream
- Deschutes WRIA Boundary

DATA SOURCES

USGS, Water Resources Investigations Report 92-4109

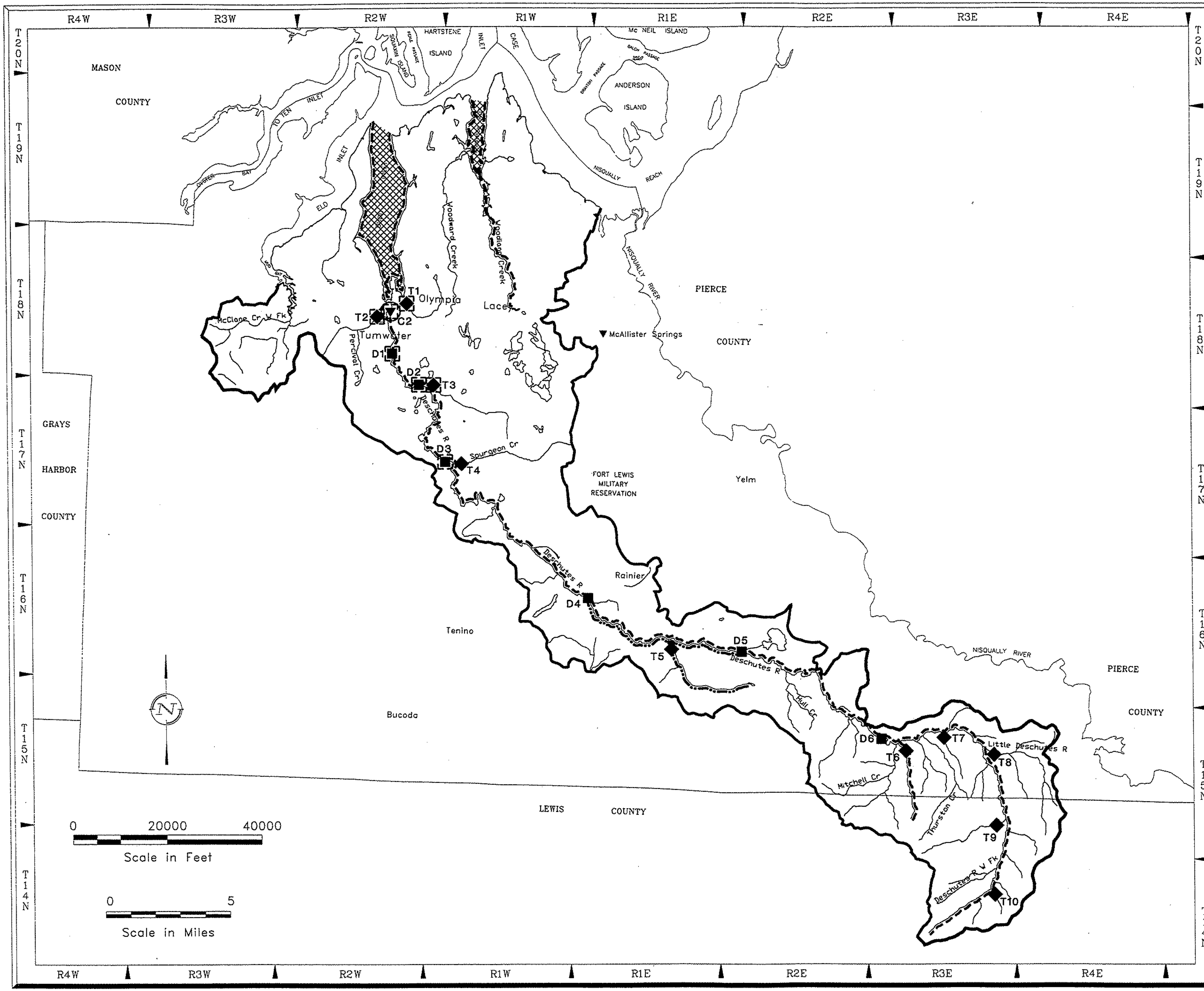


FIGURE 7-1

Water-Quality Areas of Concern

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group

EXPLANATION

- 303(d) Water Quality Limited Water Bodies
- Temperature Concern Areas[1]

Sampling Stations

- D1 Mainstem Deschutes
- T1 Tributary
- C2 Capitol Lake
- Stations Recording Fecal Coliform Violations[1]
- Stations Recording Dissolved Oxygen Violations[1]
- Stream
- Deschutes WRIA Boundary

1 - Class A Standards, WAC 173-201A

DATA SOURCES

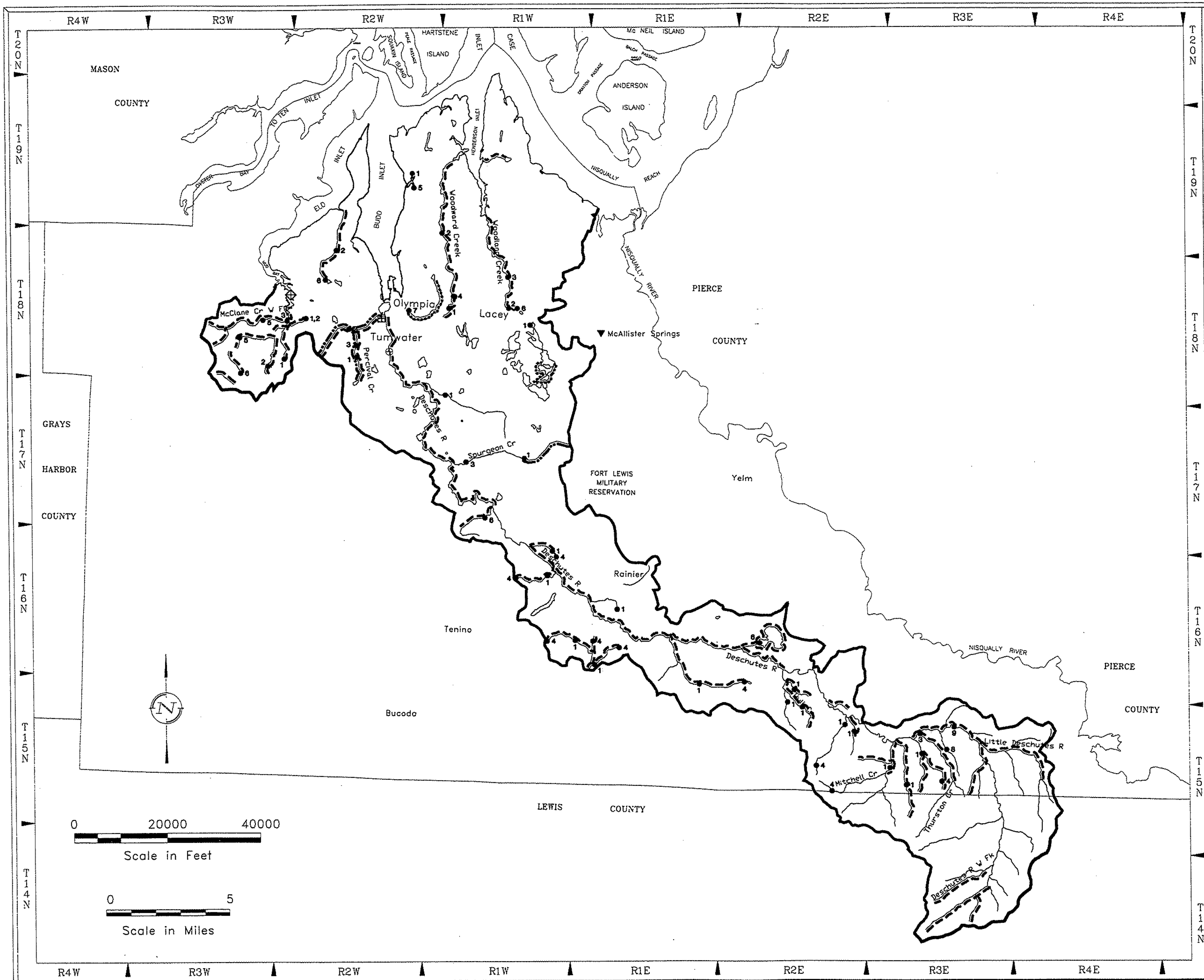
Washington State Department of Ecology, Water Resources Division 303d List

FIGURE 7-2

Fish Distribution and Factors Impacting Fish Populations

Initial Watershed Assessment Program
Deschutes Basin

Pacific Groundwater Group



EXPLANATION

Factors Present and are Annually Impacting Fish Populations

Key Reaches With Spawning Habitat Critical to Fish Populations

Presence of One or More WDFW Classified Species of Concern:
- Dolly Varden / Bull Trout
- Olympic Mudminnow
- Pygmy Whitefish
- Sea-run Cutthroat Trout

Species Upper Extents

- ●1 Coho Salmon
- ●2 Chum Salmon
- ●3 Fall Chinook
- ●4 Winter Steelhead
- ●5 Coho & Chum Salmon
- ●6 Coho Salmon & Winter Steelhead
- ●7 Chum Salmon & Winter Steelhead
- ●8 Coho & Fall Chinook Salmon
- ●9 Coho, Fall Chinook & Winter Steelhead

Production Facilities

- Net Pen
- Rearing Pond
- Hatchery

Stream

Deschutes WRIA Boundary

DATA SOURCES

Washington State Department of Wildlife WARIS Database